OECD*publishing*

Please cite this paper as:

OECD (2013-07-12), “Measuring the Internet Economy: A Contribution to the Research Agenda”, *OECD Digital Economy Papers*, No. 226, OECD Publishing, Paris.
http://dx.doi.org/10.1787/5k43gjg6r8jf-en

OECD Digital Economy Papers No. 226

Measuring the Internet Economy

A CONTRIBUTION TO THE RESEARCH AGENDA

OECD

OECD

OECD DIGITAL ECONOMY PAPERS

The OECD's Directorate for Science, Technology and Industry (STI) undertakes a wide range of activities to better understand how information and communication technologies (ICTs) contribute to sustainable economic growth, social well-being and the overall shift toward knowledge-based societies.

The OECD Digital Economy Papers series covers a broad range of ICT-related issues, both technical and analytical in nature, and makes selected studies available to a wider readership. It includes *policy reports*, which are officially declassified by an OECD committee, and occasionally *working papers*, which are meant to share early knowledge and elicit feedback. This document is a working paper.

The views expressed in this presentation are those of the authors and do not necessarily reflect the opinions of the OECD, or their respective membership.

FOREWORD

This working paper was prepared by a team from the OECD's Information Economy Unit of the Information, Communications and Consumer Policy Division within the Directorate for Science, Technology and Industry. The principal author was Piotr Stryszowski, with Cristina Serra-Vallejo, Karine Perset and Taylor Reynolds as contributing authors. This report brings together research completed for the Internet Economy Outlook and four working papers commissioned for this project from Russel J. Cooper, Shane Greenstein, Tobias Kretschmer, Ryan McDevitt, William Lehr, and Patrick Scholten, and available on OECD iLibrary (http://www.oecd-ilibrary.org/science-and-technology/oecd-digital-economy-papers_20716826).

The views expressed in this working paper are those of the authors and do not necessarily reflect the opinions of the OECD or its member countries.

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of OECD concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

In addition the OECD has made every effort to ensure that the information contained in this publication is correct and current at the time of publication but takes no responsibility of its frontiers or boundaries.

This work benefited from a grant provided by Google and we thank them for their support.

.

TABLE OF CONTENTS

INTRODUCTION

The economic importance of the Internet

The Internet is profoundly shaping modern society. It facilitates interconnectivity between individuals and information, and has important impacts on society, the economy and culture. At no other time in history has global communication and access to information been so pervasive. This study takes a practitioner's approach to examining how the Internet is shaping economies and societies around the world.

The Internet began as an important tool for improving communication but has transformed into an ubiquitous technology supporting all sectors across the economy. In fact, the Internet is now widely considered a fundamental infrastructure in OECD countries, in much the same way as electricity, water and transportation networks. To evoke the key economic role that the Internet has gained in recent years, the term *Internet economy* has become a widely used expression.

Why do we need measurements?

Even though policy makers have been keenly aware of the Internet's increasing economic importance, there is no widely accepted methodology for assigning an economic value to the Internet. Policy makers look to broadband and mobile data networks as platforms for innovation and development. Governments increasingly fund broadband rollouts, either through direct public investment or via the modification of universal service programmes, to extend access and achieve these goals.

Given the growing importance of the Internet as a policy tool, the question about the value of the Internet economy becomes particularly relevant. There is a high level of interest, therefore, in being able to measure the size of the Internet economy as a way to understand the effects of various investment strategies, regulatory rulings and policy decisions. There have been various studies that attempt to address this issue, but the methodologies are not always consistent with statistical standards and economic concepts.

An illustrative example was the case of Egypt, where Internet access was disrupted for a few days in early 2011. This event lead to a question about the economic consequences of such a service disruption and consequently about the economic dimension of the Internet and the size of the *Internet economy*.

What is the Internet economy?

In the OECD Declaration for the Future of the Internet Economy, the *Internet economy* is defined as covering "the full range of our economic, social and cultural activities supported by the Internet and related information and communications technologies" (OECD 2008a). Indeed, a first understanding of the *Internet economy* refers, often implicitly, to the notion that the Internet is a core infrastructure of the economy. A large proportion of economic transactions of all kinds including production, sales, distribution or consumption, takes place on the Internet. This observation suggests the broadest understanding of the Internet economy as the value of all economic activities that are undertaken on or supported by the Internet.

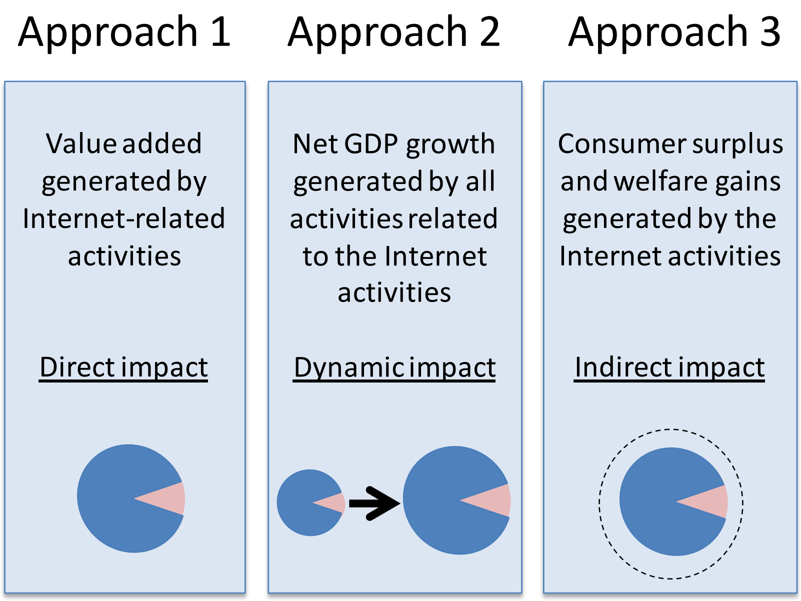
Indeed, the Internet began as an important tool for improving communication but has transformed into a universal technology supporting all sectors across the economy. In economics this is referred to as a general purpose technology (GPT) and corresponds to other phenomena such as electricity (Guerrieri and Padoan, 2007; Carlaw *et al.* 2007)

Approaches to measuring the Internet economy

In searching for appropriate terminology and measurement concepts, the OECD held an expert roundtable focusing on methodologies to measure the *Internet economy*. The roundtable took place in September 2011 and brought together academics, policy makers, researchers and the business community. One key output of the meeting was that participants concluded that the term *Internet economy* refers to various types of quantifiable economic impacts of the Internet, and that this concept varies in scope.

Consequently, the roundtable adopted several general approaches to measure the broad universe of the *Internet Economy*. These involved measuring the: *i*) direct impact; *ii*) dynamic impact; and *iii*) indirect impact (Figure 1).

Figure 1. Classification mechanism



The first approach (the **direct impact**) is the most conservative and relies mainly on official data. It groups studies that measure the **size of the Internet economy expressed as a part of GDP**. Studies that follow this approach look at those parts of the economy that are closely related to the Internet. These parts are then aggregated, and the result is interpreted as a conservative measure of the Internet economy since they only capture effects that can be separated out of specific sectors of the economy.

The second approach looks at the **dynamic impact** that the Internet might have on all industries and hence on the rates of productivity growth and eventually GDP growth. The scope of studies that follows this approach includes the effects that the Internet has on productivity and profitability of firms. Consequently these studies evaluate the **contribution of the Internet to the net growth of the economy as measured by official statistics**.

Finally, the last, broad approach takes into account the **indirect impact** of the Internet. Studies within this approach examine the effects of the Internet on economic phenomena like consumer surplus or how the Internet contributes to social welfare gains. These studies look at the **additional impacts of the Internet on economic welfare that are not necessarily measured by official statistics**.

Each of the approaches plays an important part in increasing understanding of the process of measuring the Internet economy. This study will examine the process in several steps. First, the next section discusses the data challenges related to the measuring of the Internet Economy. The next sections outline each approach and link it to relevant literature and initial estimates. The box at the beginning of each section briefly explains the approach, findings, and highlights areas for continued research. Key methodological details are summarised in the Annex.

THE DATA CHALLENGE

Measuring the Internet and its economic and social impacts presents a number of significant data challenges. These include all of the same ones that have bedevilled efforts to estimate the economic impacts of computers, broadband, and other Information and Communications Technology (ICT) components.

Although a number of firm-level studies were able to demonstrate the positive productivity contributions of computers in the 1990s (Brynjolfsson and Hitt, 1998; Lehr and Lichtenberg, 1999,) it was not until after 2000 that the large contribution of ICTs to economic growth was demonstrable in macroeconomic data (Oliner and Sichel, 2000; Jorgenson, 2001; Colecchia and Schreyer, 2002a; Pilat 2004) The so-called Solow's paradox still applies.[1]

This earlier experience offers several important and illustrative lessons in the context of measuring the *Internet Economy*. First, one is likely only to be able to reliably estimate the economic impacts of the Internet *after* these impacts occur. However, investments in ICTs must take place *before* researchers are able to demonstrate that economic impacts of these investments are, in fact, positive. Second, the first and best evidence of economic impacts is likely to come from micro-data (firm or smaller) before it shows up in macro-data (industry or national).

These challenges of measuring ICTs and the Internet are largely related to their general and transformational economic character. In fact it is often argued that ICTs, including the Internet are a "special" technology in the sense that they affect a multitude of sectors and economic activities, and most importantly make other sectors more productive. A narrow definition of just the ICT and the Internet sectors would not capture their true impact on the economy. Rather, ICT and the Internet are often considered to be general purpose technologies (GPTs).

Is the Internet a general purpose technology (GPT)?

The idea of ICTs and the Internet as GPTs is based on concepts associated with ICT and investments going beyond the notion of conventional capital equipment and being more of an "enabling technology" (Jovanovic and Rousseau, 2005). This may be especially true as knowledge has become qualitatively and quantitatively more important to economic activities. The Internet facilitates communication and the creation of new knowledge through more efficient processes of collaboration and information processing.

In firms, it is possible to observe how the Internet enables and facilitates information sharing. Faster information processing may allow firms to think of new ways to communicate with suppliers or arrange distribution systems. Processes can be reorganised and streamlined, which allows for a reduction in capital needs through better utilisation of equipment and reduction in inventories or space requirements. Increased communication also reduces co-ordination costs and the number of supervisors required. More timely and widespread transfers of information enable better decision making and reduce labour costs (Arvanitis and Loukis, 2009; Atrostic *et al*., 2002; Gilchrist *et al*., 2001). Lower communication and replication costs also help businesses innovate by offering new products (Brynjolfsson and Saunders, 2010).

Scholars interested in transaction costs consider communication technologies as lowering the fixed costs of acquiring information and the variable costs of participating in markets (Norton, 1992; Leff, 1984), thus initiating a shift towards efficient market-based solutions. In these examples, the productivity enhancing effects of ICT and the Internet previously mentioned are associated with spillovers. Spillovers constitute positive externalities and lead to excess rates of social return over private rates of investment eventually affecting many sectors in the economy. The notion of new ideas or techniques that influence the economy on a broad basis was first published by Bresnahan and Trajtenberg (1995), who coined the phrase of GPTs. The main characteristics of a GPT are the following:

- Applicability across a broad range of uses – "pervasiveness";
- Wide scope for improvement, experimentation and elaboration, continuously falling costs – "improvement"; and
- Facilitating further product and process innovations – "innovation spawning".

Although the concept of spillovers is intuitively appealing, in practice it can take a long time to fully transform business processes to reap the full benefits of GPTs (David, 1990; David and Wright, 1999). The spillover effects from ICT and the Internet are reflected in the dramatic price decreases leading to a substitution of ICT equipment for less productive assets (Jorgenson, 2005).

Generally, the focus of GPT-related ICT and Internet studies has been the price of computers and embedded semi-conductors as the foundation of ICT innovations. This innovative foundation has been supported by improvements in tangible hardware equipment, often described with Moore's Law. A broad consensus attributes strong IT investment to be the main driving force behind the surge in recent US productivity, with much of it originating in the ICT-producing sectors.

Nevertheless, there is at least some indication that efficiency gains from the implementation of more productive investment equipment were not limited to the production sectors only, but also spilled over to industries that heavily used these new technologies. These gains can be seen during the second surge of the US economy post-2000, which was much broader (Stiroh and Botsch, 2007). It is particularly this latter characteristic that convincingly suggests that ICTs should be considered GPTs since computers and related ICT equipment are now used in most sectors of the economy. Although it might be reasonable to claim that productivity gains from ICT can be found all around daily business life, quantifying the effect of spillovers from ICT is difficult, especially as these effects are hard to isolate. Thus, this study also provides a closer look on how spillovers of ICT and the Internet work and the current status of the existing empirical evidence.

Empirical evidence

A large volume of literature checks whether the GPT hypothesis passes empirical testing in the case of ICTs and the Internet.

Jorgenson and Stiroh (1999) do not report spillovers and argue that the rewards are large because of the swift pace of technical change in the production of computers and the rapid deployment of IT equipment through substitution (Jorgenson *et al*., 2008). Oz (2005) argues that excess IT returns may have been accrued in its early days (when IT, especially software was hard to measure), but today a firm without PCs will simply not survive as IT has become a mature and ubiquitous technology. Gordon (2000), based on growth accounting figures, finds that the productivity resurgence was driven by ICT production and can only be seen in the sector of manufacturing durable goods. For the remaining 88% of the economy, the "new economy's" effects on productivity growth are surprisingly absent, and capital deepening has been remarkably unproductive. Gordon concludes that no structural acceleration throughout the economy in productivity took place during 1995-99, and the pervasiveness of the technology is absent, which is constituent for a GPT. In later work, Gordon (2003) adds that the investment in IT has been largely exaggerated.

One important characteristic of a GPT is its pervasiveness. Despite large variations in ICT intensity regarding the adoption in households, Jovanovic and Rousseau (2005) show that households adopted electricity about as rapidly as they are adopting the PC and that such disparities are not unique for digital technologies.[2]

ICTs comprise a large part of overall business investment. ICT investment accounted for 20% of total investments by US firms in the 1990's and 15% of total investments in the United Kingdom (Colecchia and Schreyer, 2002b). Triplett and Bosworth (2006) argue that the only real change over time is that IT capital is much larger than it once was and, therefore not surprisingly, contributes more to recent growth than it did in earlier periods. Even though ICT investment levels vary greatly among sectors, the ICT phenomena is not confined to a narrow sector but has a broad range of applications, *e.g.* transport, health services or banking. Investments in ICTs have been large, their applications are widespread, but full diffusion to all firms and households is not complete.

In an industry study, Stiroh (2002b) shows with a difference-in-difference methodology that industries that are above the median in their information technology intensity have about 2 percentage points larger acceleration in labour productivity after 1995 than other industries. He evaluates this evidence by showing that the IT phenomena was widespread because the productivity surge was not only limited to the ICT production sector and cannot be explained by cyclical factors only. Stiroh makes no judgement regarding the spillover properties of ICTs, but instead states that the strong and robust correlation between IT intensity and the subsequent productivity acceleration implies that there may be a deeper relationship between IT investment and productivity growth. Similarly, Baily and Lawrence (2001) find substantial acceleration in labour productivity outside the computer sector with a labour productivity measure (gross domestic income per employee) that incorporates both capital deepening and TFP growth and interprets their findings as some support for the GPT hypothesis. Bosworth and Triplett (2003) calculate the labour productivity and TFP by industry and find that the accelerating productivity in the service sector plays a crucial part in the productivity resurgence post-1995 and states that these industries are intensive users of ICT, thereby giving some evidence of a relationship between ICT usage and TFP growth. In a later study, Bosworth and Triplett (2007) confirm that non-ICT-producing sectors saw a sizeable acceleration in TFP, especially in the service industries in the 2000s, whereas TFP growth in ICT-producing sectors declined in the 2000s compared to its "golden era" in the 1990s. Descriptive studies therefore indicate that ICT triggers innovation in the ICT using sector. All of these studies have been conducted with data from the United States, potentially limiting the ability to draw global conclusions.

Table 1 presents an overview of the main approaches to empirically assess the GPT hypothesis and lists the studies that applied the approaches according to their main outcome – support of the GPT hypothesis or not.

Table 1. Overview of the studies testing the GPT hypothesis

Method	GPT Hypothesis confirmed	GPT Hypothesis refused
Industry study	Stiroh (2002b) Baily and Lawrence (2001) Bosworth and Triplett (2003)	
TFP regression with lagged ICT variable as explanatory	Brynjolfsson and Hitt (2003) Basu *et al*. (2003) Basu and Fernald (2007) Greenan and Mairesse (2000)	Stiroh (2002a) van Ark and Inklaar (2005) Wolff (2002) Inklaar *et al*. (2008)
Comparing with other GPTs of the past	Crafts (2002) Jovanovic and Rousseau (2005)	Gordon (2000)
Excess return	Brynjolfsson and Hitt (2003) Lichtenberg (1995) Gilchgrist *et al*. (2001) O'Mahony and Vecchi (2005) Venturini (2009)	Stiroh (2005)

To reiterate, there are numerous strong indications but no ultimate evidence that the ICTs and the Internet are indeed a GPT. However, interestingly most positive evidence was found for US data, and it is more difficult to find evidence in Europe. Therefore a better understanding of how spillovers work with ICT might help bridge the gap, especially since many questions regarding possible externalities remain unanswered: Do management ideas and knowledge on ICT diffuse among firms? How can this knowledge best be transferred? Which time lag is needed for spillovers to materialize? Moreover, while the GPT property of ICTs is widely discussed and empirically tested, it has not been tested explicitly for broadband, even though this seems to be the main target of policy agendas.

Measuring the Internet (economy)

The Internet is often classified as a GPT because it supports economic and social activity in a way that is similar to electricity. But quantifying the benefits deriving from the Internet is not a straightforward task precisely because it is so pervasive. Firstly, it needs to be clearly stated whether a given study or exercise attempts to measure *the Internet* or *the Internet economy*. Although both concepts might sound similar, they refer to different economic notions. The "Internet" can be defined here as physical networks and the provision of data connectivity. The "Internet economy" is a much broader concept that covers the full range of our economic, social and cultural activities supported by the Internet, and that can encompass all uses and benefits resulting from the connectivity that the Internet provides (OECD 2008a).

Indeed, to measure the economic impact of *the Internet*, one must first measure the Internet. This is problematic because the Internet is itself changing. To date, the focus has been on measuring the availability and adoption of Internet access, first dial-up and now broadband. Heterogeneity in adoption behaviour across firms, households, and industries provided a reasonable proxy for use, which is what is ultimately of interest, since economic impacts arise only consequent to Internet usage.[3] As the Internet becomes a universal basic infrastructure and adoption saturates, the Internet economy will become increasingly indistinguishable from the overall economy. What will matter is how different firms, workers, or consumers utilise the Internet; measuring that utilisation becomes inherently more difficult.

More granular data will be needed at the business location or unit level, or even better, at the worker activity level to understand how the Internet is being used in productive activities. This is due in part to the fact that the Internet enables the creation of virtual organisations and flexible outsourcing of business activities, blurring the boundaries between firms and markets and also between work and social life.[4]

The growth of the self-service economy and the changing role for consumers as producers of media content, participants in product design, promotion, and transaction processing all illustrate this phenomenon. Separating consumption from production when the boundary between firm and customer blurs requires ever-more detailed information about the specific activities being undertaken. Increasingly detailed business and labour surveys will be needed to track how the Internet is being used to accomplish the varied tasks that go into business production. Initially, focus might be placed on the time spent using the Internet in different business functions (*e.g.*, research and development, supply chain management or retailing) or worker activities (*e.g.*, web browsing, word processing or communications).

However, in the increasingly *always-on/everywhere connected* world, one may find the time not spent on the Internet the exception. Even more granular data on the location and intensity of usage will be needed – the volume of traffic, input/output activity, and perhaps even, the level of attention of the worker (*i.e.*, was use of the Internet intrinsic to performing the activity or in the background?).

Moreover, as one seeks to measure the Internet itself by counting first the number of broadband connections, and more recently, the number of broadband connections by speed tier and for increasingly smaller geo-locations, one will find that the resources one needs to track are becoming more varied and complex.

For example, there are a number of important trends emerging in the Internet ecosystem. These include mobility, cloud computing, social networking, and sensor-based networks. All of these trends are central to current strategic business decision-making about ICT usage and to enabling the heralded future of *smart everything* (grids, homes, business processes, energy, healthcare, transport and government). Yet, none of these issues is readily measurable via the traditional metrics focusing on subscriber line counts, fibre-miles, megabytes of traffic, or IP addresses. Furthermore, the entities one needs to sample to collect information also are changing. Internet Service Providers (ISPs) are becoming more heterogeneous as the value chain for the Internet grows more complex. Increasingly, non-communications-sector participants may be responsible for key decisions about the deployment of new Internet infrastructure. This may include energy and transport providers deploying fibre for smart grids; healthcare providers deploying eHealth data systems; or resource companies deploying resource management systems.

The need for a broad range of granular data suggests yet another problem that commonly arises in Internet measurement (but is also commonly associated with the measurement of other complex phenomena). In short, no single metric is sufficient because the Internet is a bundle of complementary components that are used in different proportions in different contexts. Composite indices are commonly used to summarise a variety of metrics (see Box 1).

Box 1. Quantitative indices of the Internet (economy)

In the context of growth economics, the economic role of the Internet is motivating a new breed of researchers to look for explanations for cross-country differences in income and economic growth using new approaches and ways of processing data. For example, Hausmann, *et al.* (2011) have sought to map the productive capabilities of nations to come up with an Economic Complexity Index (ECI) that captures significantly more information and performs substantially better than other well-known indices of international economic performance.[5] Their visualisation and graphic presentations offer a novel way to interact with the economic data and to explore dynamic changes over time.

Atkinson *et al.* (2008) constructed a composite index that combined data on household penetration rates, broadband speeds, and the lowest offered price per megabit per second in order to facilitate cross-national broadband rankings. Such composite indices often have great appeal to policymakers interested in rendering the multidimensional phenomena more tractable and understandable. Unfortunately, composite indices can be misleading. The choice of components and their weightings may emphasise some points and obscure others. Analysts differ on the cost/benefit tradeoffs of composite indices, but they are likely to remain a feature of future Internet policy debates.[6] To help avoid the pitfalls inherent in any such index, it is important that the methods used in constructing any indices be fully disclosed and the underlying data be verifiable.

Fortunately, with the growing recognition that the Internet constitutes a basic infrastructure, tracking the state of critical infrastructure components, their availability, costs, investment, and usage will be motivated by more than a desire for better policymaking for economic development in the information society. Communications regulators and service providers will need to collect and track such data, constructing detailed and very granular Geographic Information Systems (GIS) similar to what currently exist for other key infrastructures like electric power distribution grids, water systems, and roads. They will need such data to manage network performance and infrastructure investments. ISPs and other value-chain participants such as Akamai, Amazon, Google and Netflix are all upgrading equipment in their networks to provide detailed real-time data on a growing number of traffic attributes to manage individual and aggregate traffic flows across time and across the end-to-end Internet.

Towards new Internet metrics

Although significant volumes of data are being collected using tools like the Deep Packet Inspection (DPI) products from companies like Sandvine[7] and Arbor Networks,[8] there are no generally agreed standards on metrics for measuring or classifying traffic, and the appropriate business uses for such data.[9] Even seemingly simple measurement questions such as "how best to characterise the 'actual' speed of broadband access services?" prove to be quite complex (Bauer, Clark *et. al* 2010.) In response to the inadequacy of previously available tools, regulatory authorities first in the United Kingdom, then in the United States, and now in the European Union are deploying traffic measurement infrastructure from companies such as SamKnows.[10] When such platforms are extended to mobile devices, the potential for finer-grained traffic measurements and characterisation have the potential to expand significantly.

As another example, consider a project in which public transport buses in the Madison, Wisconsin area have been equipped with mobile wireless broadband access for the benefit of riders (Sen *et al.*, 2011.) This platform also is being used to make real-time network measurements for multiple mobile service providers in the area. Such information and platforms can be used to obtain a very granular picture of mobile broadband performance by time of day and location throughout the area.

Data is increasingly available from multiple sources, even from the Internet itself (see Box 2) but difficult questions remain. For example, how much information is needed for different purposes (sampling)? How long is it useful to keep the data (what sorts of trend analysis is worth doing)? ISPs maintain very detailed data for relatively short periods of time in support of their business operations, but most compute summary statistics and traffic aggregates for longer-term data storage. Whether the loss of the historical granular data matters or not depends on the questions you want to ask. It certainly poses a challenge for *ex post* forensic analysis of network behaviours that might be of policy interest for regulatory enforcement.[11]

Box 2. The Internet as a data source: Using "big data" for statistics

With the proliferation of Internet access, big data sets and data mining tools will be increasingly available to users. Tools and platforms like the WeFeelFine.org project, Wordle.net,[12] or mash-up tools like Yahoo Pipes[13] provide a range of easy-to-use tools for collecting, processing, and presenting information. New data projects like Google's Measurement Lab[14] are making terabytes of Internet traffic measurement data freely accessible, and with an expanding set of visualisation tools that allow anyone to work with the data. Government agencies like the National Telecommunications Information Agency (NTIA) provide free download access to the complete 25 million record database they collected on broadband service availability in the United States.[15] Finally, a number of cloud-service providers like Google, Dropbox, and others are making petabytes of on-line storage freely available where data and analysis tools may be stored and presented.

All of this activity is democratising data analysis – virtually anyone can collect, analyze, and creatively present large volumes of data on a growing number of policy-relevant issues. Unfortunately, it is far from clear whether the skill sets of potential users and consumers of all this analysis are keeping pace with the increased availability of tools and data. Whether from ignorance or from calculated misuse, it is increasingly easy to get the data support any hypothesis. How persuasive false-data arguments will be ultimately remains to be seen.

The potential problem becomes even more significant when one considers the need to increasingly move toward automated decision-making as the reliance on machine-to-machine (m2m) systems and software-agent-based control systems expands. As one becomes further removed from the raw data and an understanding of the methods and models used to process the data, it will become more difficult to detect and correct errors in analysis. Ultimately, this is not a problem created by ICTs or the Internet, but a challenge of living in a faster-paced, more integrated, crowded, and complex world. With this comes a number of challenges to the statistical institutions as discussed in OECD (2012a).

The significant trends changing the Internet will have profound implications for Internet measurement and metrics. For example, consider the challenge of comparing the performance of fixed and mobile broadband services: the latter may vary in geo-space as well as across time (Lehr, *et al.*, 2011.) Mobility allows us to consider more localised contextual information (the micro climate) that may have bearing on the decision-making (*e.g.* do I need an umbrella here at this particular time and place and given what I am doing?). Just as the mobile telephone personalised telephony, mobile broadband has the potential to personalise/individualise Internet usage.[16] When augmented with sensors, cloud-based resources, and the other components that support pervasive computing environments, it becomes feasible to undertake real-time, dynamic, interactive control/optimisations (of traffic on a highway, of energy usage in a household, or of pricing in a market) to customise system performance to local conditions in time, space, or in response to other contextual factors.

The increasing availability of data will drive policymakers and researchers to expand the range of questions related to the Internet economy they may seek to answer. Economies and markets are complex systems, but traditional economic methods have focused on simplified models based on limited data. The data limitations were often imposed by cost and observability considerations. The result is that traditional economic methods often do a poor job at explaining the dynamic behaviour of complex systems (Tesfatsion and Judd, 2006.)

In the context of growth economics, this is motivating a new breed of researchers to look for explanations for cross-country differences in income and economic growth using new and ways of processing data. For example, Hausmann, *et al.* (2011) have sought to map the productive capabilities of nations to come up with an Economic Complexity Index (ECI) that captures significantly more information and performs substantially better than other well-known indices of international economic performance. Their visualisation and graphic presentations offer a novel way to interact with the economic data and to explore dynamic changes over time.

This suggests yet another problem that commonly arises in Internet measurement (but is also commonly associated with the measurement of other complex phenomena). In short, because the Internet is a bundle of complementary components that are used in different proportions in different contexts, no single metric is sufficient. Thus, it is common to seek to summarise a mixture of metrics with a composite index. For example, Atkinson *et al.* (2008) constructed a composite index that combined data on household penetration rates, broadband speeds, and the lowest offered price per megabit per second in order to facilitate cross-national broadband rankings. Such composite indices often have great appeal to policymakers interested in rendering the multidimensional phenomena more tractable and understandable. Unfortunately, composite indices can be misleading. The choice of components and their weightings may emphasise some points and obscure others. Analysts differ on the cost/benefit tradeoffs of composite indices, but they are likely to remain a feature of future Internet policy debates. To help avoid the pitfalls inherent in any such index, it is important that the methods used in constructing any indices be fully disclosed and the underlying data be verifiable.

Key conclusions and the way forward

Measuring the Internet and the Internet economy is not a straightforward task and is a challenge already at the data level. The illustrative experiences from the quantitative assessments of the economic impact of the ICTs and the analysis of available datasets provide some suggestive insights. In particular, three main conclusions can be derived.

First, it must be highlighted that the measures of the *Internet* (*i.e*. measures of the *Internet* as a global network of interconnected computer networks using a standard Internet protocol) cannot be interchangeably used with the measures of the *Internet economy* that refer to various types of economic impact (direct and indirect, static and dynamic) of the Internet. Of course both measures are conceptually related, as any robust quantitative analysis of the impact of the *Internet* first requires a reliable, aggregated proxy of *Internet* development. This implies that measures of the *Internet Economy* (*e.g*. measures of the economic *impact of the Internet*) need not be identical to proxies of the *Internet*. Even though the term *Internet economy* lacks a precise, statistical definition, there are several measures that describe the *Internet* only and cannot be used to measure the *Internet economy* and vice versa.

Possible measures of the *Internet* that do not measure the *Internet economy* include adoption rates (such as penetration rates) and measures of access prices that do not attempt to quantify the economic impact of the Internet, but focus on measurement of one of its other dimensions (*e.g.* technical). Examples of measures that refer to the *Internet economy* only, and do not address the issue of measurement of the Internet mostly describe the economic effects of the Internet including measures of the effects that the Internet might have on firms’ profits, or on the growth of GDP. Measures that address both, the *Internet* and the *Internet economy* focus on the size of the Internet expressed in monetary terms, *e.g.* investments in the Internet infrastructure.

Second, the vast empirical literature on the economic impact of ICTs provides some illustrative lessons. Overall the empirical studies demonstrate that ICT is a massive story not only ostensibly in everyday lives but very ostensibly in the productivity statistics as well. Thanks to the existence of computerisation, the possibilities to empirically investigate the economic impact of ICTs have improved greatly which should help to continue to empirically observe how exactly ICTs are changing the economy. Thus far the evidence is clear at the firm-level and more complex at the macroeconomic, country-level. Moreover, the ICT-focused studies highlight its complex and dynamic character; the productivity effect of ICTs is not only significant and positive, but also increasing over time. Regarding the GPT hypothesis the existing studies provide the strong indication about the GPT character of ICTs but no final evidence.

Third, given the general, transformational character of the Internet and the large area of its economic impact, the scope of an exercise that attempts to measure the *Internet economy* must be precisely defined.

Indeed the economic impact area of the Internet is striking because if Internet connectivity failed on a large scale over an extended period of time, the whole economy would probably suffer a major shock in the short run, similar to the effects of oil shortages during the oil crisis or extended electricity black outs. The myriad of areas where the economic dimension of the Internet or its economic impact can be observed and measured calls for attention when defining the scope of the measurement, and choosing the methodology. For example, one needs to determine whether the measurement of the Internet economy would focus on a given country or a given industry, or what would be the time horizon of the assessed economic impacts of the Internet.

Clearly, the large spectrum of possible impact areas could result in a trade off between precision and scope of measurement. Significant changes underway in the Internet – to enable mobility, cloud computing resources, social-networking, and sensor networks – imply that tomorrow's critical Internet components are not well-measured by today's Internet metrics. Line counts, fibre miles, megabytes of traffic, or IP addresses alone are not good proxies for assessing the intensity of the trends identified.

To reiterate, it is extremely difficult to provide a single measure to capture the whole Internet economy. The continuously evolving Internet has changed from a service used by some to an essential, basic economic infrastructure that will soon be used by nearly everyone in nearly all places. It affects almost all economic activities and its impact is found in numerous short and long-term economic processes.

As a way to move the research agenda forward, this study offers a method for categorising different approaches to measuring the Internet economy (see Figure 1). Approach 1, the **direct impact**, is the most conservative and relies mainly on official data. It groups studies that measure the size of the Internet economy expressed as a part of GDP or business output. Approach 2, the **dynamic impact**, looks at the dynamic impact that the Internet might have on all industries, and hence on rates of productivity growth and eventually GDP growth. Approach 3, the **indirect impact**, takes into account the indirect impact of the Internet. Studies within this broader approach examine the effects of the Internet on economic phenomena such as consumer surplus, or explore how the Internet contributes to social welfare gains. These studies look at additional impacts of the Internet on economic welfare not measured by official statistics.

The three approaches are elaborated in the following sections.

APPROACH 1: DIRECT IMPACT OF THE INTERNET

Approach 1: Direct impact of the Internet

This approach attempts to measure the share of GDP value added that is generated by Internet-related activities. This includes value added generated by:

- Activities supporting the Internet (*e.g.* ISPs, Internet equipment manufacturers, etc.)
- Activities purely based on the Internet (*e.g.* search engines, e-commerce services, etc.)

Studies within this approach do not include benefits outside of those captured by GDP.

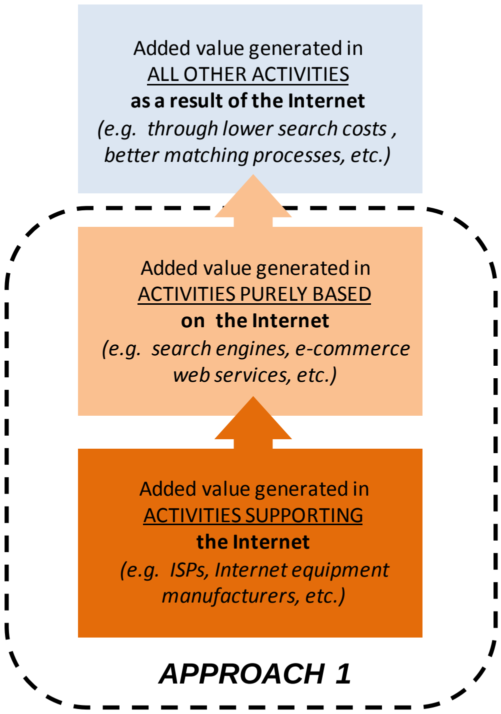
The Internet economy may be defined as the value generated by undertaking economic activities either supporting the Internet or purely based on the Internet (see Figure 2.) This definition includes the value generated by two sets of economic activities:

- Activities undertaken for the operation and use of the Internet, *e.g*. production of broadband equipment, provision of ISP services, etc. (Figure 2, bottom box),
- Activities purely based on the Internet, *e.g*. e-commerce, digital content, search, etc. (Figure 2, middle box).

In terms of this approach, the activities reported above are referred to as Internet-related activities. These activities are narrowly defined as the direct impact that the Internet has on economies.

Moreover, it is important to underline that the economic impact is not limited only to the activities that support the Internet or that are purely based on the Internet. In fact, the economic impact of the Internet is much broader through, for example, reduced search costs for firms, better access to information or improved search and matching processes in the economy. Hence, the total economic impact of the Internet is much broader than this approach can capture, and reaches virtually all economic activities.

Figure 2. Direct impact of the Internet



Existing results

There are only a few studies that attempt to define and measure the value of Internet-related activities. These include recent studies by Hamilton Consultants (2009), BCG (2010 and 2011), Deloitte (2011), and McKinsey (2011). All of these studies analyse the size of the Internet-related activities as a percentage of total GDP for different developed economies. The estimated results range between 0.8% and 7% (Table 2) but the methodologies differ across research firms.

One of the earliest studies to estimate the share of Internet generated output within total GDP is Hamilton Consultants (2009). This study estimates the contribution of the Internet to total GDP based on a proxy of Internet-related jobs. The study concludes that the contribution of the Internet to US GDP in 2008 was 2% by using this proxy of the number of jobs in the United States that rely on the Internet.

The results are likely to underestimate the contribution of the Internet to GDP because the approach is based on the number of jobs deemed to be Internet-related. The focus is on some key sectors but does not take into consideration all the Internet-related employment in other sectors throughout the economy.

Table 2. Internet-related value added in various economies; results from existing studies

Study	Analysed economy	Estimated Internet-related value added (% of GDP)
Hamilton Consultants (2009),	United States	2%
BCG (2010)	United Kingdom	7.2%
BCG (2011)	Sweden	6.6%
BCG (2011)	Hong Kong, China	5.9%
BCG (2011)	Denmark	5.8%
BCG (2011)	Netherlands	4.3%
BCG (2011)	Czech Republic	3.6%
BCG (2011)	Germany	3.4%
BCG (2011)	Poland	2.7%
BCG (2011)	Belgium	2.5%
BCG (2011)	Spain	2.2%
BCG (2011)	Italy	1.9%
BCG (2011)	Egypt	1.6%
BCG (2011)	Russia	1.6%
BCG (2011)	Turkey	1.2%
McKinsey (2011)	Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, United Kingdom, United States, South Korea, Sweden	3.4% on average
Deloitte (2011)	Australia	3.6%

Sources: BCG, McKinsey, Deloitte

Another approach is put forward by the Boston Consulting Group (BCG, 2010) who produced a report looking at the size of the Internet economy in the United Kingdom. In particular, the report attempts to define and quantify the Internet economy and to evaluate how the Internet is transforming the UK economy. BCG then reapplies the methodology in other countries.

In particular, the BCG (2010) report distinguishes four key elements of the direct economic impact of the Internet:

1. The share of GDP attributed to the Internet, including consumption, investment, government spending, and net exports.

2. Consumer and business economic impacts not captured by GDP including e-commerce, online advertising, and consumer benefits.

3. Productivity impacts including gains from e-procurement in manufacturing and productivity gains through e-sales in wholesale and retail trade.

4. Broader social impacts including user-generated content, social networking, fraud and piracy.

The report concludes that the Internet economy amounts to 7.2% of GDP in the United Kingdom. The methodology applied in BCG (2010) for the United Kingdom is subsequently replicated by BCG for other economies (BCG, 2011; see Table 2). The results range from 1.2% in Turkey to 6.6% in Sweden.

Another related report on the share of the Internet economy in Australia's GDP was published by Deloitte Access Economics (Deloitte, 2011). The authors conclude that in 2010 the direct contribution of the Internet is equal to 3.6% of Australia’s GDP. The study uses the approach introduced by BCG (2010) and also evaluates the amount spent by consumers, businesses, and government on Internet-related goods and services that are produced in Australia.

A similar report by McKinsey (2011) applies a similar methodology to assess the share of the Internet in the GDP of 13 economies, including the G7 countries and the BRIC countries. The results vary between 0.8% and 6.3% of GDP (Table 2).

McKinsey (2011) also takes a similar approach to BCG (2010) in order to calculate the share of the Internet in total GDP by aggregating the components of GDP that corresponded to Internet-related consumption, investment, government spending, and net exports.

These studies are well known but it needs to be highlighted that even though the goals of their research are well defined, the studies typically do not discuss the methodologies employed and do not present the input data. Therefore these results should be interpreted cautiously.

What have we done

The goal of this specific research is to provide a clear, statistical methodology to assess the size of the direct, economic impact of the Internet. In particular, this exercise looks at possible ways:

- To identify Internet-related activities (supporting the Internet or purely based on the Internet) within commonly available international industrial classification systems (ISIC Rev.4), and

- To measure the value added created by these industries, following the concept of value added set out in the System of National Accounts (SNA).

Unfortunately, as described below, there are many challenges to face as the level of detail of data typically available and published by official statistical agencies is rarely sufficient to identify such activities and to derive such estimates. Therefore, the research presented here uses revenue data provided by businesses in the information sector, together with e-commerce statistics from other sectors of the economy as proxies, as well as assumptions to get an order of magnitude of the value added that can be attributed to the Internet.

Internet-related activities and the System of National Accounts (SNA)

In the System of National Accounts, the statistical concept of value added is used to capture the value generated by an economic activity. This concept consists of measuring the value that the firm adds to that of the firms that supply its inputs (OECD, 2006). Consequently, the value added is defined as the value of output minus the value of intermediary inputs, that is, all inputs that a firm buys from other firms and uses in its own production.

Most OECD countries are able to provide official estimates of value added, according to the International Standard Industrial Classification of All Economic Activities (ISIC), although at different levels of detail (Box 3). This classification outlines a structure of economic activities subdivided into a hierarchical, four-level structure of mutually exclusive categories.

The OECD has used the concept of value added systematically in the past to measure the economic value generated by the ICT sector (OECD, 2010a). This concept of value added can be also employed to measure the Internet economy as defined in Approach 1, that is, the direct economic value generated by activities that support the Internet and activities purely based on the Internet.

This requires identifying these activities within the relevant industrial classification sectors. Some of these activities are captured or fall within the OECD ICT sector and the Content and Media sector.[17] OECD has defined these well-known sectors according to International Standard Industrial Classification (ISIC rev.4).

Box 3. Industry classification systems

The International Standard Industrial Classification of All Economic Activities (ISIC) consists of a coherent and consistent classification structure of economic activities based on a set of internationally agreed concepts, definitions, principles and classification rules. The classification is used to classify statistical units, such as establishments or enterprises, according to the economic activity in which they mainly engage.

These economic activities are subdivided in a hierarchical, four-level structure of mutually exclusive categories, facilitating data collection, presentation and analysis at detailed levels of the economy in an internationally comparable, standardised way. The categories at the highest level are called sections, which are alphabetically coded categories intended to facilitate economic analysis. The sections subdivide the entire spectrum of productive activities into broad groupings, such as “Agriculture, forestry and fishing” (section A), “Manufacturing” (section C) and “Information and communication” (section J). The classification is then organised into successively more detailed categories, which are numerically coded: two-digit divisions (e.g.: 27 Manufacture of electrical equipment); three-digit groups (*e.g.*: 273 Manufacture of wiring and wiring devices); and, at the greatest level of detail, four-digit classes (*e.g.*: 2731 Manufacture of fibre optic cables).

The most recent version of the ISIC is Revision 4 (ISIC 4), which has been released to comply with the new statistical concepts introduced by the revision of the SNA in 2008.

Apart from ISIC, there are numerous classification schemes of industrial activity that are used regionally. For example the European countries have a common industry standard classification system (NACE) consisting of a 4-digit code linked closely to ISIC. Australia and New Zealand use the Australian and New Zealand Standard Industrial classification (ANZSIC) also consisting of a 4-digit code system also linked to ISIC but more detailed at the lower level. Canada, Mexico and the United States follow the North American Industry Classification System (NAICS) which is a more detailed (6-digit) classification but also linked to ISIC. In general every country has their own national industrial classification at various levels of detail which usually link to ISIC, *e.g*. JSIC for Japan, KSIC for Korea, etc.

The Internet economy within ISIC: challenges

Unfortunately identifying the Internet-related categories within these sectors across the entire economy is extremely difficult for two main reasons. First, the available categories are, in most cases, too broad to identify relevant activities; hence, identifying Internet-related activities using the most detailed level of ISIC (4-digit) is insufficient. A good example of this could be the newspaper publishing industry which includes mainly offline activities (traditional newspaper publishing,) but also includes some activities that are purely based on the Internet, *e.g.* publishing of online newspapers. Only some categories within these sectors seem to refer fully to the Internet-related activities, but even within these categories, there are numerous aspects that may or may not be considered as Internet-related.

Second, available data is presented at a level that is too aggregated to identify the Internet-related activities. Even though some categories within the industrial classifications seem to refer fully to the activities that support the Internet or are purely based on the Internet, the corresponding existing datasets on value added are not detailed enough. This means that without detailed, firm-level data or data held in more detailed national classification systems, the creation of an internationally consistent mechanism to identify the activities that support the Internet and activities purely based on the Internet within ISIC categories is virtually impossible.

Beyond ISIC: Revenues and e-commerce

Given that detailed data on Internet activities is usually not readily available in terms of value added, it is necessary to look for other datasets that could provide detailed information about the activities that *support* the Internet and are *purely based* on the Internet. Based on assumptions, these data could in turn be used to approximate value added estimates of the direct economic impact of the Internet.

Two industry-related datasets seem to be particularly relevant in this context: *i*) data on revenues collected through surveys; and *ii*) data on e-commerce activities (also collected through surveys). Available statistics as well as a more detailed industrial classification (NAICS) makes this type of analysis possible for the United States.

The Internet economy in the United States

The following statistics can be used in order to proxy Internet-related activities and their value added for the United States:

- Detailed revenue data on services, in particular on Internet-related activities within the information sector, identified in the North American Industry Classification System (NAICS 2002) as NAICS Code 51 (US Census Bureau, 2011 Annual Services Report).

- E commerce revenue reported across a large number of industries, also in NAICS 2002 (US Census Bureau, 2011 E-commerce Multisector E-Stats report).

These two datasets serve to identify a number of activities that support the Internet and/or are purely based on the Internet.[18] These proxies can be combined with value added data for each industry to estimate the value of the Internet-related activities. In the case of the United States, this can be done with value added per industry sector at an aggregate level, two or three digits.[19] (Table 3)

Table 3. Value added in the United States (NAICS 2002)

Value added (USD million)					As share of Business sector VA			
Industry Title	2008	2009	2010	2011	2008	2009	2010	2011
Total	**14 291 543**	**13 938 950**	**14 526 547**	**15 075 666**				
Agriculture, forestry, fishing, and hunting	159 375	139 972	156 984	173 523				
Mining	319 166	213 366	239 511	289 901	4%	3%	3%	3%
Utilities	257 663	258 324	264 862	297 928	3%	3%	3%	3%
Construction	614 204	541 905	511 639	529 545	7%	6%	6%	6%
Manufacturing	1 628 498	1 540 226	1 701 937	1 731 466	18%	18%	19%	18%
Wholesale trade	824 067	768 548	797 348	845 060	9%	9%	9%	9%
Retail trade	848 629	837 205	884 877	905 718	9%	10%	10%	10%
Transportation and warehousing	414 994	391 672	402 524	447 913	5%	5%	4%	5%
Information	636 843	615 445	623 472	646 641	7%	7%	7%	7%
Finance and insurance	1 041 460	1 098 964	1 241 946	1 159 310	12%	13%	14%	12%
Real estate	1 671 470	1 679 218	1 563 893	1 700 954				
Rental and leasing services and lessors of intangible assets	203 692	186 350	201 346	197 859	2%	2%	2%	2%
Professional, scientific, and technical services	1 100 205	1 033 270	1 095 758	1 151 455	12%	12%	12%	12%
Management of companies and enterprises	263 215	248 970	263 699	283 626	3%	3%	3%	3%
Administrative and waste management services	419 750	395 837	423 380	448 812	5%	5%	5%	5%
Accommodation and food services	404 907	387 604	416 693	443 096	5%	5%	5%	5%
Community social and personal services*	3 483 406	3 602 075	3 736 677	3 822 859				
Business sector	**8 977 293**	**8 517 686**	**9 068 992**	**9 378 330**	**100%**	**100%**	**100%**	**100%**

	2008	2009	2010	2011
Total VA	**100%**	**100%**	**100%**	**100%**
Business sector as share of total VA	63%	61%	62%	62%
Agriculture, forestry, fishing, and hunting as share of total VA	1%	1%	1%	1%
Real estate as share of total VA	12%	12%	11%	11%
Community social and personal services as share of total VA	24%	26%	26%	25%

	2008	2009	2010	2011
*** Community social and personal services includes:**	**3 483 406**	**3 602 075**	**3 736 677**	**3 822 859**
Educational services, health care, and social assistance	1 153 947	1 210 420	1 272 289	1 311 110
Arts, entertainment, and recreation	132 370	130 009	139 112	147 976
Other services, except government	342 693	340 791	356 766	369 936
Government	1 854 396	1 920 855	1 968 510	1 993 837

Notes: In order to get a comparable aggregate across countries, the business sector has been calculated following the business sector aggregate defined by ISIC Rev.4 activities 05-66 and 69-82 (highlighted in grey). It does not take into account agricultural activities; real estate; nor community, social and personal services. The community social and personal services category includes industries such as: educational services, health care and social assistance; arts, entertainment and recreation, and other non-government services, and government services.

Source: OECD, based on US Bureau of Economic Analysis data, April 2012 and June 2013 (data for 2011).

Information sector: Proxy and assumption

The first dataset focuses on the ***information sector***, and captures some of the activities supporting the Internet (*e.g*. "Internet access services") as well as some of the activities performed purely on the Internet (*e.g*. "online newspapers", "publishing and broadcasting of content on the Internet") and provides information on revenues. For a list, see Table 4.

Table 4. The information sector in the United States (NAICS 51), estimated revenue for employer firms, 2006-11

Revenue (USD million)

NAICS 02	Industries	2006	2007	2008	2009	2010	2011
51	**Information sector revenues**	**1 027 063**	**1 072 341**	**1 108 349**	**1 074 959**	**1 110 225**	**1 160 849**
511	**Publishing industries (except Internet)**	**269 907**	**282 223**	**284 613**	**264 194**	**265 718**	**273 902**
5111	Newspaper, periodical, book and directory publishers	144 704	146 822	141896	125 213	120 293	n.a.
511110	Newspaper publishers	48 949	47 563	43 919	36 358	34 695	33 164
511120	Periodical publishers	44 757	46 003	44 985	39 099	38 395	39 503
511130	Book publishers	26 722	27 807	28 032	27 404	28 121	27 530
511140	Directory and mailing list publishers	17 617	18 515	18 371	16 670	13 475	13 040
511191	Greeting card publishers	4 609	4 779	4 443	3 862	3 852	3 822
511199	All other publishers	2 050	2 155	2 146	1820	1755	1754
5112	Software publishers	125 203	135 401	142 717	138 981	145 425	155 089
511210	Software publishers	125 203	135 401	142 346	138 714	138 714	n.a.
512	**Motion picture and sound recording industries**	**93 265**	**94 986**	**95 271**	**90 398**	**95 118**	**95 762**
5122	Sound recording industries	16 821	15 189	15 267	14 419	13 787	n.a.
512210	Record production	301	338	351	425	453	495
512220	Integrated record production/distribution	10 642	9 082	8 953	8 665	8 258	7 471
512230	Music publishers	4 646	4 466	4 713	4 155	3 793	3 770
512240	Sound recording studios	831	854	810	749	839	872
512290	Other sound recording industries	401	449	S	425	444	433
515	**Broadcasting (except Internet)**	**96 311**	**99 919**	**104 584**	**98 934**	**107 520**	**112 785**
515111	Radio networks	3 829	4 124	4 341	4 307	4 883	5 007
515112	Radio stations	14 616	14 871	13 912	11643	12 135	12 167
515120	Television broadcasting	36 959	35 998	36 762	31553	35 334	35 293
515210	Cable and other subscription programming	40 907	44 926	49 569	51431	55 168	60 318
516	**Internet publishing and broadcasting**	**11 510**	**15 035**	**17 763**	**19 111**	**21 273**	**50391 (1)**
516110	Internet publishing and broadcasting	11510	15 035	17 760	19 504	19 504	n.a.
517	**Telecommunications**	**459 315**	**480 030**	**498 058**	**495 062**	**507 533**	**540 040**
518	**Internet service providers, web search portals and data processing services**	**90 427**	**93 804**	**101 411**	**100 719**	**106 582**	**n.a.**
518210	Data processing, hosting and related services	66 023	66 652	71698	71614	76 156	81091(2)
519	**Other information services**	**6 328**	**6 344**	**6 649**	**6 541**	**6 481**	**n.a.**
	Internet-related activities revenues	**83594**	**101659**	**123060**	**133191**	**147799**	**165 014**
	Share of Internet activities revenues in total information sec	**8.1%**	**9.5%**	**11.1%**	**12.4%**	**13.3%**	**14.2%**

Notes:.(1) Including Web search portals. (2) estimated value
Source: OECD based on US Census Bureau, 2010 Annual Services report, February 2012 and for 2011 data based on US Census Bureau, 2011 Annual Services report.

The table above shows the level of detailed information available for some of the categories within this sector and that had been identified as Internet-related activities. These activities add up to estimated revenue of about USD 165 billion in 2011 (up 12% from the previous year), which represents 14.2% of total revenues in the information sector.

To calculate the relevant value added from this sector the following assumption is applied:

> ***Assumption 1:*** *It is assumed that the share of revenue from Internet-related activities in total revenue for the information sector is proportional to the share of value-added from these activities in total value added for that sector.*

As a consequence, the value added generated by the Internet-related activities of the information sector in the United States is estimated at 0.9% of total business sector value added.[20]

Other business sectors: proxy and assumptions

The second dataset provides information on *e-commerce* activities and reports the value of goods and services sold online in ***various sectors***. E-commerce is considered as part of the Internet-related activities and corresponds here to the activities *purely based* on the Internet.

E-commerce data were collected in four separate Census Bureau surveys: Annual Survey of Manufactures (ASM), Annual Wholesale Trade Survey (AWTS), Annual Retail Trade Survey (ARTS) and Service Annual Survey. These surveys used different measures of economic activity such as shipments for manufacturing, sales for wholesale and retail trade, and revenues for service industries. The E-Stats data for 2011 does not cover the entire US economy and sectors such as agriculture, mining, construction and some services-related industries are not included.

The e-commerce data illustrates only the share of e-commerce in revenues in relevant industry classes (see Table 5).

Table 5. E-commerce in the United States in selected industries (NAICS 2002)

As percentage of total revenues

NAICS 2002	Industries	2008	2009	2010	2011
11	Agriculture, forestry, fishing, and hunting	n.a.	n.a.	n.a.	n.a.
21	Mining	n.a.	n.a.	n.a.	n.a.
22	Utilities	**n.a.**	**0.2**	**0.2**	**0.1**
23	Construction	n.a.	n.a.	n.a.	n.a.
31,32,33	Manufacturing	**39.7**	**42.8**	**46.4**	**49.3**
321	Wood products	22.1	25.4	28.4	31.2
327	Nonmetallic mineral products	23.1	27.0	30.5	33.4
331	Primary metals	38.7	40.4	45.7	50.6
332	Fabricated metal products	27.5	31.8	36.0	39.1
333	Machinery	36.4	41.2	46.6	48.7
334	Computer and electronic products	38.7	41.8	44.6	50.3
335	Electrical equipment, appliances, and components	34.1	40.2	43.8	46.7
3361, 3362, 3363	Motor vehicles, bodies and trailers, and parts	n.a.	n.a.	n.a.	61.1(1)
3364, 3365, 3366, 3369	Other transportation equipment	n.a.	n.a.	n.a.	n.a.
337	Furniture and related products	31.0	34.3	39.5	43.2
339	Miscellaneous manufacturing	25.1	28.9	31.0	35.4
311, 312	Food and beverage and tobacco products	40.6	45.0	48.1	47.9(2)
313, 314	Textile mills and textile product mills	42.3	47.4	50.2	48.6(3)
315, 316	Apparel and leather and allied products	28.9	34.4	35.4	40.8(4)
322	Paper products	37.8	42.9	46.5	49.4
323	Printing and related support activities	30.4	31.7	35.2	39.7
324	Petroleum and coal products	44.1	44.3	46.0	52.6
325	Chemical products	40.1	42.2	44.2	47.2
326	Plastics and rubber products	35.8	40.9	43.9	46.2
42	Wholesale trade[1]	**17.3**	**20.5**	**20.2**	**20.0**
44, 45	Retail trade	**3.6**	**4.0**	**4.4**	**4.7**
48, 49 (except 491)	Transportation and warehousing	n.a.	n.a.	n.a.	11.8
481	Air transportation	n.a.	28.1	26.2	27.5
482	Rail transportation	n.a.	n.a.	n.a.	8.0
483	Water transportation	n.a.	17.3	8.7	8.0
484	Truck transportation	3.5	3.6	3.5	7.7
485	Transit and ground passenger transportation	n.a.	0.8	n.a.	
486	Pipeline transportation	n.a.	1.0	0.9	
487, 488, 492	Other transportation and support activities	n.a.	n.a.	n.a.	
493	Warehousing and storage	n.a.	n.a.	n.a.	
51	Information	**4.6**	**5.0**	**5.0**	**5.9**
511, 516	Publishing industries (includes software)	n.a.	n.a.	n.a.	10.3
512	Motion picture and sound recording industries	n.a.	n.a.	n.a.	1.5
515, 517	Broadcasting and telecommunications	n.a.	n.a.	n.a.	11.6
518, 519	Information and data processing services	n.a.	n.a.	n.a.	
52	Finance and insurance	**n.a.**	**1.4**	**1.5**	**1.9**
53	Real estate and rental and leasing	**n.a.**	**n.a.**	**n.a.**	**4.6**
531	Real estate	n.a.	n.a.	n.a.	
532	Rental and leasing services and lessors of intangible asset	6.9	8.7	8.5	
54	Professional, scientific, and technical services	**1.6**	**1.9**	**1.9**	**2.2**
55	Management of companies and enterprises	n.a.	n.a.	n.a.	
56	Administrative and waste management services	**2.7**	**2.9**	**3.0**	**3.0**
61	Educational services	**n.a.**	**7.5**	**7.6**	**9.6**
62	Health care and social assistance	**0.1**	**0.1**	**0.2**	**0.1**
71	Arts, entertainment, and recreation	**2.1**	**2.2**	**2.4**	**29.0**
72	Accommodation and food services	**2.8**	**2.7**	**3.0**	**5.0**
81	Other services, except government	**2.0**	**2.1**	**2.3**	**2.5**

Note: Wholesale trade refers to merchant wholesale trade sales, excluding manufacturers' sales branches and offices.

Source: OECD based on US Census Bureau, 2011 E-commerce Multi-sector Data Tables, May 2012.

There are two ways of estimating e-commerce value added depending on the scope of the activities. The first one only takes into account e-commerce from the wholesale and retail sectors (narrow scope). This is because it can be argued that all of the value added generated by e-commerce in these sectors is directly related to the Internet. For example, it is credible to assume that all the added value generated by a given e-store is generated only thanks to the Internet, as without the Internet the e-store could not exist. The second one takes a broader view (broad scope) and includes e-commerce activities from all industries across the economy for which data are available (excluding the information sector to avoid double counting).

Consequently, in order to calculate the relevant value added from ***e-commerce*** activities in other business sectors of the economy (for both narrow scope and broad scope), the following assumption is applied:

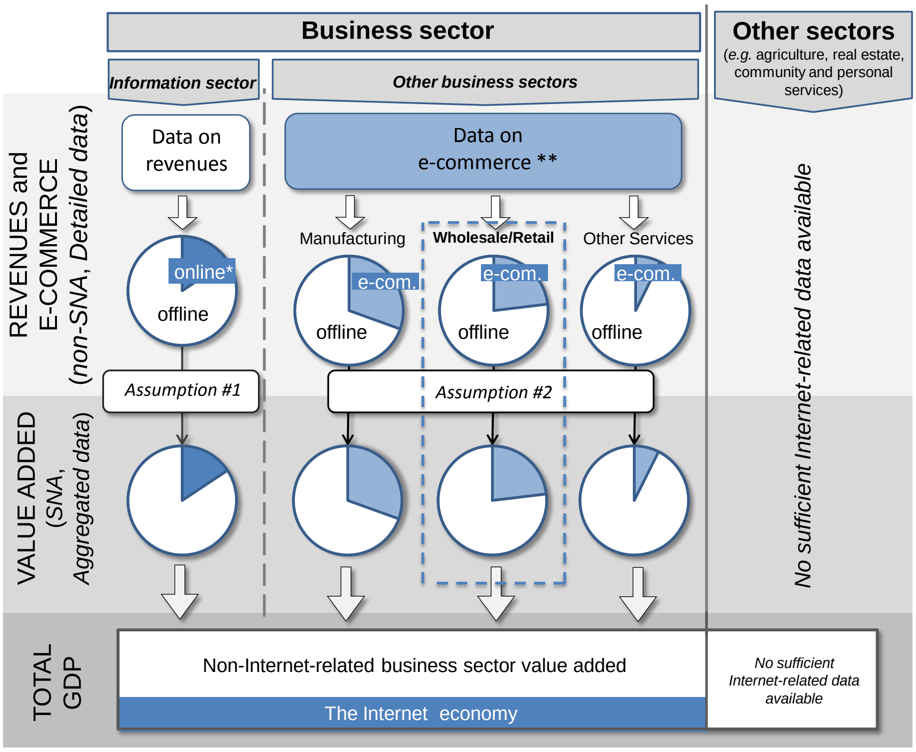
Assumption 2: *It is assumed that the share of revenue from e-commerce in total revenue for each industry sector is proportional to the share of value-added from e-commerce in total value added for that same industry sector.*

Applying the shares of e commerce in revenues of relevant industries and aggregating the results yields the estimated value added generated by e–commerce in certain sectors of the US economy as 3.2% (according to the narrow scope) and up to 13.8% (broad scope) of total business sector value added in 2011.

Results

Adding together the estimates of the value added generated by the Internet-related activities of the information sector, and the estimates of the value added generated by e commerce in certain sectors of the US economy (excluding the information sector), provides an order of magnitude of the value added in the US business sector that relies on the Internet which will vary depending on the scope of the definition (see Figure 3).

Figure 3. Estimation of the direct impact of the Internet



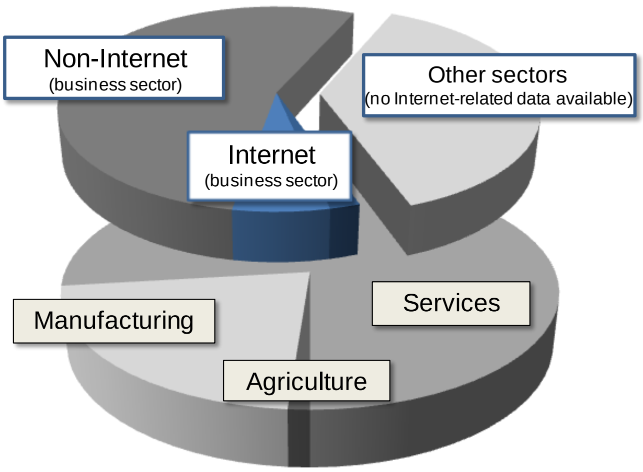
Note: The term *online* refers to activities supporting the Internet and activities purely based on the Internet within the Information sector. Data on e-commerce refer to the activities purely based on the Internet and statistics on e-commerce are based on different measures of economic activity such as shipments for manufacturing, sales for wholesale and retail trade, and revenues for service industries. The narrow scope focuses on Internet-related activities in the following business sector industries: Information services sector and the wholesale and retail sectors. The broader scope takes into account Internet-related activities across all industries in the business sector for which data are available.

In particular, at least 3.2% (using the narrow scope) and up to 13.8% (broad scope) of US business sector value added could be attributed to Internet-related activities in 2011. It is important to note that the broad scope estimate is based on the limit assumption that online sales are adding to traditional sales, with no substitution occurring. Moreover, these numbers are based on data that reflect only a part of the US economy since agricultural activities, real estate, and community and personal services are not included. The business sector accounted for 62% of total US value added (GDP) in 2011.

It needs to be highlighted that, as outlined in the OECD Internet Economy Outlook 2012 (OECD, 2012b), the respective figures for 2010 were 3% and up to 13%. This indicates that the Internet economy has reported a steady growth rate since 2010, irrespective of the approach taken.

These results are graphically presented in the upper pie chart (Figure 4).

Figure 4. Sizes of various sectors in the United States economy, 2011



Note: Dark blue corresponds to the narrow scope and dark and light blue together correspond to the broad scope.

Three elements should be highlighted:

First, the presented share of value added (GDP) that is attributed to Internet-related activities is not an independent sector as other sectors of the US economy. Instead, it is distilled from shares of other sectors and overlaps with them. In Figure 4, the share of the Internet is represented in contrast to the share of non-Internet related only.

Second, the Internet, as a general purpose technology, is not directly reflected in the national accounts system so the results presented above rely on the strong assumption that revenues are proportional to value added.

Third, the direct impact of the Internet on the economy is presented in *gross* terms. In particular, some of the activity based on the Internet may replace the activity generated in another, off-line environment. For example online shopping can substitute for traditional shopping and online banking has replaced some traditional, face-to-face banking. Indeed, several empirical studies highlight that the rapid evolution of the Internet and the emergence of this fast-changing technological environment results in some displacement of economic activities (Katz and Shapiro, 1986; Eisenach and Lenard, 1998a and b, Brynjolfsson and Hitt, 1998, McAfee and Brynjolfsson, 2007)

Future research

There is a lack of a clear, statistical methodology to identify directly the activities that support the Internet and are purely based on the Internet within the SNA. There is a need for more research in this area to assess the size of the direct, economic impact of the Internet.

Future research in this area will focus on two key areas: *i*) investigating the data available for other countries and *ii*) refining the methodology as required.

For these exercises, a more granular data collection by national statistical agencies would be required.

APPROACH 2. THE DYNAMIC IMPACT OF THE INTERNET

Approach 2: The dynamic impact of the Internet

This dynamic approach to measuring the impact of the Internet examines the **net** share of additional GDP that is generated by all Internet-related activities across the economy. This is done by looking at the statistical relationship between measures of Internet development and economic variables such as GDP growth or employment. There is an important trade-off with this approach because it captures the net GDP benefits of the Internet across all sectors of the economy but without the level of detail necessary to understand the precise sources of these benefits. Additionally, because the approach captures only "net" benefits, the Internet's full impact could be tempered by GDP or employment losses in other sectors as a result of Internet development.

The economic impact of the Internet, as captured in GDP and the system of national accounts, goes beyond firms supporting the Internet and operating purely on the Internet. In fact, the emergence of the Internet introduces a significant re-shuffle of the existing business environment and great impacts on firm efficiency across all sectors, at various stages of their activity.

This reshuffling results in significant changes to traditional business models, and as a consequence, ushers in a new structure of value added creation. Some industries observe a shift of activities and hence a shift of added value from off line to on line.

What is this approach

This approach checks what is the dynamic impact of the Internet. In particular it checks the *i*) *aggregated* and *ii*) *net* impact that the Internet has on GDP. Studies within this approach take into account:

- All possible industries that generate added value *thanks to the Internet* (not only industries supporting the Internet and operating purely on the Internet); and

- The *net* economic effect of the Internet on the GDP.

The value added generated **thanks to the Internet** refers to the simple observation that the Internet results in efficiency gains not only in industries producing *for* and *on* the Internet, but in virtually all sectors, including those that are seemingly unrelated to the Internet such as the gas and oil extraction industry (Box 4).

Box 4. The impact of the Internet on the gas and oil extraction industry

ICTs and the Internet play a significant role in the gas and oil extraction industry. An early report by UNCTAD in 2006 highlighted how the Internet and its applications are an important tool that become an essential element for various activities in these sectors for companies such a BP or Royal Dutch Shell, China National Petroleum Corporation or Gazprom (UNCTAD, 2006.)

Some solutions improve communications for the mobile work force, in cases when employees travel frequently to remote locations. Other applications are used for crisis management in case of natural disasters; quick communication saves precious time and automated data consolidation allows for quicker reaction times. Internet solutions in the gas and oil extraction industries facilitate collaboration across project teams (especially in the case of employees working in remote locations) and create a foundation for business intelligence applications, stronger content management, and consistent communications with external stakeholders.

Internet-based solutions impact the industrial performance at various stages of firms' activity. At the stage of research and development, the Internet improves efficiency of R&D and facilitates cross-firm collaboration. Several empirical studies demonstrate the positive influence of the Internet on research efficiency within firms and R&D collaboration between firms. Consequently, the use of the Internet positively impacts firms' innovation activity (Forman and van Zeebroeck, 2010; Polder *et al*., 2009; Bertschek *et al*., 2011.)

At other stages of firms' economic activity, Internet connectivity allows for more interaction among all market players. It also leads to more intense information flows, creates better and faster matching processes and consequently results in a higher rate of productivity. The positive impact of the Internet on firms efficiency has been documented by numerous empirical studies (Varian *et al*. 2002, Polder *et al*., 2009; Grimes and Ren, 2009; Majumdar *et al*., 2009; Bertschek *et al*., 2011)

Clearly, these benefits achieved *thanks to the Internet* across all sectors result in improved savings and consequently higher profits. One of the earliest studies that noted the beneficial impact of the Internet on firms' profits is Varian *et al*. (2002). The report analyses the impact of Internet technologies on economic activity, based on a survey of companies from various industries. The study is based on collected responses and finds that even at the early stage of broadband development (2002), companies actively looked for solutions using the Internet, which helped them to cut their costs and increase revenues. Specifically firms in United States, the United Kingdom, France and Germany reported realising a cumulative cost savings of USD 163.5 billion with the majority of the savings occurring since 1998.

From an economic perspective, these efficiency gains generated thanks to the Internet across all the industries translate into the higher added value reported in these industries. This Internet-generated added value has a certain meaning in the context of the Internet economy. On the one hand, it is generated *thanks to* the Internet and hence it could be included in the total Internet economy. On the other hand it is not generated to *support* the Internet or *purely based on* the Internet so it would not be captured by studies that select specific activities within existing industries as Internet-related (*e.g*. e-commerce) to be measured.

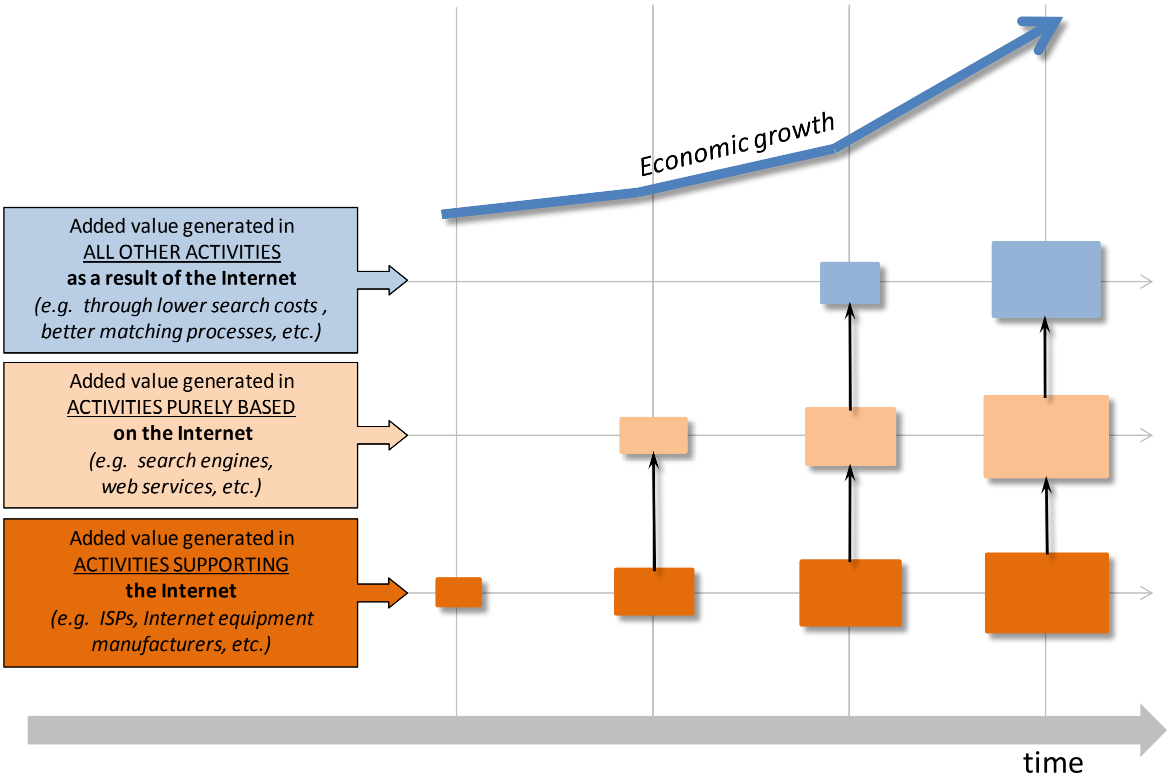
To illustrate this mechanism, assume the following dynamic sequence of events (illustrated in Figure 5). The **first stage** is the development of the Internet infrastructure (industries supporting the Internet) and it is shown on the bottom row of Figure 5. This includes companies that build, install or manage Internet infrastructure.

At the **second stage**, service providers such as search companies, e-mail hosting companies and other content firms appear and use the Internet infrastructure to provide new services. These activities also include the broad spectrum of e-commerce related businesses such as online shopping and e-banking. These Internet-specific services add to GDP but also become a key platform for the next stage (middle row in Figure 5)

In the **third stage,** the Internet's impact spreads much broader to virtually all activities in all sectors of the economy. Many of the benefits are achieved outside the traditional Internet sector (top row of Figure 5). These include sectors as diverse as automotive, agriculture, and government. The benefits in these outlying sectors rely on services and infrastructure in the bottom two levels.

The dynamic co-existence of these industries can be in turn observed at the aggregated macroeconomic scale in terms of a higher rate of economic growth.

Figure 5. Dynamic impact of the Internet



The second property that is addressed by studies that follow this second approach is the assessment of the **net effect** of the Internet of the economy. As mentioned above, the introduction of the Internet often results in displacement of economic activities from the off-line environment to the online environment. Indeed, numerous industries observe dynamic introduction of the online channels of distribution that are paralleled with the reduction of importance of the traditional offline channels. This approach takes into account only the net change, *i.e.* the net surplus in added values generated by the internet.

To reiterate, the Internet does not only impact the industries that support the Internet or operate primarily on the Internet. The Internet has a clear impact on a myriad of activities in virtually all industries. The impacts are measurable and hence are captured by the SNA but it is extremely difficult in many sectors to separate out which parts of value added are attributable to the Internet and which are not. Moreover, these transformational effects of the Internet at the firm level might also imply some shift in the structure of the GDP, which implies that the total net effect should be lower than simple aggregation of all the added values generated thanks to the Internet.

A number of studies consider these general *net* economic effects of ICTs and the Internet, and discuss the role of the Internet in the macroeconomic context.

Existing studies

Concerning the studies that look at the economic impact of ICTs, the variation and vastness of existing studies and the resulting abundance of quantifications of the ICT impact make it difficult for policymakers to base decisions on unambiguous and convincing evidence. To quantify the dynamic impact of ICTs, it is useful to classify studies by three different dimensions:

1. Employed method: two groups of approaches are distinguished, the non-parametric approaches – primarily growth accounting exercises, and parametric techniques – mainly econometric estimations of production functions.

2. Aggregation level: country, industry and firm level.

3. ICT product/measure: IT (hardware/software), data communication (Internet/broadband), telecommunication (mobile), and ICT (in its most extensive definition).

This summary focuses on studies in which the dependent variable is mainly represented by productivity or productivity growth although other concepts like output are considered in the literature as well, see *e.g.* Schreyer and Pilat (2001). Not included in this survey are studies on consumer surplus and ICT effects on employment, wages or innovation as well as quality and variety of products. The main findings show that there is a substantial variance in ICT elasticities depending on the methodology employed. While growth accounting exercises show different ICT effects for the United States and Europe, with a lower impact in the latter, econometric estimations provide no significant country differences. Moreover, there is broad evidence that over the last two decades an increase of ICT by 10% translated into higher productivity growth of 0.5% to 0.6%.

Besides its productivity enhancing effects, ICT by now has become an integral part of people's everyday lives, including the economic sphere. There have been many studies on how exactly ICTs are changing the economy. While on the one hand this helps illustrate the various aspects of how ICT affects production processes, efficiency and output growth, the abundance of studies also causes confusion arising from a broad literature at different levels of aggregation, studying different ICT products and using different methodologies. Furthermore, many of the studies report contradictory findings both at the qualitative (*e.g.* finding different answers to the question of ICT is a General Purpose Technology) and the quantitative (*e.g.* obtaining different point estimates for the output elasticity of ICT investment) levels. The large number of existing studies and findings has triggered a number of reviews as summarised in Table 6.

Table 6. Overview of existing surveys of the ICT literature.

Study	Method	Results
Brynjolfsson and Yang (1996)	Written survey based on over 150 studies.	Discusses explanations for the productivity paradox, measuring the IT output link was practically impossible due to lack of data and use of inadequate analytical methods.
Brynjolfsson and Hitt (2000)	Literature survey on how IT is linked to higher productivity and organizational transformation, based mainly of firm-level studies	IT performance depends of complementary institutional investments and these investments lead to improvements in intangible aspects. These factors are not well captured by traditional macroeconomic measurement approaches, hence the Solow Paradox.
Baily (2002)	Summarises growth accounting and case study evidence and assesses other indicators of structural change.	IT is an important, but not the only cause of the productivity resurgence in the 1990s. Competition and globalisation were the further basic drivers.
Dedrick *et al.* (2003)	Written survey on 19 firm level and 15 country level studies between 1987-2002.	Productivity paradox refuted, wide range of IT investments among different organisations can be explained by complementary investments in organisational capital
Pilat (2004)	Meta-study, based on firm-level data	Little evidence on the impact of ICT at the firm level are still relatively scarce, primarily due to data issues.
Melville *et al.* (2004)	Develop a model of IT business value added using a resource-based view to review the literature.	IT investments provide value, but the impact depends on the level of complementarity resources, competitive climate and the general macroeconomic environment. Synergies between technical and human IT resources yield a competitive advantage.
Stiroh (2005)	Meta analysis (20 studies from 1994-2002)	Study characteristics explain about 35% of the saturation in the IT elasticities. Median elasticity at 0.046.
Draca *et al.* (2006)	Survey micro and macro literature	Macro studies meanwhile show evidence of ICT impact. In micro studies the effect is larger than the neo-classical contribution would expect, which is due to organizational complements.
Holt and Jamison (2009)	Literature survey on broadband studies	Broadband has a positive impact, but cannot be measured with any precision.

In his meta-analysis, Stiroh (2005) summarises the effects of ICT on productivity and output by estimating them econometrically. He shows that the inclusion of fixed effects or estimation in first differences tends to lower the estimated ICT elasticity, while more aggregated data or utilisation of more recent data revisions tends to raise it. Brynjolfsson and Yang (1996) surveyed more than 150 studies and report there were neither robust findings on the link between IT and productivity during the 1980s and early 1990s, nor was it possible to measure this accurately due to lack of data and use of inadequate analytical methods.

By contrast, Melville *et al*. (2004) conclude that IT investments indeed provide value, but the impact of IT spending depends on levels of complementary resources, competitive climate, and the general macroeconomic environment. Moreover, synergies between technical and human IT resources only provide short-lived competitive advantage. In their survey on broadband and its contributions to economic growth Holt and Jamison (2009) suggest that broadband has had a positive impact overall, but the quantitative impact could not be measured with great precision. The review by Oz (2005) highlights the challenges researchers face and proposes a simple theory to explain the diminishing contribution of IT.

A smaller number of studies checked the dynamic economic impact of the Internet.

A study by Crandall, Lehr and Litan (2007) looked at the effects of *broadband penetration* on both output and employment, in the aggregate and by sector, using state-level data in the United States. To check the macroeconomic impact of the Internet, the authors employ an ordinary least squares regression analysis[21] using the number of broadband lines per capita as a proxy of the Internet and the ratio of employment or output in 2005 to its level in 2004 (or 2003) as dependent variables. They found that non-farm private employment and employment in several industries was positively correlated with the use of broadband. Specifically, for every 1% increase in broadband penetration in a state, the corresponding level of employment was higher by 0.2% to 0.3% per year.

An extensive study by Franklin *et al*. (2009) used a large dataset on broadband from several European countries. This statistical analysis found that the use of broadband is correlated with higher firm-level productivity. Moreover firm-level analyses in Sweden and the Netherlands indicate that it is due to ICT being a facilitator of wider innovation.

Qiang *et al*. (2009) also found the positive relationship between the adoption of broadband and the rate of economic growth. Apart from a substantial literature overview, the study introduced a cross-country empirical model to analyse this relationship. The authors used data from 120 developing and developed countries in an endogenous growth model based on Barro (1991). This approach allowed them to test the quantitative relationship between broadband penetration rates and the average growth rate of per capita GDP between 1980 and 2006 while controlling for other factors that may impact the growth rate. Qiang *et al*. (2009) found that a broadband penetration rate that is 10 percentage points higher is paralleled with an annual per-capita economic growth rate that is 1.21 percentage points higher.

Clearly correlation does not imply causation since this basic association between the stage of the Internet development and economic growth may be driven by reverse causality and other variables. In fact, several studies concluded that economic growth was one of the main determinants of the development of the Internet (Kiiski and Pohjola, 2002; Chinn and Fairlie, 2007.) These conclusions highlight the mutual dependency between the development of the Internet and the economic growth. Countries that are more developed invest more in the Internet development, but a more developed Internet may contribute to the rate of economic growth.

Several studies have addressed the question of whether Internet development drives economic growth by applying econometric techniques (*e.g.* Czernich *et al*., 2009; Koutroumpis, 2009). The results suggest that Internet development might indeed have some causal effect on growth.

The study by Czernich *et al*. (2009) examined the effect of broadband infrastructure on economic growth in a panel of OECD countries (1996-2007) using *broadband penetration rates* as the proxy for the Internet development. To overcome the potential problem with endogeneity, the authors perform the analysis in two steps. In the first step, they construct a predicted pattern of broadband evolution (free of shocks and policy interventions) using the data on cable TV and phone lines as instruments. This predicted estimator is then used in the second step to explain the rates of economic growth. The study finds that an increase in broadband penetration by 10 percentage-points raises annual per-capita growth by 0.9-1.5 percentage points.

A study by Koutroumpis (2009) also investigated how the Internet (measured by *broadband penetration rates*) affects economic growth. It was done using a macroeconomic production function based on a micro-model for broadband investments. Specifically, a structural econometric model (a framework that endogenised telecommunications investment) was inserted within the macroeconomic production function. The results suggested that there were increasing returns to broadband investments that corresponded to the persistence of network externalities.

To reiterate, with regard to the macroeconomic effects, the available evidence confirms that the intuitive dynamic *net* effects of the Internet are in fact real, and can often be quantified.

It needs to be highlighted that whereas the quantitative studies discussed above provide a strong indication about the net economic impact of the Internet, this impact cannot be measured with great precision. Following a meta-study by Holt and Jamison (2009) one can conclude that the Internet has indeed had a positive impact overall, but the quantitative impact cannot be precisely measured. Indeed, the existing studies result in the same ranges of magnitude but because of data limitations, no precise result can be established.

Moreover, it must be stressed that measuring the macroeconomic impact of the Internet requires a large, consistent, underlying dataset to produce econometrically solid and robust results. Given that the Internet is a relatively new, and rapidly growing phenomenon this data requirement cannot be fully met. Hence the results presented above cannot be interpreted as a robust confirmation of the causal effect that the Internet has on economic growth, but as a preliminary indication of such an effect.

What we have done

The results of studies that asses the dynamic, net economic impact of the Internet provide a useful tool to calculate the current net value of GDP that was generated *thanks to the Internet.* In particular, the measures of the casual effect of the Internet on economic growth can be used to evaluate the net impact that the Internet has on the total GDP of a given economy.

To do so, this research uses the findings of Koutroumpis (2009) to perform a simulation exercise for the US economy. Two findings presented in this study are particularly important for this simulation exercise.

The first one is the estimate of the impact that Internet development (measured by broadband penetration rates) has on GDP growth calculated by Koutroumpis (2009). Specifically, it measures how a 1% higher growth rate of broadband penetration rates affects economic growth. Depending on the estimation technique, the study concludes this is equal to 0.023%, or to 0.025%.

Secondly, the study highlights that the causal and positive effects of Internet on growth are particularly visible, once a critical mass of Internet infrastructure is present. In economies with low rates of Internet development, its impact on economic growth may even be undetectable, whereas in countries with rapidly developing networks the impact of the Internet on growth raises more than proportionally.

These conclusions can be used to check the size of the net share of GDP generated thanks to the Internet. It is evaluated in a quantitative simulation process according to the following hypothetical scenario with a key assumption: *Once the Internet becomes economically important its development freezes and the rate of broadband growth equals zero.* This hypothetical scenario is quantitatively evaluated based on existing empirical research; the simulation results are compared with the actual data.

Following the findings of the empirical research presented above, this lack of Internet development would in turn have an effect on economic growth. Moreover, using the measures calculated by Koutroumpis (2009), it is possible to calculate the value of the GDP that would be generated without the economic influence of the Internet.

In particular, the difference between the hypothetical value of GDP, potentially generated without the Internet, and the currently observed value of GDP is the measure of net value added generated thanks to the Internet. It is generated based on all the activities supported, enabled and facilitated thanks to the Internet, across all industries.

The study by Koutroumpis (2009) estimates two alternative proxies of the economic impact of the Internet, depending on the estimation method chosen. Consequently in this simulation exercise two corresponding scenarios are introduced. The higher value (0.025%) refers to the stronger impact of the Internet, the lower value (0.023%) refers to the weaker impact.

Moreover Koutroumpis (2009) highlights the importance of a critical mass in Internet development, without precisely estimating it. One could address this issue by checking various scenarios of Internet development that vary with respect to the year when this critical mass is reached. The scenario with the highest impact corresponds then to the upper boundary of the possible economic impact of the Internet.

In particular, four different scenarios of Internet development are analysed (see Box 3). These scenarios correspond to cases of: *i*) high economic impact of the Internet; and *ii*) low economic impact of the Internet as well as passing of the threshold value. Each scenario is analysed for 2001-11 and for 2002-11.

Box 3: Simulation exercise

The simulation exercise aims to evaluate the possible net dynamic impact of the Internet on the US economy. Table 7 and Figure 6 present the results of the simulation.

Scenarios

The four different scenarios are:

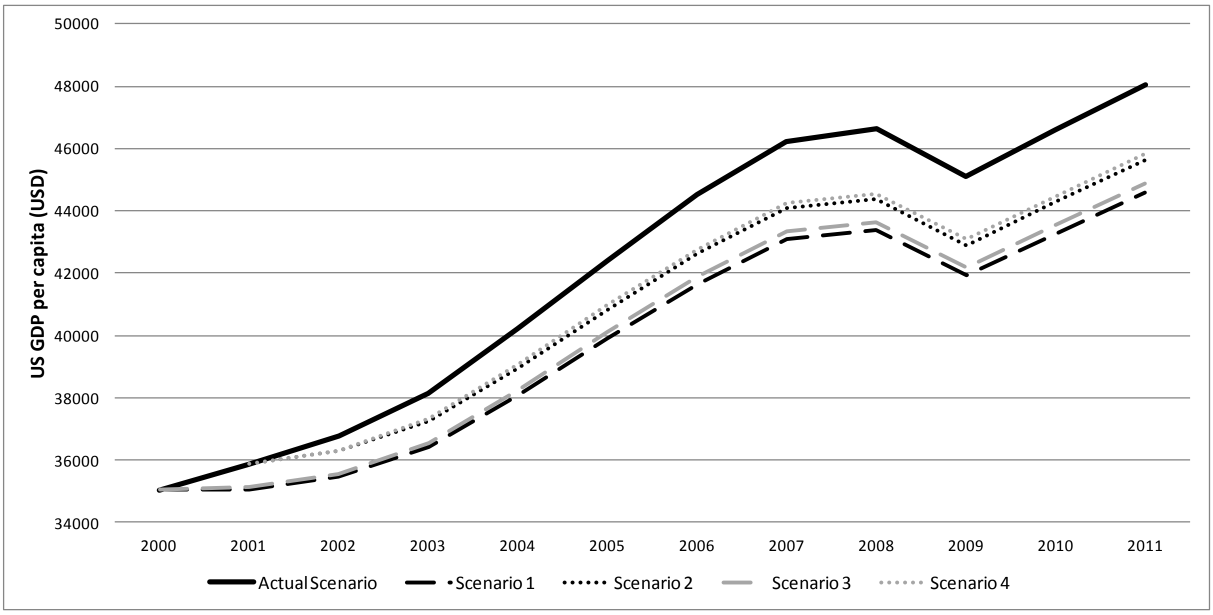
- High impact of the Internet on growth, effects begin to be observed in 2001
- Low impact of the Internet on growth, effects begin to be observed in 2001
- High impact of the Internet on growth, effects begin to be observed in 2002
- Low impact of the Internet on growth, effects begin to be observed in 2002

Input data

The input data are:

- GDP per capita (USD current prices) (BEA, 2011)
- Internet development measured by broadband penetration rates (OECD Broadband portal)
- Impact of the Internet on growth (Koutroumpis, 2009):
- *High:* 1% increase in the penetration rate increases economic growth by an average of 0.025% (scenarios 1 and 3)
- *Low*: 1% increase in the penetration rate increases economic growth by an average of 0.023% (scenarios 2 and 4)

Figure 6. The impact of the Internet on the US economy under four scenarios

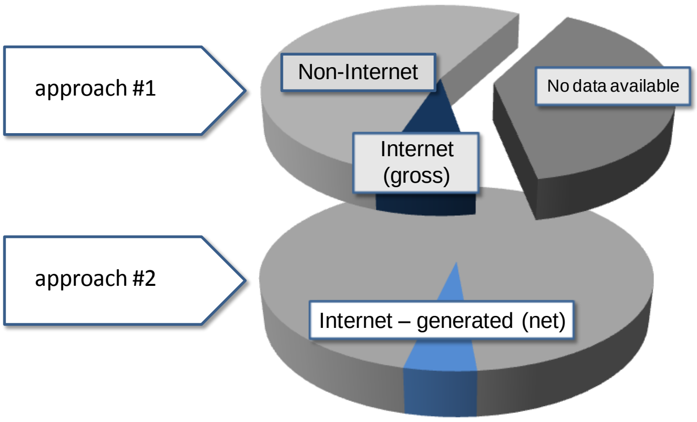


Sources: based on OECD data and Koutroumpis (2009).

The solid line in Figure 6 presents the actual evolution of US GDP between 2001 and 2011. The dashed line illustrates the assumed scenario of no-Internet development since 2000. The difference between these two lines illustrates the net, dynamic effect that Internet has on the US economy, assuming that the economic impact of the Internet was high and the critical mass was reached in 2001.

This specific approach based on Koutroumpis (2009) for impact estimations and US GDP data signals that in *2011, up to 7.2% of US gross domestic product was generated thanks to the Internet*. Graphically this result is presented on the lower chart of Figure 7.

Figure 7. The Internet economy in the United States (measured by approaches 1 and 2)



It needs to be highlighted that this exercise relies on two additional assumptions. Firstly, it is assumed that broadband penetration rates proxy for all Internet related activities. Secondly, constant elasticity of broadband penetration on growth is assumed. Although both assumptions are not unrealistic, they are in fact relatively strong. Therefore caution should be paid as to how to interpret final results that rely on these assumptions.

There are two key differences between the result of this exercise and the size of the Internet economy estimated according to Approach 1. First, the result of Approach 1 takes into account the net effect, which is only the additional extra value generated thanks to the Internet (excluding the value added that was re-allocated from offline to online,) Second it looks at all the Internet-related activities that result in a higher added value in all industries across the economy, not only activities supporting the Internet and based purely on the Internet.

Therefore, it is important to note that the results generated using Approach 2 (lower chart in Figure 7) cannot be added to the results of Approach 1 (upper chart in Figure 7). Since there is a certain overlap between the focus areas of these two approaches (*i.e*. net value generated by activities that support the Internet or are purely based on the Internet) their results cannot be aggregated. Such aggregation inevitably would result in a double counting and the final result would be overestimated.

Future research

The results presented above from the second approach should be interpreted as an indication of the order of magnitude rather than an exact estimation. In particular, this exercise should not be interpreted as an indication of potential causality. As noted by Lehr (2012), the Internet is a fast changing phenomenon, and any attempt of measurement of its dynamic impact is extremely difficult. Today statistics are already dated and only measure yesterday’s impact. Also, the simulation exercise relies on a set of strong assumptions that, to some extent, cannot be tested given current data limitations.

Future research in this area could check different scenarios and perform robustness testing across results. Moreover this simulation exercise could be repeated for other economies to analyse their net contributions to GDP from the Internet economy.

APPROACH 3. INDIRECT IMPACT OF THE INTERNET

Approach 3: Indirect impact of the Internet

This approach looks at the economic impact of the Internet that reaches beyond the GDP. It studies two main impact areas:

- The impact of the Internet on consumer surplus, and
- The broader welfare gains generated thanks to the Internet (*e.g*. welfare gains derived from non-monetary transactions, impact on the environment, social capital formation etc.).

There are many types of interactions that take place on the Internet. These interactions occur within the context of market and non-market environments or within a combination of the two. Market interactions involve transactions between buyers and sellers of a product or service and are characterised by a price and market-clearing mechanism. Some of these transactions are captured by traditional measures of economic activity in national account systems and, in turn, can be measured by one of the previous approaches.

While the Internet's impact on market transactions has been undoubtedly far-reaching, its effect on non-market interactions is even more profound. These interactions and impacts contribute to individual utility and the well-being of the entire society. They are not, however, captured within the traditional measures of national accounts. The measures of these impacts are within the scope of Approach 3 to measure the Internet economy.

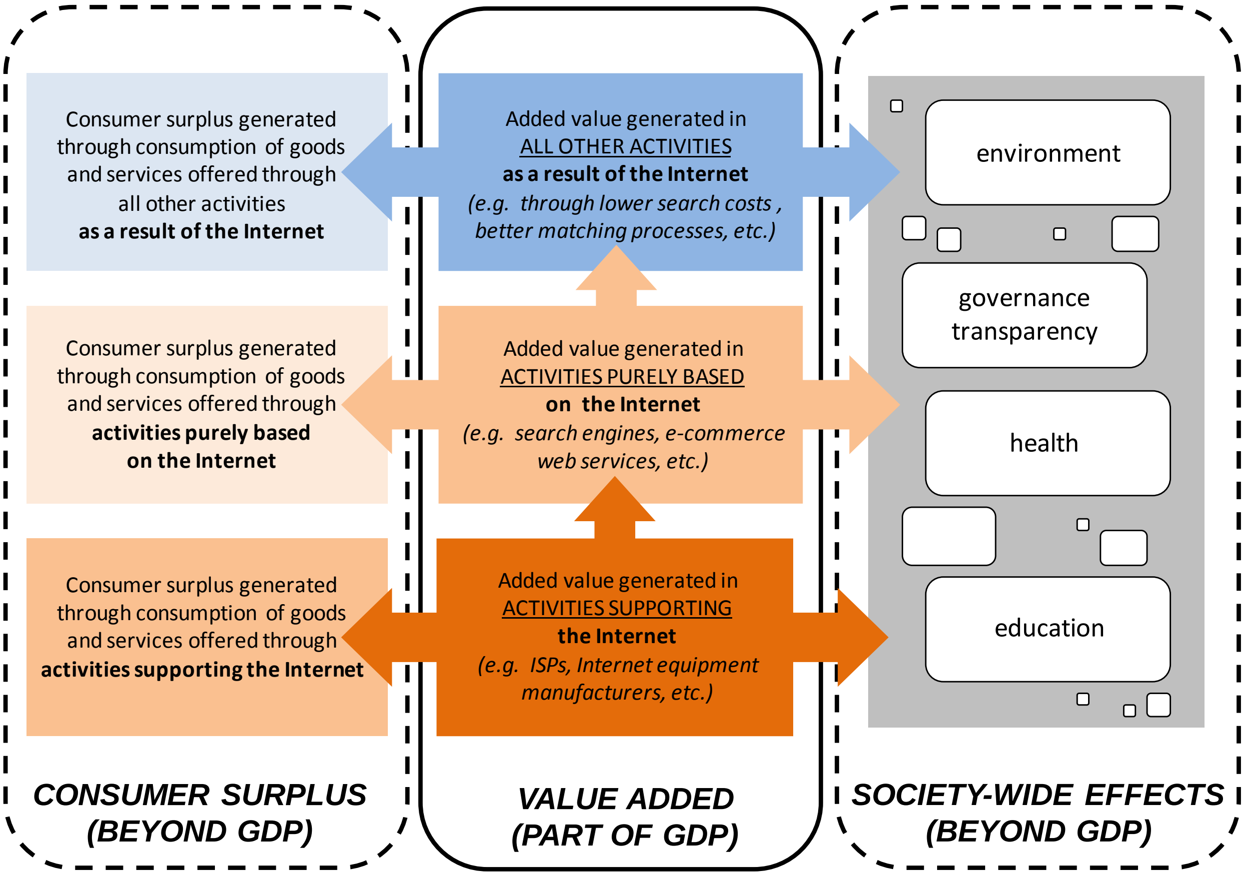
What is this approach

The economic impact of the Internet reaches beyond what one can measure using existing statistics. The Internet not only re-shuffles business models and intensifies competition in existing markets but it also introduces new economic models and paradigms whose impacts go beyond effects captured within the classical SNA framework.

Two broad impact areas could be distinguished in this context (Figure 8):

- The positive impact that the Internet has on *consumer surplus*, and
- The broader *welfare gains* generated thanks to the Internet (*e.g*. welfare gains derived from non-monetary transactions, impact on the environment, social capital formation etc.).

Figure 8. Indirect impact of the Internet



Many of these impacts are described within the modern economic framework and in certain circumstances can be quantified. Nevertheless this quantification is usually extremely difficult as it requires large amounts of data and a number of strong assumptions. Consequently, studies that fall into Approach 3 are usually partial and present just a share of total impact of the Internet on consumer surplus and social welfare.

Existing results

Several studies provide empirical evidence about the positive and measurable impact of the Internet on **consumer surplus** (Morton, 2006; Dutz *et al.*, 2009; Greenstein and McDevitt, 2011 and 2012). These studies focus mostly on the consumer's economic benefits that arise from affordable access to the Internet. This corresponds to consumer surplus derived only from the consumption of products from industries producing *for* the Internet, so findings of these studies are limited to only one (although noticeable) component of consumers' welfare.

Some studies focus on the economic impact of the Internet on consumers and study the effects on individual utility and well-being. Several studies indicate that online social networking websites such as Facebook or MySpace tend to contribute to the social capital formation that in turn can raise individual perceptions of well being (Shah *et al*. 2001; Gibson and McAllister, 2009.) These benefits are, however, a challenge to capture quantitatively.

Indeed, only some of the impacts of the Internet on welfare have been quantified. Certain effects, although significant and observed, cannot be economically measured and expressed in economic value terms. This, for instance, refers to the satisfaction individuals derive from various services offered through the Internet such as with participation in social networks (see Box 4).

Box 4: Online social networks and well-being

Online social networks (*e.g*. Facebook or MySpace) are often cited as prominent examples of services that are enabled by the rapid development of the Internet. Whereas certain social networks serve business and professional networking purposes (*e.g*. LinkedIn), most of them are designed solely for social networking.

According to recent studies, online social networks are an important medium of formation and maintenance of social capital. Some research has shown, for example, that these networks are particularly useful for people who otherwise have difficulties generating and maintaining interpersonal relationships. On-line social networks can lower barriers to interaction, encourage people to interact socially and increase psychological well-being.

Even though these impacts can, to some degree be observed and quantified at the individual level, it would not be possible for individual benefits of the Internet on individuals or the "benefits of happiness" to be taken into account and aggregated into broader economic measures (*e.g*. as a component of GDP).

Source : Bargh, McKenna, and Fitzsimons (2002), Bargh and McKenna (2004), Ellison, Steinfield and Lampe (2007).

Apart from the effects of the Internet on consumer surplus, other impact areas are the broader, society-wide effects caused by the Internet. Examples of these effects include the myriad of effects that the Internet has on environment, education, scientific research, governance, social capital, health, ageing, science, and so forth. Given the lack of proxies and consistent datasets for these phenomena, these impacts are extremely difficult to quantify in an aggregated manner. This also means that most of these impacts are not accounted for within GDP and cannot be quantified by Approaches 1 and 2.

The Internet enables solutions that could have a significant positive impact on the **environment** (OECD, 2010b). This broad impact is captured by the term *Green ICT* that in turn encompasses various solutions such as *smart grids*, *smart buildings* and *smart cities* among others. The electricity sector provides a good example where Internet connectivity will have an impact on the environment and firm efficiency (OECD, 2012c). The Internet can serve as the communication foundation of *smart electrical grids* (advanced metering infrastructure) by addressing a historical information gap between producers and end-users. Smart grids use communication networks and IT systems to inform consumers of their electricity consumption in real time as well as the overall supply and demand situation on the network, allowing them to adjust consumption based on price signals. On the supply side, the electricity provider benefits from the smart grid because they can smooth out demand by monitoring and influencing consumption in real time either through technical intervention or variable demand-based pricing. While some of the benefits of smart grids will be captured in GDP, many of the environmental benefits will not.

The Internet is also increasingly used in the field of **education** (Lenhart *et al*. 2001; OECD, 2008b; Spiezia, 2010). Remote education over radio and television has been used for many years in rural and remote areas but the Internet permits for a more general and dynamic development of education services. These impacts will not be captured by Approaches 1 and 2 for several reasons. First, even though the social benefits of education are clear, its macroeconomic impact on GDP is disputed (Krueger and Lindahl, 2000). Second, even if the impact of education was detectable, it would occur in the very long term, which is for the moment outside the scope of Approaches 1 and 2.

There are two key ways in which Internet access can help make education more efficient. First, the Internet improves education by enhancing remote communication and delivering teaching or training materials. Second, the Internet greatly facilitates gathering of information using a myriad of services and applications such as online classes and seminars, dedicated web pages and online forums for expertise exchange.

As an example of the Internet impact on education, Stanford University in the United States makes some of its classes available online to the general public for free. Videos of the classes and copies of the slides shown are posted on a dedicated webpage a few days after each class meeting.[22] This initiative was developed by Stanford University in co-operation with Apple. In terms of economic benefits for individuals, the content provides a great opportunity to acquire state-of-the-art knowledge; for Stanford it is a novel way of demonstrating its teaching quality and the richness of its curriculum.

Apart from general education, the Internet also has an impact on **scientific research**. The primary impact focuses on the areas where Internet technologies have improved access to information and facilitated communication between researchers and research centres. Notable examples include instant access to digitized scientific articles and databases offered by various providers over the Internet, (*e.g*. JStore and ScienceDirect). The development of the Internet has also enabled new forms of co-operation in research that rely on public-domain and open-access models of information creation (*e.g*. science commons) and these benefits often fall outside of GDP measures.

Healthcare is a sector where the Internet and other communication technologies are increasingly employed to address escalating healthcare costs. As an example, Internet technologies could help reduce the number of physical doctor visits needed by elderly patients who still choose to live at home. The Internet and evolving sensor technologies make remote check-ins economical. Currently the share of GDP spent on healthcare is rising across OECD economies. Moreover these costs have been rising over the past decades. According to the recent figures in the OECD, countries health expenditures amount to 8.8% of GDP.[23] This is due to the aging processes, high costs of related education and technological progress and the economic complexity of the healthcare issues.

E-health is an effective solution that could be applied to at least partially address this problem. The term e-health refers to a range of Internet-enabled solution and services solutions that enhance healthcare efficiency (*e.g.* telemedicine) enhance access to information and health records and offer other ways of healthcare improvement, *e.g*. through better access to medical journals, epidemiological tracking or sharing of patient-specific information. E-health could lead to a significant reduction of costs in the healthcare system. It is expected that these services will be rapidly developed and the share of e-health among other services offered through the Internet will continue to grow. Note that since the implementation of Internet-based solutions in the health sector is expected to reduce costs and raise efficiency, this in turn will not be translated into the final consumption (as "better health" is not a component of consumption.) Hence, most of the benefits of improved health outcomes would fall outside of traditional GDP measures.

In addition to issues related to the environment and healthcare, there are other significant areas where the Internet affects **governments**, with e-government services being an illustrative example. This term refers to the digital, mostly Internet-enabled interaction between government and citizens, firms and other public agencies. The Internet acts here as a channel to enhance the efficiency and effectiveness of the public sector. The benefits of e-government are clear; Internet based solutions improve the accessibility, efficiency, and convenience of public services by permitting for instantaneous communication and removing the requirements of physical presence at the government agency. Increased interaction with the government and easy access to documentation can also raise transparency, promote democratisation and reduce the levels of corruption (Andersen *et al*., 2011). Even though the benefits of e-government are straightforward, they do not directly impact GDP, as the efficiency of public institutions, their accessibility and openness to citizens, does not fully and directly translate onto current measures of value added.

Another channel through which the Internet might have impact on government activities is through intensified **social capital**. Higher social capital in a society translates in turn into intensified political participation of individual (Shah *et al*. 2001; Gibson *et al*., 2009.)

What we have done

The contribution of this research in Approach 3 is focused in two areas:

- Creation of a consistent framework to study the impact of the Internet on consumer surplus, and

- Quantification of some parts of the impact of the Internet on consumer surplus.

The Internet and consumer surplus: A framework for analysis

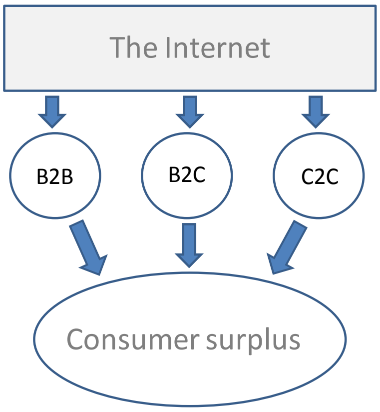
One of the main ways the Internet affects individuals is through improvements to **consumer surplus**. This term refers to the difference between the monetary value individuals are willing to pay for a product or service and the amount they actually pay (explicit or implicit price). One way to look at the Internet's impact on consumer surplus is to look at pricing on the Internet.

While the Internet’s impact on market transactions and value added has been undoubtedly far-reaching, its effect on non-market interactions and consumer surplus is even more profound. Non-market interactions on the Internet are broadly characterised by the absence of a price and market-clearing mechanism. That is, neither the production nor consumption sides of markets have well-defined pricing or market-clearing mechanisms. Non-market interactions on the Internet span economic agents ranging from businesses and consumers to governments. Typical examples of non-market Internet interactions range from electronic communications (either between private individuals or within/across business organisations) to consumption of certain Internet content – such as Wikipedia entries.

Part of the difficulty in evaluating the Internet’s impact on consumer surplus is that no single model exists for market or non-market interactions. Indeed, little attention has been paid to non-market interactions since few, if any, well-defined and well-grounded measurements have been commonly adopted. Part of the problem is that non-market activity is typically conducted internally within an organization or by an individual; it is therefore not directly observable or currently measured. However, even when non-market activities are external to organisations, it is not clear what activities are important to measure.

Specifically a set of Internet-related mechanisms that lead to higher consumer surplus is proposed. These mechanisms include: *i*) business-to-consumer interactions; *ii*) business-to-business interactions; and *iii*) consumer-to-consumer interactions (Figure 9).

Figure 9. The Internet and consumer surplus: Channels of transmission



Source: OECD based on Scholten (2012)

Some of these markets are for final goods and captured by the System of National Accounts used to measure GDP; meaning that these products and services are consumed, and not used as intermediate goods used in the production of another product or service. Markets for intermediate goods/services and second-hand/used goods markets are not captured in the System of National Accounts since, it is argued, that their values are included in either current or previous final products or services. Since the approach presented by Scholten (2012) focuses on the expenditure approach to measuring GDP, this excludes a systematic analysis of B2B markets, and leaves it for future research.

B2C market interactions

B2C market interactions on the Internet are exchanges governed by prices between businesses and consumers. While the number of these transactions is likely to be very large, comparatively the volume of these transactions will shrink due to B2B market interactions, since the typical supply chain includes interactions involving all subcomponents. The former likely consists of a single B2C market interaction, while the latter will typically involve many B2B market interactions for each B2C interaction. That is, there are likely many B2B interactions that take place to support a single B2C market interaction.

B2C interactions on the Internet are likely to create considerable value to consumers that is not captured by the current System of National Accounts. The value from the Internet likely stems from loosening day-of-week and time-of-day constraints of traditional markets by offering (almost) continuous shopping convenience and reduced transaction costs. In more traditional markets the day-of-week constraint has been found to be associated with counter-cyclical pricing patterns; whereby, as demand increases during the weekend, prices actually decline. Scholten, *et. al.* (2009) find that the counter-cyclical price pattern no longer persists on the Internet and the authors attribute this result to a reduction in search costs imposed by the removal of the day-of-the-week and time-of-day constraints of the Internet.

The Internet forms the world's largest information network. According to Nielsen - NetView (2010) in June 2009, American's spent 3.5% of their Internet time and 6.3% of mobile Internet data conducting searches. Depending on the form, activity derived from Internet searches can be within the context of a market or non-market environment. Section 2.2 will examine the implication of Internet searches with non-market environments. When consumers use the Internet to search for price information on a product or service, the Internet search occurs within a market environment. There are several economic implications for Internet searches within a market.

Since information is costly to acquire, consumers search for prices to reduce the expected price paid for a product or service. One strand of the literature rationalises price dispersion – a measure of the information and the degree of price differences for homogeneous products – by assuming that consumers incur a positive, marginal cost associated with each search; the costly consumer search literature. Another strand de-emphasises costly search, instead focusing on consumers' access to price information from an information clearinghouse. Baye *et al*. (2006) provides an extensive survey of these literatures.

The Internet reduces consumers' cost to acquire price information in B2C interactions. In the infancy of the Internet, many claimed that reduced search costs would lead to marginal cost pricing espoused in the "law of price." However, as Baye *et al*. (2006) theoretically show, search cost reductions may lead to either more or less price dispersion; depending on the market environment. Moreover, completely eliminating consumer search costs will not necessarily eliminate price dispersion.

Understanding the impact that search costs have on the level of price dispersion observed in a market is one measure of competitiveness in B2C Internet market interactions. Another measure of competiveness in these markets is the number of firms that offer a homogeneous product. Baye *et al*. (2006), again theoretically show that price dispersion may increase or decrease as the number of firms increases. This result depends on the market environment. In some models this heightened competition increases the transaction prices for all consumers; while in other models, the level of welfare depends on which side of the "digital divide" it resides. Baye *et al*. (2004) find empirical evidence that the percentage difference between the two low-price firms – the percentage "gap," a conservative measure of price dispersion – varies systematically with the number of firms. The average percentage gap is about 23% when two firms compete on an Internet information clearinghouse, and falls to 3.5% in markets where 17 firms list prices.

In addition to reduced search costs and higher competition among B2C competitors, the Internet expands consumers' geographical search capabilities. This implies that consumers are now able to obtain price information beyond firms that are geographically close and access greater product variety than is available within their local geographic region. Brynjolfsson *et al*. (2003) examine the excess value – surplus – consumers derive from increased product variety of a particular market from the Internet and World Wide Web; Amazon.com's obscure book titles, which have an Amazon sales rank greater than 100 000. They estimate that in the year 2000, consumer surplus from the introduction of obscure books alone was between USD 731 million and USD 1.03 billion.[24]

B2C markets on the Internet make search for products and price information very efficient. From a theoretical vantage point, reduced consumers' search costs and increased competition from more competitors does not necessarily lead to lower price dispersion, which measures the information and uncertainty in the market. The impact and magnitude from the competitive effects associated with reduced search costs on price dispersion broadly remains an open empirical question. However, empirical estimates of the number-of-competitor effects are available for B2C Internet markets for consumer electronics, and range from an average of 23% in few firm markets to 3.5% in many firm markets.

In addition, the Internet expands consumers' geographical search and access to product variety. Estimates of consumers' value – measured by consumer surplus – stemming from increased product variety range in the United States from USD 731 million to USD 1.03 billion in 2000. These consumer benefits from B2C Internet markets are not measured in the System of National Accounts, which only records the value of the transactions. While these studies illustrate the competitive and value effects of the Internet, they do not directly examine the impact of prices relative to traditional markets. Indeed, from a theoretical perspective, the Internet's impact on transaction prices may be lower or higher. This suggests that estimated GDP under the System of National Accounts is systematically lower if the competitive effects from B2C market interactions result in lower prices, holding quantity fixed. Alternatively, the competitive effects are overestimated if the competitive effects result in higher prices, holding quantity fixed. However, when viewed from a product variety perspective, the reported estimates suggest that the impact of the Internet on B2C markets, the current System of National Accounts methodology significantly underestimates the benefit consumers derive from B2C interactions on the Internet.

C2C market interactions

Commercialization of the Internet in 1995 has created some wide-reaching markets that previously tended to be geographically localised. These markets tend to be for second-hand or used goods and permit consumers to transact with other consumers; hence, C2C. These Internet properties build a strong community of consumers (and small businesses) such that these properties are likely to exhibit strong network externalities. Examples of these types of worldwide Internet properties include eBay and Craigslist. The market mechanism for these Internet properties is vastly different: eBay uses an Internet "set-time" auction mechanism for consumers to exchange items whereas Craigslist is an International posted-price environment similar to traditional classified ads of local newspapers.

Internet properties – like eBay and Craigslist – derive their revenue stream from charging posting fees to consumers. The value of most items exchanged at these Internet properties are not reported in the System of National Accounts since their value was recorded during the period when the item was considered a final good. That is, these properties facilitate value transfers of (mainly) second-hand or used items. The value of the merchandise sold on eBay alone during the second quarter of 2012 reached USD 16.16 billion. The fee revenue generated from these transactions over the same time period amounted to USD 3.4 billion. However, the fee revenue generated from these value transfers are captured by the System of National Accounts as new services in the current period. Thus, some of the value of the Internet is captured in current GDP estimates.

After controlling for the depreciable portion of a product's lifetime value and transaction fees, the transfer value for goods exchanged in C2C markets for Internet properties like eBay and Craigslist are likely to exceed the fee-revenue stream of the company. This value measures economic activity attributable to the benefits of the Internet but largely unreported. Bapna *et al*. (2008) explore the additional value that accrues to consumer (consumer surplus) resulting from eBay Internet auctions. Using a sample of 4 514 auctions, the authors estimate that the median surplus consumers' extract from each eBay auction is at least USD 4. This translates into at least USD 7.05 billion in total consumer surplus in 2003 alone and may be higher depending on the assumptions used in the auction mechanism.

The academic literature provides some interesting techniques for measuring the economic activity and the impact of the Internet on B2C and C2C market interactions. This provides a guide to estimating the value of the Internet that is left unaccounted for through the traditional System of National Accounts. Initial estimates suggest that the value not measured by the Systems of National Accounts for even narrowly defined markets – individual or segments of individual businesses by Internet properties – is significant and potentially staggering. These studies provide a foundational methodology that can be used to guide future data collection endeavours and estimation techniques to improve measuring and estimating the economic activity and the extra value consumers (consumer surplus) derive from using the Internet. However, economic activity on the Internet is not relegated to markets. The Internet economy has spurred on significant activity in non-market environments, which is explored in the next section.

Non-Market activity and the Internet economy

There are many economic activities that occur within the Internet economy that do not occur within well-defined, final product markets. That is, there is no explicit price mechanism governing exchange between economic agents. Yet, these activities add value or other forms of capital to economic agents. As a result, this study classifies these as non-market activities, which contribute to the Internet economy, but are unmeasured using the current System of National Accounts methodology.

Table 7 lists the top 10 activities – in terms of percentage share of time – in which Americans engage while accessing the Internet. As the table indicates, between June 2009 and 2010, Americans spent the following proportions of time on the following Internet activities: 22.7% on social networking sites, 10.2% on games, 8.3% on e-mailing, 4% on instant messaging and 3.5% on general information searches. These are all examples of non-market activities.

Some could believe the activities listed in Table 7 are "free" in the sense that there is no explicit price associated with many of these activities. Stated somewhat differently, there is an "implicit price" individuals pay to engage in these activities that is not always obvious to the consumer. In this section, this study explores the economic implications of non-market activities on the Internet in B2C and C2C environments.

Table 7. Top 10 activities by share of Americans' Internet time

Rank	**Category**	**Share of Time June 2010**
1	Social Networks	22.7%
2	Online Games	10.2%
3	E-mail	8.3%
4	Portals	4.4%
5	Instant Messaging	4.0%
6	Videos/Movies	3.9%
7	Search	3.5%
8	Software Manufacturers	3.3%
9	Multi-category Entertainment	2.8%
10	Classifieds/Auctions	2.7%
	Other	34.3%

The Share of time may not sum to 100 due to rounding errors.

Source: Scholten (2012) based on Nielsen NetView (2010)

B2C Non-Market Interactions

Many businesses that operate in the Internet economy provide goods and services valued by consumers at no explicit price. More succinctly, these businesses offer "free" goods and services to consumers. Casual observation of these phenomena are often perplexing and leads to misleading generalisations that the Internet is "free" or a "public good." This section examines B2C non-market interactions to shed light on the “free” Internet misconception, and explain how some firms provide “free” content and earn profits.

First, Internet access is not typically a B2C non-market interaction; consumers must pay an Internet service provider (ISP) to access the Internet. Therefore, consumers’ value for Internet access is correctly classified as a B2C market interaction, and is at least partially captured by GDP. However, conditional on having Internet access, consumers have many opportunities to consume goods and services from businesses through many B2C non-market interactions via the World Wide Web. Does this suggest that “free” content available from the World Wide Web is a “public good?”

To be a public good requires that the individual websites on the World Wide Web be both non-excludable and non-rivalrous. From a purely technical standpoint, Internet property owners can exclude individuals from accessing their content by restricting or blocking IP addresses. Therefore, the individuals *can* be excluded from accessing content on the World Wide Web, but rarely are in practice. Moreover, individual websites can be rivalrous in the sense that an individual’s consumption can be impacted by another at times of congestion. That is, there is a technical boundary for many Internet properties that is defined by the property owner’s host server, Internet line capacity among other hardware characteristics. Most Internet property owners invest in hardware or pay for services that minimise congestion. Taken together these observations suggest that the content of many Internet properties *appear* to be more of a quasi-public good. An Internet property with these characteristics is the non-profit firm, Wikipedia.

This quasi-public-good view, however, is inconsistent with the casual observation that many Internet properties earn substantial profits from goods and services that are seemingly “free”, suggesting that the quasi-public-good view may be incomplete in many of these non-market environments. Profitability in non-market environments can be reconciled by examining how Internet properties cross-subsidize their “free” content. Two models are typically utilized. First, B2C non-market environments can be part of a two-sided market with an intermediary. The intermediary in a two-sided, non-market environment permits consumers access to “free” content and requires firms wishing access to these consumers to pay. Another way that Internet properties use cross-subsidization to fund “free” content is through online advertising. The online advertising model permits firms to generate revenue via adverting on its Internet property and offer other content for “free”.

Online advertising models are continually evolving. Examples include banner ads, sponsored blogs, social network advertising, e-mail marketing (including spam) and advertising above and next to search engine results. While it is beyond the scope of this study to examine all advertising forms, it is useful to describe one of the richer advertising forms and to understand advertising more generally.

Advertising is a sub-branch of information economics, as argued by Nelson (1974). Google, for example, uses banner ads and search engine advertising (among other forms) to cross-subsidises much of its “free” content: an Internet browser (Chrome), an email account (gmail), search engine (Google), calendars, maps/directions, office suites (Google docs), instant messaging services (Google Talk), phone services (Google Voice), social networking (Google+), entertainment (YouTube), among others. Essentially, this list mimics much of the activities listed in Table 7. According to articles by Varian (2008) and Levy (2009), Google’s unique way of selling ads requires firms to *i*) select AdWords related to their advertised product or service; and *ii*) a bid function that represents the amount firms are willing to pay each time a consumer “clicks” or accesses their ad. This is the basis for Google’s AdWords program and mimics selling advertising using a variation of the second-price auction. When consumers use certain AdWords, it triggers an advertising auction where the winner’s ad is displayed. As Varian noted in regard to the number of these auctions that take place daily, “… Millions is actually quite an understatement.”

While the explicit price of accessing or using much of the content is zero, there is an implicit price. That price is privacy. Google, and other companies, largely rely on private information to create matches between these consumers and sellers. Increasingly, awareness on how the Internet is being used to impinge on consumer privacy is being explored. Determining the price of privacy will be a key question in future research. However, great care must be given to this area of research since it requires a delicate balancing act between "free" content and consumer privacy. Over-regulation of privacy on the Internet may stifle the innovation and stream of "free" content and services. Under-regulation implies consumers' rights are violated. Weighing the surplus consumers receive against their privacy is at the heart of the problem and requires new data and methodology measuring the optimal balance in these non-market environments.

"Free" content and services available on the Internet is not captured by GDP since there are no explicit prices that govern these transactions. The value of some of this content is implicitly captured by GDP through advertising since, in some instances, firms are bidding their value to displaying the advertisement to consumers and reflected in profit. However, there is a trade-off between the value of this content and consumer privacy concerns that continue to linger. As this debate continues to unfold, new data sources and measurement techniques are necessary to strike the optimal balance.

C2C non-market interactions

Digitisation has made replication and distribution of information goods over the Internet very convenient and efficient. While formal B2C market exchanges have captured some of these interactions, technological innovation has also given rise to new, peer-to-peer distribution technologies that permit consumers to directly engage in exchanges with one another. That is, a consumer with content located on her computer can use a peer-to-peer network to permit other consumers to transfer this content directly to their own computer. These C2C interactions typically occur at an explicit price of zero and create a non-market environment for exchange. Therefore, these interactions are not measured in the System of National Accounts, but likely contribute to the Internet economy by transferring value between consumers.

While these C2C non-market interactions create exchange efficiencies and likely exhibit direct, positive network externalities there are several potential downsides to these peer-to-peer interactions. Namely, some of the content that is exchanged between consumers over peer-to-peer networks is copyrighted material that is non-legally transferable. Another potential downside to these C2C interactions is that they likely cause negative network externalities by creating network congestion. Given the lack of transparency in these markets, it is very difficult to quantify the impact of the Internet economy. An interesting line of research would be to procure new data sets in attempt to quantify the impact of these C2C non-market interactions on the Internet economy.

Measurement of Internet-generated consumer surplus

Although the influence of the Internet in transforming the way in which business and consumer transactions are carried out is clear to all participants in the production-consumption process, it is difficult to attribute a specific value to and precisely measure the importance of the role of the Internet in raising consumer surplus.

Two additional approaches can be highlighted in this context. The first relies on Greenstein and McDevitt (2012) and attributes a monetary value to the consumer surplus in the OECD countries that is based solely on the use of the Internet-services. The second one is based on Cooper (2012), who presents a simulation exercise based on a quantitative model to measure the value of Internet-generated consumer surplus. Both examples are outlined below, with more detailed discussion summarised in the Annex at the end of this paper.

Example 1: The broadband bonus

The majority of households with residential Internet service among OECD countries now have broadband connections. How much new economic value has resulted from the global transition to broadband Internet? This approach derives estimates to answer this question by considering both new gross domestic product (GDP) and additional consumer surplus for thirty OECD nations between 2005 and 2011.

The economic determinants behind the growth of broadband are straightforward to state: dial-up became available first and diffused to households as a means to deliver the Internet. Broadband emerged later as a higher quality and more expensive alternative, albeit one available in only a few places and from a limited set of providers, if any. Over time, broadband became more reliable and more widely available, and as that happened, many households paid to upgrade their Internet service. The adoption of broadband motivated application developers to find ways to take advantage of faster throughput, and their success raised the value of the service to broadband users. A virtuous cycle resulted, with such improvement motivating even further adoption of broadband.

There are two common approaches to measuring gains from a new good. First, what is the increase in revenue (GDP) above and beyond what would have been generated had dial-up continued to be the only means to access the Internet? Second, what is the increase in consumer surplus beyond what would have occurred had dial-up continued to be the only means to access the Internet? When addressing these questions, traditional approaches do not worry about which vendor or user gains or losses. This analysis does the same, and will only compute an aggregate measure.

Because of the lack of precise information about the unit cost of provision, which is necessary for an estimate of producer surplus at each point in time, this approach focuses on focus on revenue instead of producer surplus. It examines the difference in vendor revenue between what actually occurred and a hypothetical scenario without broadband, absent multiplier and general equilibrium effects.

To measure consumer surplus, ideally one should measure the difference in “areas under the demand curves” between the actual demand for broadband and what consumer’s would have demanded had dial-up not been replaced by broadband. This is challenging to do for many reasons, but one is primary here: it is impossible to observe what the dial-up market would have looked like had broadband not diffused. Instead of measuring two demand curves, one can approach the ideal measure by looking at estimates of users’ willingness to pay for the upgrade to broadband.

For estimates of consumer surplus in the United States market, Greenstein and McDevitt (2011) employ one set of estimates from Savage and Waldman (2004). It is representative of the type of findings seen in other studies. They conducted an extensive survey of dial-up and broadband users in 2002. This study had advantages over other sources because it is a survey of both users and nonusers. The authors also used this survey to directly estimate “willingness to pay” measures for attributes of dial-up and broadband service, which facilitates some simple accounting of the value of broadband in comparison to dial-up for existing dial-up users.

While this is sufficient for United States data, it comes with three drawbacks for a cross-country comparison. First, it is very data-intensive. It requires yearly data on both broadband and dial-up use. Second, it does not fully account for heterogeneity in household willingness to pay. It averages out such differences. Third, to our knowledge there are only a limited number of similar estimates for demand in the United States, or, for that matter, other countries.

As such, this approach implements an alternative method for estimating consumer surplus, similarly to Greenstein and McDevitt (2011). Applying the methods used in Greenstein and McDevitt (2011) to a non-U.S. country would require data on the total number of households, number of Internet users, number of broadband users, and information relevant to the cost of adoption, such as the price of access or cost of second lines. In general, however, older data are difficult to obtain, particularly about the cost of dial-up and the cost of a second line to support it. Hence, the strategy favours recent data over older data, and broadband data over all other data, consistent with the focus of this approach.

The strategy is the following. First, a lower bound for a consumer's willingness to pay is derived, by assuming that anyone who adopts broadband in year t and pays the prevailing price, pt, would be willing to pay at least that much for broadband in later years. As prices decline—in both a real and nominal sense—this consumer is better off in later years. That is, he would be willing to pay pt for broadband in year t+1, but only has to pay p_{t+1} < pt. The difference, $p_t - p_{t+1} > 0$, is his additional consumer surplus.

This forms the basis of a feasible measurement strategy within a country. As the real price falls, the demand for broadband rises. Over time, the declining price "traces" out the demand curve. With this approach, it is also possible to trace the change in additional consumer surplus in a country.

This approach has two advantages. First, it is quite simple, and that has advantages for cross-country comparisons. Second, it can apply to any country in which the underlying premises of the model remain valid.

More concretely, this model assumes a stable set of factors determines demand, and these same factors are not shifting the demand over time, which is reasonable over short periods. In addition large year-to-year increases and decreases in broadband demand are not expected. Nonetheless, countries with rapidly growing incomes might depart from these assumptions if one tried to extend the study a few more years, so one remains alert for other issues.

One crucial drawback, however, is that this method gives no scope for incorporating improvements to broadband. For instance, someone who was willing to pay p_t in year t for broadband speeds of 5 MB/s would likely be willing to pay even more than p_t in year t+1 for broadband speeds of, say, 10 MB/s. One straightforward way to incorporate this detail is to apply a similar logic as above but to per-MB prices. That is, if a subscriber was willing to pay USD 0.01/KB in 2005 but only has to pay USD 0.005/KB in 2010, the difference can be thought of as a quality-adjusted consumer surplus.

In practice, this approach is likely to help in understating the additional consumer surplus. This approach is conservative in that it does not stress "indirect" benefits from broadband, a topic commonly discussed in policy debates. More concretely, though the diffusion of broadband clearly helps firms in the same country whose revenue depends on electronic commerce and advertising-supported online media, it is unclear how large such "spillovers" are. Also, more broadband may generate educational or civic benefits that lie beyond direct economic measurement. While the size of indirect benefits could differ substantially across countries, there is no practical way to measure their size in a way that allows for meaningful comparison across countries.

That circumscribes the interpretation of this approach. It measures the economic factors considered by parties involved in a transaction—anything that shapes the perceived or anticipated costs of using dial-up, the willingness to pay for an upgrade to broadband, and/or the decision not to return to dial-up.

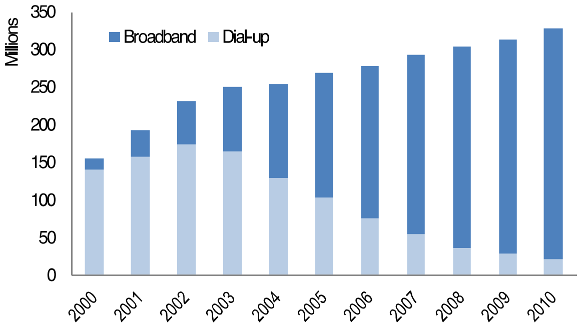
For suppliers, these factors include: sale of second lines, revenue for dial-up access, and revenue for broadband access. For households, the following factors shape the anticipated value of broadband service and, hence, the willingness to pay for an upgrade: savings on a second line, savings on commute time, anticipated health and entertainment benefits, and anticipated savings on phone bill (*e.g.*, if a user moves to VoIP, or Voice-Over Internet Protocol).

The understanding of these factors shapes the interpretation of the estimates, which do not include externalities, namely, benefits or costs not considered by the parties involved in the transaction. For example, it does not include externalities to suppliers, such as the benefits to Cisco from selling more Wi-Fi equipment to users, to Amazon from additional sales because broadband users experience more satisfying service, or to Google from more advertisement sales because users stay on-line longer.

Similarly, the interpretation of this approach does not include externalities to users. Those would be unanticipated or unperceived costs or gains—such as the unanticipated slowness that one neighbour's use imposes on another's in a cable architecture, or the benefits that one person's participation in a p2p (peer-to-peer) network confers on another (as long as there is no membership fee). That also does not include such externalities as changes to privacy (for good or ill) or crime (online identity theft, etc).

Finally, the proposed approach must account for the revenue lost from cancelled dial-up subscriptions. Because the transition from dial-up to broadband access is nearly complete during this time period, the approach will say comparatively little about whether the revenue from broadband contracts has cannibalized dial-up revenue. At this point, that matter is relatively settled for OECD nations, as shown in Figure 10.

Figure 10. Number of OECD fixed Internet subscriptions



Source: OECD Broadband Portal

Instead, the presented approach assumes that all dial-up subscribers in 2001 represent cannibalised revenue in 2005-2011 and that the net price of dial-up would be approximately 50% of the DSL price. This is a rough approximation, but captures the crux of the issue—while it overstates cannibalised dial-up revenue in the sense that some households still access the Internet in this manner though it has assumed all users from 2001 have switched modes, the approach is interpreting it in the sense that many new Internet users likely would use dial-up service in a counterfactual world in which broadband had not diffused. See Greenstein and McDevitt (2011) who present a more thorough and precise treatment.

The approach results in an estimation of additional consumer surplus and the net gain in producer revenue (broadband revenue minus lost dial-up revenue), expressed in a single currency for comparability. These estimates are in Table 8 that outlines a broadband bonus estimate that takes broadband revenue less cannibalized dial-up revenue plus additional consumer surplus USD in 2010. A more detailed discussion of all the intermediate steps towards those final results is presented in the Annex.

Table 8. Broadband bonus estimate in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	2,269,253,209	4,184,460,121	4,550,942,509	4,231,555,466	4,983,790,899	21.7%
Austria	898,854,357	1,189,022,461	1,568,938,644	1,560,987,899	1,588,084,472	15.3%
Belgium	1,769,056,219	2,295,894,957	2,718,756,095	2,726,590,118	2,748,329,103	11.6%
Canada	4,489,319,056	5,302,389,579	5,560,832,487	5,641,599,799	6,536,457,288	9.8%
Czech Republic	1,208,961,587	1,454,748,379	1,803,466,981	1,670,619,861	1,787,584,982	10.3%
Denmark	947,533,295	1,430,621,947	1,713,239,555	1,618,638,016	1,553,317,186	13.2%
Finland	1,073,233,179	1,340,928,232	1,506,038,463	1,640,483,978	1,695,451,006	12.1%
France	6,094,968,247	8,375,998,524	10,273,402,143	10,218,629,806	10,457,607,100	14.4%
Germany	4,736,927,685	7,667,870,793	10,978,474,734	11,708,380,670	11,805,349,996	25.6%
Greece	165,097,282	392,822,692	469,145,998	557,632,228	624,257,109	39.4%
Hungary	1,469,267,694	1,823,191,919	2,053,698,531	1,830,305,501	1,840,717,873	5.8%
Iceland	92,870,204	117,693,463	91,747,792	66,827,280	67,975,537	-7.5%
Ireland	171,326,556	290,725,197	375,536,384	412,210,731	431,086,010	25.9%
Italy	3,396,787,439	4,807,016,514	5,846,002,232	5,957,779,455	6,144,472,581	16.0%
Japan	7,986,437,793	9,442,239,913	11,013,690,335	12,596,712,802	16,037,489,162	19.0%
Korea	7,033,460,274	7,595,733,247	6,685,112,681	6,042,117,582	6,909,435,862	-0.4%
Luxembourg	87,730,475	135,088,241	160,613,807	166,578,923	173,804,143	18.6%
Mexico	2,218,736,412	2,919,061,342	4,883,636,075	4,058,295,871	5,201,042,620	23.7%
Netherlands	3,829,311,219	4,708,908,743	5,334,530,660	5,224,372,829	5,110,764,958	7.5%
New Zealand	175,859,546	323,861,513	426,848,481	428,589,041	561,756,380	33.7%
Norway	949,735,813	1,282,655,517	1,556,806,636	1,631,215,557	1,819,624,016	17.7%
Poland	2,356,709,034	3,086,317,717	3,681,565,650	3,062,811,215	3,135,730,728	7.4%
Portugal	30,535,065	472,127,036	644,260,817	961,288,303	1,083,773,386	144.1%
Slovak Republic	4,673,154	5,777,801	8,221,613	6,421,059	6,512,674	8.7%
Spain	3,330,278,261	4,500,415,423	5,400,722,723	5,678,121,263	5,840,456,978	15.1%
Sweden	892,117,965	1,290,824,336	1,448,094,574	1,268,175,355	1,383,955,411	11.6%
Switzerland	1,104,164,466	1,542,910,204	1,766,364,578	1,899,751,164	2,095,157,808	17.4%
Turkey	7,028,687,537	7,472,329,573	8,236,883,145	6,932,419,989	7,332,215,006	1.1%
United Kingdom	5,622,771,004	8,057,538,292	8,466,185,627	7,595,183,554	8,040,702,957	9.4%
United States	30,297,456,872	35,341,386,445	37,444,033,873	39,890,590,086	39,789,809,212	7.1%

Source: Greenstein and McDevitt (2012)

These results conform with expectations, as there is a positive correspondence between GDP and the broadband bonus among OECD nations in 2010. Larger countries like the United States, Japan, and Germany enjoy very large broadband bonuses, while smaller nations such as the Slovak Republic and Iceland have correspondingly smaller ones.

Example 2: An ICT-enhanced stylised consumer demand model

The second study by Cooper (2012) commissioned for this work employs an economic model that looks at the end result – observations on changes in the pattern of consumer spending behaviour – and econometrically estimates the extent of the link between these behavioural changes and their drivers. These drivers are traditional economic stimuli as well as changes in the economic environment due to advances in technology and improved provision of public sector IT infrastructure. Counterfactual simulations with the estimated model provide money-metric measures of the welfare benefits of innovations in Internet-based public sector IT infrastructure in a variety of OECD economies.

Indeed, in the new Internet-based economy it is arguably becoming more difficult to track the detailed price plans that are available to consumers for custom applications of IT-enhanced products and services as the range of options expands. The pace of innovation in IT and the complementary field of telecommunications have meant that official price statistics, especially aggregate price indexes, lag behind the innovations, with quality-adjusted prices only following after the event, if they are computed at all.

Endorsing the view that the influence of these events is evident in changed consumer expenditure patterns, Huttner (2007) noted the ubiquitous increase in final demand for the Internet. Arguably the Internet has saturated all aspects of the economy to such levels that makes it difficult to measure. In response to the measurement problem, Cooper (2012) utilises a specially developed economic model that econometrically explains the trends in consumer spending with main economic stimuli and changes in the Internet environment and public IT infrastructure. The detailed discussion of the model and the result of the simulation exercise are presented in the Annex.

Future research

The framework for analysing the impact of the Internet on consumer surplus suggested by Scholten (2012) indicates some areas for future research. Indeed, the broader welfare gains generated thanks to the Internet have their origin in some non-monetary transactions, as well as from broader impacts that the Internet has on the environment and social capital formation, for example.

Future research in this area could focus on targeted analyses of these Internet impact areas that raise consumer surplus and the levels of social well being but are not fully captured by the national accounts, hence they are not captured in GDP. These analyses could be done at the level of individuals, governments or society.

At the individual level, the analysis could determine and analyse the channels of impact of the Internet on consumer welfare. Following Scholten (2012) the analysis would then focus on B2B, B2C and C2C relationships in order to determine the potential for surplus generation and to identify possible scope for policy intervention.

At the governmental level, the analysis could assess the benefits of the Internet that cannot be accounted for within existing SNA frameworks. The analysis could then suggest how to leverage and how to fully exploit these benefits.

Finally, at the societal level, the analysis would add to our measurement of the wider impact of the Internet on welfare that fall outside GDP statistics. This would include the identification of impact areas, the assessment of possible measurement techniques and the determination of the potential scope of policy intervention.

CONCLUSION

The Internet has recently become a ubiquitous economic infrastructure but measuring the size of the *Internet economy* is not straightforward. The measurement of the economic impact of the Internet as an ecosystem depends largely on the approach taken and can be performed at different levels, according to different approaches.

The three approaches presented above set a methodological structure for studies that attempt to quantify the Internet economy. Moreover, the initial investigations within each approach provide some information about the order of magnitude of the economic impacts of the Internet.

In terms of next steps, these investigations indicate the data requirements necessary to refine the methodologies and to broaden the scopes of measurement onto more economies. Moreover, more work is needed to understand the causality of the relationship between the Internet and GDP, as well as Internet impacts in important areas of life, but that do not show in the SNA statistics.

NOTES

1 In 1987, Robert Solow commented, "we can see the computer age everywhere but in the productivity statistics" (see New York Times, 20 May 1987, p. A1). The measurement of ICT impacts is difficult because both input and output quantities and prices are hard to measure, and because ICTs are General Purpose Technologies (see Bresnahan and Trajtenberg, 1995) that change how goods and services are produced. The measurement difficulties arise for numerous reasons, including the fact that Moore's Law-like productivity improvements in ICTs result in rapid technological progress and economic depreciation; ICT usage is especially intense in the service sectors which are notoriously poorly measured; and the impacts of ICTs take time to be realised.

2 For explanations of different demand structures see Savage and Waldman (2009).

3 Although both business and consumer Internet usage is of interest, this paper will focus on business usage to explicate the challenges.

4 Internet-enabled telecommuting, business-to-business, and business-to-consumer electronic commerce allow firms organisational structures to be dynamically adjustable.

5 Hausmann, *et al.* (2011) find their ECI is significantly better at explaining the relative economic performance of nations during the 2002-2007 period than the World Bank's Worldwide Governance Index (WGIs, see *http://info.worldbank.org/governance/wgi/index.asp*) or the World Economic Forum's Global Competitiveness Index (GCI, see *www.weforum.org/issues/global-competitiveness*).

6 For examples of popular Internet indices, consider the following: EIU, 2010; Waverman, 2011; BGG, 2010; ITU, 2011; McKinsey Institute, 2011; and WWW Foundation, 2011. All of these indices seek to integrate multiple supply and demand side metrics of Internet performance that may prove helpful in explaining relative performance differences across countries.

7 See *www.sandvine.com/*.

8 See *www.arbornetworks.com/*.

9 In addition to policy questions about whether DPI violates subscriber privacy rights (see Ou, 2009,) the different vendors rely on proprietary algorithms and code for traffic measurement and classification that needs to continuously evolve as applications change, motivated in part by a desire to evade traffic limiting controls by operators.

10 See *www.samknows.com/broadband/index.php*.

11 In 2006, the European Union adopted legislation requiring ISPs to retain traffic data, motivated by the needs of law enforcement to protect public safety and national security (see, *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006L0024:EN:NOT*).

12 See *www.wordle.net/* a "toy for generating 'word clouds' from user-provided text" that allows users to quickly generate graphic images that highlight prevalent words in the text.

13 See *http://pipes.yahoo.com/pipes/*, a mash up tool from Yahoo that allows you to combine RSS feeds, reorganise, filter, and sort Web-based information, and integrate other Web 2.0 interactive tools for user-generated analysis tools on the fly.

14 *www.measurementlab.net/*.

15 See *www.broadbandmap.gov/data-download*. The NTIA data includes 25 million records listing the availability by service provider and speed-tier by Census Block, allowing one to discern which service providers are offering what level of service at a very fine level of granularity. The NTIA includes a number of APIs for analysing and presenting the data, as well as linking it to other data sources, including speed-testing data from Google's Measurement Lab.

16 When one seeks to measure broadband access to fixed broadband, one naturally focuses on household subscriptions, whereas with mobile broadband, one focuses on individual subscriptions. In the former case, the service is typically shared with all members of the household; while in the latter, usage is typically (but not necessarily) not shared. As Wallsten (2008) showed, the drop in the United States. broadband ranking from 2002 to 2007 in OECD and other data sources that ranked countries on the population penetration of broadband could be explained on the basis of systematic differences in household sizes. Decline in broadband ranking in the United States was a topic for heated policy debate for several years, prompting a number of papers like Wallsten's that sought to make sense of international broadband comparisons.

17 The Content and Media sector consists of all industries (manufacturing and services) whose production is primarily … intended to inform, educate and/or entertain humans through mass communication media. These industries are engaged in the production, publishing and/or the distribution of content (information, cultural and entertainment products), where content corresponds to an organised message intented for human being (OECD, 2011b, p. 164).

18 For the United States, the only sector for which information is available on Internet-related activities (both supporting and purely based on the Internet) is the Information sector (NAICS 51). For the other sectors of the economy, only information on e-commerce (purely based on the Internet) is available.

19 US Bureau of Economic Analysis GDP by Industry Data.

20 The business sector is an aggregate commonly used for international comparisons, and here it is defined as per the ISIC Rev.4 activities 05-66 and 69-82. It does not take into account agricultural activities; real estate; or community, social and personal services. The community social and personal services category includes industries such as: educational services, health care and social assistance; arts, entertainment and recreation, and other non-government services, and government services.

21 Thus, the quantitative results present the correlation rather than causality.

22 *http://itunes.stanford.edu*

23 *Source*: OECD Health Data 2010 homepage

24 Brynjolfsson *et al*. (2003) report the standard errors of these estimates to be USD 46.7 and USD 65.8 million, respectively.

ANNEX: METHODOLOGICAL NOTE

This annex illustrates the quantitative exercises that feed into the examples provided in Approach 3. The annex is based on Greenstein and McDevitt, 2012 (Example 1), and on Cooper, 2012 (Example 2).

Example 1: The broadband bonus[1]

The primary goal of this example is to compute something equivalent to the estimate of the broadband bonus found in Greenstein and McDevitt (2011). That is, the estimation of additional consumer surplus and the net gain in producer revenue (broadband revenue minus lost dial-up revenue), expressed in a single currency for comparability. These estimates are in Tables A6 and A7, and they are discussed at the end of this section. However, to clarify the construction and robustness of these results, several intermediate steps towards those final tables are presented.

Table A1 presents the first step to the main results. It shows the number of broadband subscribers in each of the thirty OECD countries between 2005 and 2010. Not surprisingly, large, developed nations such as the United States and Japan had the most broadband subscribers by 2010. Perhaps more surprising, nations such as Greece, Mexico and the Slovak Republic experienced the most substantial growth in subscribers over this period.

Table A1. Broadband subscribers

	2005	2006	2007	2008	2009	2010	CAGR
Australia	2,785,000	3,816,172	4,830,200	5,336,000	5,236,000	5,020,000	12.5%
Austria	1,181,692	1,383,798	1,597,991	1,768,941	1,877,815	1,965,075	10.7%
Belgium	1,902,739	2,355,603	2,715,793	2,962,450	3,133,881	3,340,223	11.9%
Canada	6,695,546	7,929,081	8,975,902	9,405,318	10,290,000	9,987,482	8.3%
Czech Republic	661,000	1,136,758	1,501,420	1,769,684	2,034,986	858,814	5.4%
Denmark	1,350,415	1,728,337	1,945,842	2,021,404	2,067,000	2,052,458	8.7%
Finland	1,174,200	1,429,200	1,617,100	1,616,900	1,459,000	1,591,000	6.3%
France	9,465,600	12,718,313	15,550,000	17,725,000	19,582,000	20,930,000	17.2%
Germany	10,706,600	14,982,600	19,531,000	22,532,000	24,977,400	26,221,320	19.6%
Greece	156,560	509,081	1,084,115	1,506,614	1,918,630	2,287,074	71.0%
Hungary	639,505	965,384	1,395,612	1,696,714	1,880,226	1,860,072	23.8%
Iceland	78,017	87,738	97,937	103,697	107,072	105,444	6.2%
Ireland	274,100	519,029	767,736	896,346	961,748	853,970	25.5%
Italy	6,896,696	8,393,000	10,131,542	11,283,000	12,281,429	13,416,719	14.2%
Japan	27,972,788	26,438,351	28,749,525	30,107,327	31,630,781	35,011,355	4.6%
Korea	13,810,713	14,012,921	14,709,998	15,474,931	16,347,716	17,230,624	4.5%
Luxembourg	67,357	99,280	129,260	143,766	158,548	168,530	20.1%
Mexico	2,301,054	2,978,359	4,457,247	7,528,969	9,488,780	11,863,822	38.8%
Netherlands	4,114,573	5,065,000	5,617,902	5,855,000	6,130,000	6,378,000	9.2%
New Zealand	374,000	490,067	757,132	914,961	988,993	1,108,043	24.3%
Norway	1,045,589	1,250,899	1,436,255	1,607,750	1,633,592	1,676,872	9.9%
Poland	920,752	2,736,923	3,297,700	3,995,458	4,682,835	4,365,591	36.5%
Portugal	1,165,440	1,423,687	1,513,314	1,692,306	1,902,273	2,124,787	12.8%
Slovak Republic	133,900	274,108	413,244	618,871	627,722	674,814	38.2%
Spain	4,994,274	6,658,907	7,898,436	9,156,969	9,786,578	10,737,288	16.5%
Sweden	2,182,000	2,398,000	2,780,000	2,905,000	2,941,648	2,978,352	6.4%
Switzerland	1,788,829	2,064,118	2,438,128	2,523,649	2,793,723	2,984,517	10.8%
Turkey	1,530,000	2,773,685	4,395,800	5,736,619	6,446,374	7,114,584	36.0%
United Kingdom	9,826,300	12,995,140	15,606,100	17,275,660	18,213,290	19,428,446	14.6%
United States	48,474,844	60,642,869	70,056,146	77,600,095	79,331,337	80,776,663	10.8%

Table A2 presents a broadband revenue estimate calculated in 2010 in USD. These calculations take the price quotes from Tables 7.17 and 7.18 in the OECD Communications Outlook 2011 (OECD, 2011b) multiplied by the estimated subscribers by access type in Table 4.16.

1 This example is based on Greenstein and McDevitt (2012).

Table A2. Broadband revenue estimate in USD 2010

	2005	2006	2007	2008	2009	2010	CAGR
Australia	3,544,709,488	3,826,018,072	3,950,957,035	4,148,509,218	3,937,119,753	2,460,998,530	-7.0%
Austria	1,319,500,171	1,494,154,602	1,698,713,171	1,109,021,890	1,148,987,839	723,479,614	-11.3%
Belgium	1,793,797,424	2,174,657,705	2,774,187,867	3,111,133,287	2,413,393,628	1,983,859,310	2.0%
Canada	4,378,320,766	4,202,084,562	5,234,056,990	5,263,007,981	5,673,160,692	6,576,327,700	8.5%
Czech Republic	1,177,940,966	424,574,051	359,827,366	481,481,511	360,837,098	642,744,957	-11.4%
Denmark	1,496,984,686	1,762,615,829	1,458,338,590	986,290,538	1,024,297,246	979,229,726	-8.1%
Finland	1,271,374,303	1,310,773,819	1,306,575,098	769,887,823	1,158,992,257	826,464,763	-8.3%
France	6,066,540,723	7,054,737,964	9,135,570,954	10,892,772,331	9,769,550,756	10,108,162,238	10.8%
Germany	6,042,580,359	8,280,542,851	9,386,707,718	15,525,971,528	15,960,040,527	15,737,936,419	21.1%
Greece	90,556,595	235,526,545	422,928,939	464,924,622	552,490,039	618,206,698	46.8%
Hungary	1,247,238,113	1,373,969,008	654,384,202	693,914,404	609,322,250	576,706,297	-14.3%
Iceland	128,318,479	123,015,965	143,064,758	101,100,930	47,156,047	32,259,756	-24.1%
Ireland	235,017,626	202,975,876	398,418,212	385,474,145	437,452,134	456,736,833	14.2%
Italy	4,764,706,719	5,003,936,471	6,442,803,577	5,050,265,953	5,171,326,786	5,329,930,956	2.3%
Japan	13,032,981,114	10,584,945,077	9,633,587,936	12,308,831,076	15,404,002,698	17,270,072,210	5.8%
Korea	6,148,697,082	7,094,801,951	6,992,972,944	5,676,740,778	5,049,282,680	5,506,905,317	-2.2%
Luxembourg	99,618,775	121,221,315	168,149,082	191,977,206	195,675,928	198,547,391	14.8%
Mexico	2,405,757,884	1,488,123,658	2,058,002,946	4,550,955,916	3,210,633,155	4,338,225,643	12.5%
Netherlands	5,124,227,123	4,365,822,491	5,196,589,562	5,690,749,710	4,181,414,394	4,053,948,279	-4.6%
New Zealand	268,935,815	181,411,602	513,942,777	630,066,787	549,226,690	670,299,835	20.0%
Norway	1,339,181,201	1,394,786,177	1,676,270,730	1,893,474,523	1,632,882,877	1,633,124,713	4.0%
Poland	1,153,231,646	2,362,003,625	2,845,762,511	2,534,461,556	1,934,326,231	1,874,101,806	10.2%
Portugal	1,149,686,990	1,113,288,400	904,079,640	1,044,381,800	938,590,046	1,135,747,264	-0.2%
Slovak Republic	3,366,994	3,482,921	2,486,993	4,372,252	3,575,382	3,593,253	1.3%
Spain	3,340,343,448	4,118,675,318	5,236,162,518	5,187,180,207	5,596,873,426	5,399,440,124	10.1%
Sweden	1,562,564,608	1,561,226,479	1,874,592,966	1,839,755,785	1,597,106,310	1,636,819,901	0.9%
Switzerland	1,647,031,643	1,088,160,845	1,185,754,328	1,333,022,988	1,501,988,993	1,674,878,542	0.3%
Turkey	4,948,089,434	5,369,129,127	3,614,201,123	4,200,802,273	3,423,084,455	3,641,335,891	-5.9%
United Kingdom	7,579,396,623	8,562,656,587	10,211,719,111	10,017,031,578	8,295,857,036	8,624,336,265	2.6%
United States	34,984,151,357	32,835,644,922	37,505,675,270	33,860,117,038	40,880,090,062	44,264,378,671	4.8%

An immediate question stands out: How could revenue decline in a country like Australia that experienced 12.5% compound annual growth in subscribers? Declining prices provide the answer. The nominal price of a DSL subscription fell from USD 129 to USD 40 over this period, while the cable price fell from USD 75 to USD 60. Incorporating inflation only furthers the decline. While perhaps an incredible figure, this is the result. Fortunately, it also highlights an advantageous feature of this approach: any mismeasurement of revenue will be offset, at least partially, by a corresponding change in additional consumer surplus in the other direction. If the prices are lower than what consumers actually pay and the revenue is consequently undercounted, then the additional consumer surplus will be higher in the calculations and the net effect for the broadband bonus will be essentially unchanged.

Table A3 accounts for cannibalized dial-up revenue. As discussed above, many broadband subscribers would have subscribed to dial-up had broadband not diffused. As such, the broadband revenue figures in Table A2 substantially overstate broadband’s contribution to GDP. For instance, cannibalized dial-up revenue represents 30.7% of broadband revenue in the United States in 2010. Other countries that did not have sizable populations of dial-up subscribers, such as Turkey and the Slovak Republic, have comparatively less cannibalised revenue.

Table A3. Cannibalised dial-up revenue estimate in USD 2010

	2005	2006	2007	2008	2009	2010	CAGR
Australia	2,617,163,705	2,115,483,715	1,457,671,197	1,408,608,821	1,470,024,505	838,589,301	-20.4%
Austria	622,902,993	614,051,157	718,635,891	497,877,048	467,848,452	218,545,280	-18.9%
Belgium	444,991,423	437,162,107	488,484,813	501,872,887	262,267,672	252,108,678	-10.7%
Canada	850,017,560	837,898,905	921,716,161	864,504,048	876,301,814	952,730,815	2.3%
Czech Republic	457,637,248	94,541,855	68,125,820	76,149,312	71,054,040	104,935,769	-25.5%
Denmark	989,805,833	930,529,651	673,410,304	422,475,175	498,967,414	474,579,494	-13.7%
Finland	499,678,210	421,281,124	374,036,634	192,925,409	364,414,662	279,654,488	-11.0%
France	2,060,101,594	1,772,106,089	1,913,558,897	1,998,038,648	1,615,264,640	1,517,093,692	-5.9%
Germany	3,685,995,320	3,632,101,497	3,180,135,908	4,651,280,472	4,376,454,036	4,127,056,823	2.3%
Greece	101,222,561	84,969,614	68,270,031	54,003,088	50,393,123	47,449,035	-14.1%
Hungary	254,503,230	163,323,762	76,665,064	44,604,516	56,116,280	58,460,576	-25.5%
Iceland	38,651,631	33,635,165	35,076,599	23,436,005	10,577,141	7,036,032	-28.9%
Ireland	262,894,514	139,304,322	194,027,827	150,122,681	149,026,129	142,895,451	-11.5%
Italy	2,611,826,554	2,256,098,012	2,428,009,957	1,703,017,611	1,596,039,912	1,499,098,262	-10.5%
Japan	4,457,369,554	3,745,957,774	2,998,995,599	3,744,702,632	4,531,755,972	4,309,261,071	-0.7%
Korea	152,523,485	160,076,953	160,394,341	122,744,841	103,023,188	104,798,205	-7.2%
Luxembourg	59,610,115	50,683,771	54,287,998	56,363,262	53,035,834	49,450,222	-3.7%
Mexico	794,559,230	513,735,378	489,892,232	687,026,585	349,074,936	358,442,122	-14.7%
Netherlands	3,209,316,862	2,114,145,040	2,282,349,242	2,390,722,528	2,231,353,621	2,100,996,541	-8.1%
New Zealand	209,382,531	106,674,822	206,593,147	217,538,118	165,417,193	186,448,944	-2.3%
Norway	670,452,520	598,290,308	649,707,487	650,549,929	513,741,793	522,080,865	-4.9%
Poland	732,284,052	404,199,933	441,589,607	340,456,608	288,231,423	234,292,103	-20.4%
Portugal	1,646,947,934	1,318,125,796	1,013,458,508	1,051,802,363	709,489,592	667,310,137	-16.5%
Slovak Republic	1,145,823	577,241	210,221	372,033	273,648	252,401	-26.1%
Spain	1,053,891,024	1,018,099,305	1,085,480,321	856,870,414	811,603,866	760,252,121	-6.3%
Sweden	858,485,133	816,372,503	828,250,571	778,040,389	673,563,994	677,703,010	-4.6%
Switzerland	949,580,682	654,890,364	480,922,829	521,701,933	519,411,327	539,262,035	-10.7%
Turkey	0	0	0	0	0	0	0.0%
United Kingdom	4,135,400,150	4,445,341,709	4,344,375,428	3,882,283,563	3,138,223,451	3,068,428,075	-5.8%
United States	16,037,469,915	10,496,123,119	10,205,007,622	11,797,973,509	11,840,070,441	13,590,525,060	-3.3%

Table A4 computes an estimate for additional consumer surplus indexed to 2010 prices in USD. It is constructed with OECD's price estimates and accounts for users' willingness to pay by assumption. As stated earlier, a decline in real prices generates consumer surplus. Such declines are common in all these economies from the combination of general price inflation even with flat or no growth in nominal prices for broadband.

Table A4. Additional broadband consumer surplus estimate in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	558,718,852	1,691,174,283	1,811,042,113	1,764,460,218	3,361,381,670	56.6%
Austria	18,750,912	208,945,182	957,793,802	879,848,511	1,083,150,138	175.7%
Belgium	31,560,621	10,191,902	109,495,694	575,464,162	1,016,578,472	138.2%
Canada	1,125,133,400	990,048,750	1,162,328,554	844,740,921	912,860,403	-5.1%
Czech Republic	878,929,391	1,163,046,834	1,398,134,781	1,380,836,803	1,249,775,794	9.2%
Denmark	115,447,117	645,693,662	1,149,424,192	1,093,308,184	1,048,666,954	73.6%
Finland	183,740,483	408,389,768	929,076,050	845,906,383	1,148,640,730	58.1%
France	812,336,372	1,153,986,467	1,378,668,460	2,064,343,690	1,866,538,554	23.1%
Germany	88,486,330	1,461,298,983	103,783,678	124,794,178	194,470,401	21.8%
Greece	14,540,351	38,163,784	58,224,465	55,535,312	53,499,446	38.5%
Hungary	258,622,448	1,245,472,781	1,404,388,642	1,277,099,531	1,322,472,152	50.4%
Iceland	3,489,404	9,705,303	14,082,867	30,248,375	42,751,812	87.1%
Ireland	107,655,002	86,334,812	140,184,920	123,784,727	117,244,627	2.2%
Italy	648,948,979	792,222,894	2,498,753,889	2,382,492,581	2,313,639,886	37.4%
Japan	1,147,450,490	2,807,647,577	2,449,561,890	1,724,466,076	3,076,678,023	28.0%
Korea	98,735,275	763,154,644	1,131,116,744	1,095,858,089	1,507,328,750	97.7%
Luxembourg	17,192,931	21,227,157	24,999,862	23,938,829	24,706,974	9.5%
Mexico	1,244,348,132	1,350,950,627	1,019,706,744	1,196,737,652	1,221,259,099	-0.5%
Netherlands	1,577,633,768	1,794,668,423	2,034,503,478	3,274,312,056	3,157,813,220	18.9%
New Zealand	101,122,766	16,511,883	14,319,812	44,779,544	77,905,489	-6.3%
Norway	153,239,944	256,092,274	313,882,042	512,074,473	708,580,169	46.6%
Poland	398,905,343	682,144,812	1,487,560,702	1,416,716,407	1,495,921,025	39.2%
Portugal	235,372,461	581,505,904	651,681,381	732,187,850	615,336,260	27.2%
Slovak Republic	1,767,473	3,501,030	4,221,394	3,119,324	3,171,822	15.7%
Spain	229,702,248	349,733,226	1,070,412,930	892,851,703	1,201,268,975	51.2%
Sweden	147,263,989	244,481,941	386,379,177	344,633,039	424,838,520	30.3%
Switzerland	670,893,984	838,078,705	955,043,522	917,173,498	959,541,301	9.4%
Turkey	1,659,558,411	3,858,128,449	4,036,080,872	3,509,335,534	3,690,879,115	22.1%
United Kingdom	1,505,456,125	2,190,194,610	2,331,437,613	2,437,549,970	2,484,794,768	13.3%
United States	7,957,935,068	8,040,718,796	15,381,890,344	10,850,570,466	9,115,955,601	3.5%

Additional surplus grows over time in most cases, but the movement in prices from 2006 shapes the growth rate at any particular point. For example, additional consumer surplus increased fairly little in the United States since real broadband prices changed little as well. Other countries, such as Austria and Belgium, have experienced remarkable gains in additional consumer surplus.

Table A5 considers an alternative formulation of additional consumer surplus measured in willingness to pay for download speeds. As discussed above, this partly adjusts for improvements to broadband quality over time. That is, some countries have experienced rapid improvements in broadband quality over this time period, and Table A4 may be severely understating their gains in consumer surplus.

Table A5. Broadband quality-adjusted additional consumer surplus estimate in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	1,508,544,999	2,917,109,501	4,764,924,109	4,346,006,059	7,121,522,696	47.4%
Austria	18,750,912	208,945,182	1,033,447,361	1,166,001,764	3,887,563,887	279.5%
Belgium	739,547,018	786,067,406	962,254,622	2,055,048,324	6,080,766,270	69.3%
Canada	1,125,133,400	1,873,180,357	2,079,890,087	5,574,894,564	6,114,718,121	52.7%
Czech Republic	1,882,950,769	2,368,089,630	11,167,812,155	10,396,026,415	10,247,860,944	52.7%
Denmark	115,447,117	742,498,034	1,379,749,271	1,261,840,882	2,177,031,753	108.4%
Finland	183,740,483	589,444,906	1,276,694,436	648,815,760	887,988,420	48.3%
France	1,088,798,271	1,874,511,695	2,255,731,062	6,211,607,620	7,144,449,341	60.0%
Germany	85,850,932	2,416,307,104	922,407,785	1,107,246,702	1,398,045,636	100.9%
Greece	14,540,351	84,808,801	210,525,351	842,004,325	809,563,244	173.2%
Hungary	359,059,618	2,390,654,167	5,845,360,842	9,078,032,830	8,857,968,314	122.9%
Iceland	41,874,024	52,355,017	46,750,601	59,543,728	129,193,671	32.5%
Ireland	107,655,002	86,334,812	690,430,915	1,525,843,223	1,729,848,932	100.2%
Italy	20,279,540,660	22,322,689,755	26,361,590,384	24,933,727,563	23,850,643,941	4.1%
Japan	1,147,450,490	2,807,647,577	2,449,741,373	2,664,071,444	4,306,783,788	39.2%
Korea	1,610,511,050	2,318,127,428	34,083,508,535	29,550,796,448	33,026,225,183	112.8%
Luxembourg	20,511,019	626,002,062	699,561,397	661,403,687	883,195,180	156.2%
Mexico	1,244,348,132	2,608,546,942	2,244,928,632	3,079,770,143	3,323,959,589	27.8%
Netherlands	815,146,100	966,643,778	67,223,297,466	115,462,020,634	141,815,037,814	263.2%
New Zealand	101,122,766	3,098,255,537	2,946,795,682	2,688,950,137	3,141,933,287	136.1%
Norway	667,098,928	819,408,235	933,943,338	1,637,963,096	1,769,060,929	27.6%
Poland	398,905,343	1,506,655,113	2,875,357,873	3,217,594,778	5,467,399,204	92.4%
Portugal	235,372,461	904,342,528	2,500,098,168	5,619,859,692	5,235,009,155	117.2%
Slovak Republic	1,996,588	7,409,534	266,361,903	189,843,471	191,453,466	212.9%
Spain	951,780,164	1,165,401,328	3,342,083,746	2,918,074,097	3,085,713,223	34.2%
Sweden	147,263,989	252,799,040	517,578,167	467,040,948	547,184,835	38.8%
Switzerland	1,486,122,897	1,822,716,563	3,466,838,119	4,631,606,345	7,391,461,952	49.3%
Turkey	1,659,558,411	5,453,214,319	5,838,033,570	5,350,556,285	5,970,435,845	37.7%
United Kingdom	14,248,857,592	16,119,581,465	20,512,712,006	45,237,066,513	45,342,575,373	33.6%
United States	7,957,935,068	8,083,372,945	46,556,196,742	93,752,058,262	95,043,752,646	85.9%

As expected, many countries have higher additional consumer surplus in quality-adjusted terms, and all have experienced a net gain between 2006 and 2010. Some countries, such as the Netherlands, do remarkably well. This is not surprising given the evolution of broadband in the Netherlands. The typical DSL subscriber there paid USD 75 in 2005 for a download speed of 8 MB/s. In 2010, that same consumer paid USD 50 for 40 MB/s – a 33% price decline combined with a fivefold quality improvement. One hastens to note, however, that advertised download speeds may differ from those actually attainable, so these figures may be overstating quality improvements.

Table A6 provides the first set of main results, a broadband bonus estimate that takes broadband revenue less cannibalized dial-up revenue plus additional consumer surplus in 2010 in USD.

Table A6. Broadband bonus estimate in 2010 USD

	2006	2007	2008	2009	2010	CAGR
Australia	2,269,253,209	4,184,460,121	4,550,942,509	4,231,555,466	4,983,790,899	21.7%
Austria	898,854,357	1,189,022,461	1,568,938,644	1,560,987,899	1,588,084,472	15.3%
Belgium	1,769,056,219	2,295,894,957	2,718,756,095	2,726,590,118	2,748,329,103	11.6%
Canada	4,489,319,056	5,302,389,579	5,560,832,487	5,641,599,799	6,536,457,288	9.8%
Czech Republic	1,208,961,587	1,454,748,379	1,803,466,981	1,670,619,861	1,787,584,982	10.3%
Denmark	947,533,295	1,430,621,947	1,713,239,555	1,618,638,016	1,553,317,186	13.2%
Finland	1,073,233,179	1,340,928,232	1,506,038,463	1,640,483,978	1,695,451,006	12.1%
France	6,094,968,247	8,375,998,524	10,273,402,143	10,218,629,806	10,457,607,100	14.4%
Germany	4,736,927,685	7,667,870,793	10,978,474,734	11,708,380,670	11,805,349,996	25.6%
Greece	165,097,282	392,822,692	469,145,998	557,632,228	624,257,109	39.4%
Hungary	1,469,267,694	1,823,191,919	2,053,698,531	1,830,305,501	1,840,717,873	5.8%
Iceland	92,870,204	117,693,463	91,747,792	66,827,280	67,975,537	-7.5%
Ireland	171,326,556	290,725,197	375,536,384	412,210,731	431,086,010	25.9%
Italy	3,396,787,439	4,807,016,514	5,846,002,232	5,957,779,455	6,144,472,581	16.0%
Japan	7,986,437,793	9,442,239,913	11,013,690,335	12,596,712,802	16,037,489,162	19.0%
Korea	7,033,460,274	7,595,733,247	6,685,112,681	6,042,117,582	6,909,435,862	-0.4%
Luxembourg	87,730,475	135,088,241	160,613,807	166,578,923	173,804,143	18.6%
Mexico	2,218,736,412	2,919,061,342	4,883,636,075	4,058,295,871	5,201,042,620	23.7%
Netherlands	3,829,311,219	4,708,908,743	5,334,530,660	5,224,372,829	5,110,764,958	7.5%
New Zealand	175,859,546	323,861,513	426,848,481	428,589,041	561,756,380	33.7%
Norway	949,735,813	1,282,655,517	1,556,806,636	1,631,215,557	1,819,624,016	17.7%
Poland	2,356,709,034	3,086,317,717	3,681,565,650	3,062,811,215	3,135,730,728	7.4%
Portugal	30,535,065	472,127,036	644,260,817	961,288,303	1,083,773,386	144.1%
Slovak Republic	4,673,154	5,777,801	8,221,613	6,421,059	6,512,674	8.7%
Spain	3,330,278,261	4,500,415,423	5,400,722,723	5,678,121,263	5,840,456,978	15.1%
Sweden	892,117,965	1,290,824,336	1,448,094,574	1,268,175,355	1,383,955,411	11.6%
Switzerland	1,104,164,466	1,542,910,204	1,766,364,578	1,899,751,164	2,095,157,808	17.4%
Turkey	7,028,687,537	7,472,329,573	8,236,883,145	6,932,419,989	7,332,215,006	1.1%
United Kingdom	5,622,771,004	8,057,538,292	8,466,185,627	7,595,183,554	8,040,702,957	9.4%
United States	30,297,456,872	35,341,386,445	37,444,033,873	39,890,590,086	39,789,809,212	7.1%

These results conform with expectations, as there is a positive correspondence between GDP and the broadband bonus among OECD nations in 2010. Economies like the United States, Japan, and Germany enjoy very large broadband bonuses, while smaller nations such as the Slovak Republic and Iceland have correspondingly smaller ones. Perhaps more informative are the growth rates. Portugal has experienced explosive growth in economic value associated with broadband over the past five years, while nations such as Korea and Iceland have stagnated.

Table A7 presents the broadband bonus in quality-adjusted terms. Here, the mapping between each nation's GDP and broadband economy becomes less mechanical—the simple correlation is 0.61 rather than 0.98 for Table A6. The countries that have experienced rapid improvements in quality with declining prices, such as the Netherlands, once again stand out.

Table A7. Quality-adjusted broadband bonus estimate in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	3,219,079,355	5,410,395,340	7,504,824,505	6,813,101,307	8,743,931,924	28.4%
Austria	898,854,357	1,189,022,461	1,644,592,202	1,847,141,152	4,392,498,220	48.7%
Belgium	2,477,042,616	3,071,770,461	3,571,515,023	4,206,174,280	7,812,516,901	33.3%
Canada	4,489,319,056	6,185,521,186	6,478,394,020	10,371,753,442	11,738,315,006	27.2%
Czech Republic	2,212,982,965	2,659,791,176	11,573,144,354	10,685,809,473	10,785,670,131	48.6%
Denmark	947,533,295	1,527,426,320	1,943,564,634	1,787,170,714	2,681,681,985	29.7%
Finland	1,073,233,179	1,521,983,370	1,853,656,849	1,443,393,355	1,434,798,696	7.5%
France	6,371,430,147	9,096,523,752	11,150,464,744	14,365,893,736	15,735,517,887	25.4%
Germany	4,734,292,287	8,622,878,914	11,797,098,841	12,690,833,194	13,008,925,231	28.7%
Greece	165,097,282	439,467,709	621,446,884	1,344,101,241	1,380,320,907	70.0%
Hungary	1,569,704,864	2,968,373,306	6,494,670,730	9,631,238,800	9,376,214,035	56.3%
Iceland	131,254,824	160,343,177	124,415,526	96,122,633	154,417,396	4.1%
Ireland	171,326,556	290,725,197	925,782,380	1,814,269,227	2,043,690,315	85.8%
Italy	23,027,379,120	26,337,483,375	29,708,838,727	28,509,014,437	27,681,476,635	4.7%
Japan	7,986,437,793	9,442,239,913	11,013,869,818	13,536,318,170	17,267,594,927	21.3%
Korea	8,545,236,049	9,150,706,031	39,637,504,472	34,497,055,940	38,428,332,295	45.6%
Luxembourg	91,048,563	739,863,147	835,175,342	804,043,781	1,032,292,349	83.5%
Mexico	2,218,736,412	4,176,657,657	6,108,857,963	5,941,328,363	7,303,743,110	34.7%
Netherlands	3,066,823,551	3,880,884,098	70,523,324,648	117,412,081,407	143,767,989,552	161.7%
New Zealand	175,859,546	3,405,605,166	3,359,324,351	3,072,759,634	3,625,784,178	113.1%
Norway	1,463,594,796	1,845,971,478	2,176,867,931	2,757,104,180	2,880,104,776	18.4%
Poland	2,356,709,034	3,910,828,018	5,069,362,820	4,863,689,586	7,107,208,907	31.8%
Portugal	30,535,065	794,963,660	2,492,677,605	5,848,960,146	5,703,446,281	269.7%
Slovak Republic	4,902,268	9,686,305	270,362,123	193,145,205	194,794,317	151.1%
Spain	4,052,356,177	5,316,083,525	7,672,393,539	7,703,343,657	7,724,901,225	17.5%
Sweden	892,117,965	1,299,141,435	1,579,293,563	1,390,583,265	1,506,301,726	14.0%
Switzerland	1,919,393,379	2,527,548,062	4,278,159,174	5,614,184,012	8,527,078,459	45.2%
Turkey	7,028,687,537	9,067,415,442	10,038,835,843	8,773,640,740	9,611,771,737	8.1%
United Kingdom	18,366,172,471	21,986,925,148	26,647,460,020	50,394,700,098	50,898,483,562	29.0%
United States	30,297,456,872	35,384,040,593	68,618,340,272	122,792,077,883	125,717,606,257	42.7%

Table A8 provides a global total for the broadband bonus in both general and quality-adjusted terms. The sum across the thirty OECD countries is large and growing. Currently, the bonus stands at USD 156.7 billion when not adjusted for quality and at USD 548.3 billion when factoring in quality improvements. In addition, the growth rate for the quality-adjusted broadband bonus is nearly four times as large. This reflects the simultaneous change in quality and price currently underway across the OECD.

Table A8. The global broadband bonus in USD 2010

	2006	2007	2008	2009	2010	CAGR
Global Broadband Bonus	101,732,120,895	128,850,560,121	146,667,793,820	147,284,885,402	156,786,712,441	11.4%
Global Broadband Quality-Adjusted Bonus	139,984,597,378	182,420,265,422	355,714,218,903	491,201,033,058	548,267,408,930	40.7%

Table A9 presents the ratio of the quality-adjusted bonus to non-quality-adjusted for each country. These calculations provide a sense of the nations for which not adjusting for quality improvements will lead to grossly understated estimates.

Table A9. Quality-adjusted broadband bonus / broadband bonus estimate in USD 2010

	2006	2007	2008	2009	2010
Australia	1.42	1.29	1.65	1.61	1.75
Austria	1.00	1.00	1.05	1.18	2.77
Belgium	1.40	1.34	1.31	1.54	2.84
Canada	1.00	1.17	1.17	1.84	1.80
Czech Republic	1.83	1.83	6.42	6.40	6.03
Denmark	1.00	1.07	1.13	1.10	1.73
Finland	1.00	1.14	1.23	0.88	0.85
France	1.05	1.09	1.09	1.41	1.50
Germany	1.00	1.12	1.07	1.08	1.10
Greece	1.00	1.12	1.32	2.41	2.21
Hungary	1.07	1.63	3.16	5.26	5.09
Iceland	1.41	1.36	1.36	1.44	2.27
Ireland	1.00	1.00	2.47	4.40	4.74
Italy	6.78	5.48	5.08	4.79	4.51
Japan	1.00	1.00	1.00	1.07	1.08
Korea	1.21	1.20	5.93	5.71	5.56
Luxembourg	1.04	5.48	5.20	4.83	5.94
Mexico	1.00	1.43	1.25	1.46	1.40
Netherlands	0.80	0.82	13.22	22.47	28.13
New Zealand	1.00	10.52	7.87	7.17	6.45
Norway	1.54	1.44	1.40	1.69	1.58
Poland	1.00	1.27	1.38	1.59	2.27
Portugal	1.00	1.68	3.87	6.08	5.26
Slovak Republic	1.05	1.68	32.88	30.08	29.91
Spain	1.22	1.18	1.42	1.36	1.32
Sweden	1.00	1.01	1.09	1.10	1.09
Switzerland	1.74	1.64	2.42	2.96	4.07
Turkey	1.00	1.21	1.22	1.27	1.31
United Kingdom	3.27	2.73	3.15	6.64	6.33
United States	1.00	1.00	1.83	3.08	3.16

Here, the Netherlands and the Slovak Republic stand out. Simpler measures of additional consumer surplus miss a large portion of the economic value created by broadband in these countries, mostly because broadband quality has improved while prices have declined.

Table A10 provides the ratio of additional consumer surplus to broadband revenue. These calculations allow us to understand how much simple GDP figures understate the economic value generated by broadband.

Table A10. Additional broadband consumer surplus / broadband revenue in USD 2010

	2006	2007	2008	2009	2010
Australia	0.15	0.43	0.44	0.45	1.37
Austria	0.01	0.12	0.86	0.77	1.50
Belgium	0.01	0.00	0.04	0.24	0.51
Canada	0.27	0.19	0.22	0.15	0.14
Czech Republic	2.07	3.23	2.90	3.83	1.94
Denmark	0.07	0.44	1.17	1.07	1.07
Finland	0.14	0.31	1.21	0.73	1.39
France	0.12	0.13	0.13	0.21	0.18
Germany	0.01	0.16	0.01	0.01	0.01
Greece	0.06	0.09	0.13	0.10	0.09
Hungary	0.19	1.90	2.02	2.10	2.29
Iceland	0.03	0.07	0.14	0.64	1.33
Ireland	0.53	0.22	0.36	0.28	0.26
Italy	0.13	0.12	0.49	0.46	0.43
Japan	0.11	0.29	0.20	0.11	0.18
Korea	0.01	0.11	0.20	0.22	0.27
Luxembourg	0.14	0.13	0.13	0.12	0.12
Mexico	0.84	0.66	0.22	0.37	0.28
Netherlands	0.36	0.35	0.36	0.78	0.78
New Zealand	0.56	0.03	0.02	0.08	0.12
Norway	0.11	0.15	0.17	0.31	0.43
Poland	0.17	0.24	0.59	0.73	0.80
Portugal	0.21	0.64	0.62	0.78	0.54
Slovak Republic	0.51	1.41	0.97	0.87	0.88
Spain	0.06	0.07	0.21	0.16	0.22
Sweden	0.09	0.13	0.21	0.22	0.26
Switzerland	0.62	0.71	0.72	0.61	0.57
Turkey	0.31	1.07	0.96	1.03	1.01
United Kingdom	0.18	0.21	0.23	0.29	0.29
United States	0.24	0.21	0.45	0.27	0.21

In the United States, for example, additional consumer surplus represents more than one fifth of broadband revenue in 2010. In other countries, such as Hungary, additional consumer surplus constitutes even more of the economic value generated by broadband, as additional consumer surplus dwarfs revenue there — consumers would be willing to pay much more for broadband access than they currently do. In quality-adjusted terms, these effects become even more pronounced, for the most part, as shown in Table A11.

Table A11. Quality-adjusted additional broadband consumer surplus / broadband revenue in 2010 USD

	2006	2007	2008	2009	2010
Australia	0.39	0.74	1.15	1.10	2.89
Austria	0.01	0.12	0.93	1.01	5.37
Belgium	0.34	0.28	0.31	0.85	3.07
Canada	0.27	0.36	0.40	0.98	0.93
Czech Republic	4.43	6.58	23.19	28.81	15.94
Denmark	0.07	0.51	1.40	1.23	2.22
Finland	0.14	0.45	1.66	0.56	1.07
France	0.15	0.21	0.21	0.64	0.71
Germany	0.01	0.26	0.06	0.07	0.09
Greece	0.06	0.20	0.45	1.52	1.31
Hungary	0.26	3.65	8.42	14.90	15.36
Iceland	0.34	0.37	0.46	1.26	4.00
Ireland	0.53	0.22	1.79	3.49	3.79
Italy	4.05	3.46	5.22	4.82	4.47
Japan	0.11	0.29	0.20	0.17	0.25
Korea	0.23	0.33	6.00	5.85	6.00
Luxembourg	0.17	3.72	3.64	3.38	4.45
Mexico	0.84	1.27	0.49	0.96	0.77
Netherlands	0.19	0.19	11.81	27.61	34.98
New Zealand	0.56	6.03	4.68	4.90	4.69
Norway	0.48	0.49	0.49	1.00	1.08
Poland	0.17	0.53	1.13	1.66	2.92
Portugal	0.21	1.00	2.39	5.99	4.61
Slovak Republic	0.57	2.98	60.92	53.10	53.28
Spain	0.23	0.22	0.64	0.52	0.57
Sweden	0.09	0.13	0.28	0.29	0.33
Switzerland	1.37	1.54	2.60	3.08	4.41
Turkey	0.31	1.51	1.39	1.56	1.64
United Kingdom	1.66	1.58	2.05	5.45	5.26
United States	0.24	0.22	1.37	2.29	2.15

Table A12 deflates the broadband bonus to per capita terms. This provides a sense of how much each resident gains in addition from access to broadband. Here, Finland, Luxembourg, the Netherlands, and Norway do very well. Others, such as the Slovak Republic, receive comparatively little per capita benefit from broadband.

Table A12. Broadband bonus per capita in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	108.73	197.05	210.28	191.46	223.07	19.7%
Austria	108.72	143.24	188.20	186.65	189.33	14.9%
Belgium	167.80	216.15	253.91	252.70	254.71	11.0%
Canada	137.81	161.01	166.85	167.21	191.64	8.6%
Czech Republic	117.75	140.92	172.91	159.00	169.97	9.6%
Denmark	174.28	262.02	311.95	293.13	280.19	12.6%
Finland	203.79	253.55	283.44	307.27	316.12	11.6%
France	96.14	131.32	160.17	158.44	162.15	14.0%
Germany	57.51	93.21	133.69	143.00	144.19	25.8%
Greece	14.81	35.10	41.75	49.52	55.44	39.1%
Hungary	145.89	181.31	204.59	182.62	184.07	6.0%
Iceland	305.16	377.95	287.29	209.33	213.76	-8.5%
Ireland	40.21	66.60	84.52	92.26	96.42	24.4%
Italy	57.63	80.96	97.71	98.86	101.96	15.3%
Japan	62.51	73.90	86.38	98.93	125.95	19.1%
Korea	145.63	156.76	137.53	123.95	136.78	-1.6%
Luxembourg	185.63	281.43	328.72	334.76	349.28	17.1%
Mexico	21.18	27.62	45.82	37.77	47.98	22.7%
Netherlands	234.34	287.51	324.48	316.11	309.24	7.2%
New Zealand	42.40	77.15	100.65	100.11	128.61	32.0%
Norway	203.76	272.56	326.51	337.80	372.17	16.3%
Poland	61.80	80.97	96.59	80.28	82.12	7.4%
Portugal	2.89	44.51	60.65	90.41	101.94	143.8%
Slovak Republic	0.87	1.07	1.52	1.19	1.20	8.5%
Spain	75.57	100.29	118.45	123.63	126.77	13.8%
Sweden	98.24	141.10	156.45	135.76	147.56	10.7%
Switzerland	146.09	202.51	229.07	243.59	267.84	16.4%
Turkey	101.25	106.36	115.88	96.42	101.98	0.2%
United Kingdom	92.80	132.14	137.92	122.97	131.06	9.0%
United States	101.31	117.01	122.84	129.73	128.75	6.2%

Table A13 looks at the per capita broadband bonus in quality-adjusted terms. By this measure, the Netherlands, Luxembourg, Switzerland, and the Czech Republic have done remarkably well over the past half decade.

Table A13. Quality-adjusted broadband bonus per capita in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	154.24	254.77	346.77	308.27	391.37	26.2%
Austria	108.72	143.24	197.28	220.87	523.68	48.1%
Belgium	234.95	289.20	333.55	389.82	724.05	32.5%
Canada	137.81	187.83	194.39	307.40	344.14	25.7%
Czech Republic	215.54	257.66	1,109.60	1,017.02	1,025.52	47.7%
Denmark	174.28	279.75	353.89	323.65	483.72	29.1%
Finland	203.79	287.78	348.86	270.35	267.52	7.0%
France	100.51	142.62	173.84	222.75	243.98	24.8%
Germany	57.48	104.82	143.66	155.00	158.89	28.9%
Greece	14.81	39.26	55.30	119.37	122.58	69.6%
Hungary	155.86	295.19	647.00	960.95	937.62	56.6%
Iceland	431.29	514.92	389.58	301.09	485.58	3.0%
Ireland	40.21	66.60	208.37	406.06	457.13	83.6%
Italy	390.68	443.58	496.54	473.08	459.34	4.1%
Japan	62.51	73.90	86.38	106.31	135.62	21.4%
Korea	176.93	188.85	815.47	707.68	760.72	44.0%
Luxembourg	192.65	1,541.38	1,709.32	1,615.84	2,074.54	81.1%
Mexico	21.18	39.52	57.32	55.30	67.38	33.5%
Netherlands	187.68	236.96	4,289.74	7,104.26	8,698.98	160.9%
New Zealand	42.40	811.24	792.11	717.77	830.08	110.4%
Norway	314.01	392.26	456.56	570.95	589.07	17.0%
Poland	61.80	102.60	133.00	127.48	186.12	31.7%
Portugal	2.89	74.94	234.67	550.13	536.44	269.3%
Slovak Republic	0.91	1.79	50.01	35.65	35.87	150.6%
Spain	91.96	118.47	168.28	167.72	167.67	16.2%
Sweden	98.24	142.01	170.62	148.87	160.60	13.1%
Switzerland	253.96	331.74	554.81	719.86	1,090.10	43.9%
Turkey	101.25	129.06	141.23	122.03	133.69	7.2%
United Kingdom	303.14	360.59	434.12	815.88	829.65	28.6%
United States	101.31	117.16	225.10	399.35	406.79	41.6%

To examine whether per capita figures mechanically provide higher bonuses to those countries with higher broadband adoption rates, Tables A14 and A15 consider estimates similar to Tables A12 and A13 but in per subscriber terms. Not surprisingly, the per-subscriber numbers are larger because no country has full adoption. The rankings between Tables A12 and A14 do change somewhat. For instance, in 2010 the Czech Republic has a much larger per-subscriber bonus than a per-capita one, mainly because the number of broadband subscribers declined as a proportion of its population. Similar findings hold for a comparison of quality-adjusted bonuses in per-subscriber relative to per-capita terms.

Table A14. Broadband bonus per subscriber in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	594.64	866.31	852.88	808.17	992.79	13.7%
Austria	649.56	744.07	886.94	831.28	808.15	5.6%
Belgium	751.00	845.39	917.74	870.04	822.80	2.3%
Canada	566.18	590.74	591.24	548.26	654.46	3.7%
Czech Republic	1,063.52	968.92	1,019.09	820.95	1,052.25	-0.3%
Denmark	548.23	735.22	847.55	783.09	756.81	8.4%
Finland	750.93	829.22	931.44	1,124.39	1,065.65	9.1%
France	479.23	538.65	579.60	521.84	499.65	1.0%
Germany	316.16	392.60	487.24	468.76	450.22	9.2%
Greece	324.30	362.34	311.39	290.64	272.95	-4.2%
Hungary	1,521.95	1,306.37	1,210.40	973.45	989.59	-10.2%
Iceland	1,058.49	1,201.73	884.77	624.13	644.66	-11.7%
Ireland	330.09	378.68	418.96	428.61	504.80	11.2%
Italy	404.72	474.46	518.12	485.10	457.97	3.1%
Japan	302.08	328.43	365.81	398.24	458.07	11.0%
Korea	501.93	516.37	432.00	369.60	401.00	-5.5%
Luxembourg	883.67	1,045.09	1,117.19	1,050.65	1,031.29	3.9%
Mexico	744.95	654.90	648.65	427.69	438.40	-12.4%
Netherlands	756.03	838.20	911.11	852.26	801.31	1.5%
New Zealand	358.85	427.75	466.52	433.36	506.98	9.0%
Norway	759.24	893.06	968.31	998.55	1,085.13	9.3%
Poland	861.08	935.90	921.44	654.05	718.28	-4.4%
Portugal	21.45	311.98	380.70	505.34	510.06	120.8%
Slovak Republic	17.05	13.98	13.28	10.23	9.65	-13.3%
Spain	500.12	569.79	589.79	580.19	543.94	2.1%
Sweden	372.03	464.33	498.48	431.11	464.67	5.7%
Switzerland	534.93	632.83	699.92	680.01	702.01	7.0%
Turkey	2,534.06	1,699.88	1,435.84	1,075.40	1,030.59	-20.1%
United Kingdom	432.68	516.31	490.06	417.01	413.86	-1.1%
United States	499.60	504.47	482.53	502.84	492.59	-0.4%

Table A15. Quality-adjusted broadband bonus per subscriber in USD 2010

	2006	2007	2008	2009	2010	CAGR
Australia	843.54	1,120.12	1,406.45	1,301.20	1,741.82	19.9%
Austria	649.56	744.07	929.70	983.67	2,235.28	36.2%
Belgium	1,051.55	1,131.08	1,205.60	1,342.16	2,338.92	22.1%
Canada	566.18	689.13	688.80	1,007.94	1,175.30	20.0%
Czech Republic	1,946.75	1,771.52	6,539.67	5,251.05	6,348.94	34.4%
Denmark	548.23	784.97	961.49	864.62	1,306.57	24.2%
Finland	750.93	941.18	1,146.43	989.30	901.82	4.7%
France	500.97	584.99	629.08	733.63	751.82	10.7%
Germany	315.99	441.50	523.57	508.09	496.12	11.9%
Greece	324.30	405.37	412.48	700.55	603.53	16.8%
Hungary	1,625.99	2,126.93	3,827.79	5,122.38	5,040.78	32.7%
Iceland	1,495.99	1,637.21	1,199.80	897.74	1,464.45	-0.5%
Ireland	330.09	378.68	1,032.84	1,886.43	2,393.16	64.1%
Italy	2,743.64	2,599.55	2,633.06	2,321.31	2,063.21	-6.9%
Japan	302.08	328.43	365.82	427.95	493.20	13.0%
Korea	609.81	622.07	2,561.40	2,110.21	2,230.23	38.3%
Luxembourg	917.09	5,723.84	5,809.27	5,071.30	6,125.27	60.8%
Mexico	744.95	937.05	811.38	626.14	615.63	-4.7%
Netherlands	605.49	690.81	12,044.97	19,153.68	22,541.23	147.0%
New Zealand	358.85	4,498.03	3,671.55	3,106.96	3,272.24	73.8%
Norway	1,170.03	1,285.27	1,353.98	1,687.76	1,717.55	10.1%
Poland	861.08	1,185.93	1,268.78	1,038.62	1,628.01	17.3%
Portugal	21.45	525.31	1,472.95	3,074.72	2,684.24	234.5%
Slovak Republic	17.88	23.44	436.86	307.69	288.66	100.4%
Spain	608.56	673.06	837.87	787.13	719.45	4.3%
Sweden	372.03	467.32	543.65	472.72	505.75	8.0%
Switzerland	929.89	1,036.68	1,695.23	2,009.57	2,857.11	32.4%
Turkey	2,534.06	2,062.75	1,749.96	1,361.02	1,351.00	-14.6%
United Kingdom	1,413.31	1,408.87	1,542.49	2,766.92	2,619.79	16.7%
United States	499.60	505.08	884.26	1,547.84	1,556.36	32.9%

Finally, Table A16 presents the broadband bonus as a percentage of GDP per capita. This provides a measure of how much broadband Internet is contributing to each country's economy on a relative basis. Here, Hungary and Turkey have bonuses equivalent to over 1% of their GDP per capita.

Table A16. Broadband bonus as a percentage of GDP per capita in USD 2010

	2006	2007	2008	2009	2010
Australia	0.28%	0.42%	0.43%	0.43%	0.49%
Austria	0.28%	0.32%	0.38%	0.41%	0.41%
Belgium	0.44%	0.50%	0.54%	0.58%	0.57%
Canada	0.35%	0.37%	0.37%	0.42%	0.48%
Czech Republic	0.85%	0.83%	0.83%	0.88%	0.93%
Denmark	0.35%	0.46%	0.50%	0.52%	0.49%
Finland	0.52%	0.54%	0.55%	0.69%	0.70%
France	0.27%	0.32%	0.36%	0.39%	0.39%
Germany	0.16%	0.23%	0.30%	0.35%	0.35%
Greece	0.06%	0.13%	0.14%	0.17%	0.18%
Hungary	1.30%	1.32%	1.32%	1.42%	1.36%
Iceland	0.56%	0.58%	0.55%	0.55%	0.53%
Ireland	0.08%	0.11%	0.14%	0.19%	0.20%
Italy	0.18%	0.23%	0.25%	0.28%	0.29%
Japan	0.18%	0.22%	0.23%	0.25%	0.32%
Korea	0.74%	0.72%	0.72%	0.73%	0.81%
Luxembourg	0.21%	0.26%	0.28%	0.32%	0.32%
Mexico	0.23%	0.29%	0.45%	0.47%	0.57%
Netherlands	0.57%	0.60%	0.61%	0.66%	0.64%
New Zealand	0.16%	0.24%	0.33%	0.37%	0.47%
Norway	0.28%	0.33%	0.35%	0.43%	0.47%
Poland	0.69%	0.73%	0.70%	0.71%	0.71%
Portugal	0.02%	0.20%	0.25%	0.41%	0.46%
Slovak Republic	0.01%	0.01%	0.01%	0.01%	0.01%
Spain	0.27%	0.31%	0.34%	0.39%	0.39%
Sweden	0.22%	0.28%	0.30%	0.31%	0.34%
Switzerland	0.28%	0.36%	0.35%	0.39%	0.42%
Turkey	1.33%	1.15%	1.13%	1.13%	1.10%
United Kingdom	0.23%	0.29%	0.32%	0.35%	0.36%
United States	0.23%	0.25%	0.26%	0.28%	0.28%

By quality-adjusted measures, shown in Table A17, the Netherlands, Hungary, and the Czech Republic, are receiving large benefits from broadband as a proportion of their overall economies.

Table A17. Quality-adjusted broadband bonus as a percentage of GDP per capita in USD 2010

	2006	2007	2008	2009	2010
Australia	0.39%	0.55%	0.71%	0.69%	0.85%
Austria	0.28%	0.32%	0.40%	0.48%	1.13%
Belgium	0.62%	0.67%	0.70%	0.89%	1.62%
Canada	0.35%	0.43%	0.43%	0.77%	0.86%
Czech Republic	1.55%	1.53%	5.36%	5.62%	5.59%
Denmark	0.35%	0.49%	0.57%	0.58%	0.85%
Finland	0.52%	0.62%	0.68%	0.61%	0.60%
France	0.28%	0.35%	0.39%	0.54%	0.59%
Germany	0.16%	0.26%	0.32%	0.38%	0.39%
Greece	0.06%	0.14%	0.18%	0.42%	0.41%
Hungary	1.39%	2.15%	4.18%	7.48%	6.94%
Iceland	0.79%	0.78%	0.74%	0.79%	1.21%
Ireland	0.08%	0.11%	0.35%	0.82%	0.93%
Italy	1.24%	1.24%	1.29%	1.35%	1.29%
Japan	0.18%	0.22%	0.23%	0.27%	0.34%
Korea	0.90%	0.87%	4.26%	4.14%	4.48%
Luxembourg	0.21%	1.44%	1.43%	1.52%	1.91%
Mexico	0.23%	0.41%	0.56%	0.68%	0.80%
Netherlands	0.45%	0.50%	8.04%	14.78%	17.87%
New Zealand	0.16%	2.56%	2.58%	2.63%	3.03%
Norway	0.43%	0.48%	0.49%	0.73%	0.74%
Poland	0.69%	0.92%	0.96%	1.13%	1.61%
Portugal	0.02%	0.34%	0.99%	2.51%	2.42%
Slovak Republic	0.01%	0.01%	0.29%	0.22%	0.22%
Spain	0.33%	0.37%	0.48%	0.53%	0.52%
Sweden	0.22%	0.28%	0.32%	0.34%	0.37%
Switzerland	0.49%	0.58%	0.85%	1.14%	1.72%
Turkey	1.33%	1.40%	1.37%	1.43%	1.44%
United Kingdom	0.75%	0.79%	0.99%	2.31%	2.26%
United States	0.23%	0.25%	0.48%	0.87%	0.88%

Example 2: An ICT-enhanced stylized consumer demand model[2]

Many modern approaches to estimation of consumer demand systems make use of flexible function forms in some aspect of the price index specification. For example, the Almost Ideal Demand System (AIDS) popularised by Deaton and Muellbauer (1980) contains, in its specification of the indirect utility function (IUF), two price indexes, one of which is Cobb-Douglas and the other of which is Translog. The Translog price index is a flexible functional form in the sense of Diewert (1971), in that it allows at least one free parameter for each separate own and cross price effect after allowing for relationships implied by optimisation, such as homogeneity and symmetry, but it requires data on individual prices for implementation.

With lack of full information on quality-adjusted prices following as a natural consequence of fast paced ICT innovation, specification of a Translog price index is not fully viable and another approach to ensuring commodity share equation flexibility will be important. This paper begins with a stylized version of the Modified Almost Ideal Demand System (MAIDS) model to ensure Engel Curve regularity and flexibility. This is a modification of AIDS initially introduced by Cooper and McLaren (1992) to correct an inherent irregularity in AIDS associated with the zero-degree homogeneity of the Cobb-Douglas price index. MAIDS was further extended in Cooper and McLaren (1996) to allow more flexibility in the specification of the degree of non-homotheticity of preferences. It provides a consumer demand system in fractional form, so that budget share equations (Engel Curves) are modelled in a non-linear fractional specification that is fully consistent with a consumer utility maximising paradigm.

For the purposes of handling the inadequate price issue that is a major problem for ICT-related research, the consumer demand model CHI-MAIDS that is the focus of this paper is further enhanced by a hedonic-type approach to prices. However, in CHI-MAIDS, rather than being constructed beforehand, the appropriate price adjustments are built directly into the consumer demand estimation process. This procedure introduces sufficient additional parameters to allow the consumer demand system to be flexible in the sense of Diewert, even though a Translog price index is not employed and the price component of the IUF specification is based on two Cobb-Douglas price index pairs.

2 This Annex is based on Cooper (2011).

In a two-commodity stylized representation of MAIDS where the first commodity q_1 is the most basic necessity (here, food) and the second commodity is a composite good representing all the remaining products, say Q_R, the IUF is:

$$V(c,p) = \left(\frac{c}{P_B}\right)^{\eta} \ln\left(\frac{c}{P_A}\right) \tag{1}$$

where

$c = p_1 q_1 + P_R Q_R$, $\ln P_A = \alpha \ln p_1 + (1-\alpha)\ln P_R$ and $\ln P_B = \beta \ln p_1 + (1-\beta)\ln P_R$.

Applying Roy's Identity to (1), the commodity share equations corresponding to the stylized MAIDS preferences can be seen to take the fractional form:

$$\begin{aligned} s_1 &= \frac{\alpha + \beta\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} \\ s_R &= \frac{(1-\alpha) + (1-\beta)\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} \end{aligned} \tag{2}$$

where $s_1 = p_1 q_1 / c$ and $s_R = P_R Q_R / c$. It is important to note that this specification is really reasonably general. In particular, the price index parameters α and β may be time varying as long as they are not functions of (current levels of) p_1, p_R and c. There is, however, a preference separability assumption implicit in the specification employed for stylized MAIDS. In particular, the 'rest of expenditure' price and quantity aggregators P_R and Q_R, while not needing to be precisely specified, are understood not to depend on p_1 and q_1. It is also useful to assume that the consumer optimisation that is represented in this way mimics a situation in which consumers act as if they do not believe that their individual decisions affect aggregate outcomes. This being so, the α and β parameters can be modelled as functions of past consumer decisions without requiring a full intertemporal optimisation model. This variable parameter specification is helpful for generating the required flexibility as well as mopping up autocorrelation in the estimation routine. As is reasonably standard, two stage budgeting allows atemporal and intertemporal decisions to be considered in tandem and the research for this paper concentrates on the atemporal stage, *viz*. allocation of predetermined c between s_1 and $s_R \equiv 1 - s_1$.

Interpretation and issues for empirical implementation

A further interpretation of MAIDS shares needs to be noted. Suppose c / P_A is a low value for the first period in the sample (say unity, as could be imposed by scaling the data and treating the first period as the base period). Then $\ln\left(c / P_A\right)$ is zero in this base period and the implied shares at that point in time, from (2), are $s_1 = \alpha$ and $s_R = 1 - \alpha$. Over time of course one might hope that real incomes rise and c / P_A trends upwards. Another implication of (2) is that as $c / P_A \to \infty$, $s_1 \to \beta$

and $s_R \to 1-\beta$. From the definitions of P_A and P_B (given following (1)) this means that, as a cost of living indicator, emphasis changes from P_A in the base period to P_B asymptotically. Preferences are not homothetic (unless $\alpha = \beta$). This of course is what gives rise to non-constant Engle Curves.

If data were to be available on total expenditure c, on the disaggregated expenditure component $p_1 q_1$ and on the aggregate price index P_A, then using the identity $s_1 + s_R = 1$ and appending disturbance terms to the deterministic specification (2), one could write a stochastic version for estimation as:

$$\begin{aligned} s_1 &= \frac{\alpha + \beta\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} + \varepsilon_1 \\ 1 - s_1 &= \frac{(1-\alpha) + (1-\beta)\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} + \varepsilon_2 \end{aligned} \tag{3}$$

However, adding up the two equations in (3) clearly shows that the disturbances are linearly dependent and one equation is redundant. Without loss of generality, parameter estimation can proceed on the single equation (for current purposes, the MAIDS Engel Curve for food):

$$s_1 = \frac{\alpha + \beta\eta \ln\left(c / P_A\right)}{1 + \eta \ln\left(c / P_A\right)} + \varepsilon_1 \tag{4}$$

It should be noted that, although the MAIDS IUF (1) is a function of two aggregate price indexes, P_A and P_B, only one of these, P_A, features as an aggregate price index in the estimating form (4). Thus, of the two price indexes P_A and P_B, it is P_A that has claim to being the key cost of living indicator in this model. It follows that a variable parameter specification for the key food price elasticity α, which allows α to be updated regularly based on the most recent consumer behaviour, will be an important component of the empirical specification.

To proceed, it is necessary to recognise that, with innovations in ICT, official price indexes do not adequately represent the theoretical aggregate price index P_A. On the other hand appropriate quality-adjusted variants of the individual prices p_1 and the sub-index P_R, or its component prices, are not readily available. This introduces the reason for the point of departure from MAIDS to CHI-MAIDS: to handle lack of appropriately defined official data for ICT-enhanced products. In the research reported here, to address this issue it is specified in CHI-MAIDS that

$$P_A = \theta P_{GDP} \tag{5}$$

where P_{GDP} is an available official price index (typically, the GDP deflator). The variable parameter θ is defined to equal unity in the base period (chosen here as the initial sample point) so that all price indexes are normalised at unity at that time. However, θ needs to be specified in such a way as to allow it to fall over time if innovations in ICT occur that add to the quality of products consumed (or, equivalently, reduce the quality-adjusted price) before this information becomes available to be incorporated into the official GDP deflator.

One interpretation of (5) is that this is a stylized approach to hedonic price index construction. If data permitted, it might be more accurate to consider individual prices, p_i say, and to define a quality adjusted price, $p_{A,i}$ say, where

$$p_{A,i} = \theta_i p_i \tag{6}$$

with θ_i a function of the various attributes that change with improvements in quality. That is, $1/\theta_i = \sum_{j=1}^{m} \kappa_{ji} x_j$ for preference parameters κ_{ji} and a set of attributes x_j, so that the observed price of an individual product in the market, p_i, is related to an underlying quality-adjusted price, $p_{A,i}$ as $p_i = \left(\sum_{j=1}^{m} \kappa_{ji} x_j\right) p_{A,i}$. If p_i is a representative market price for a product that is improving in quality over time, then p_i will be rising relative to $p_{A,i}$ and hence θ_i should be falling over time to reflect the quality advances. Rather than concentrate on constructing the various hedonic sub-components of price corresponding to specific attributes, however, at the level at which we will be working with a representative consumer model, it is the average price that matters, albeit ideally the average quality adjusted price.

In addition, however, working with aggregate data pooled across a number of economies, even individual prices p_i, unadjusted for quality, are difficult to obtain in a harmonized form. Hence (5) applies the quality adjustment paradigm at the level of the official GDP deflator. If one conceives of the GDP deflator being at least roughly approximated by a Cobb-Douglas price index of the form $P_{GDP} = \Pi_{i=1}^{n} p_i^{\omega_i}$ for some weights ω_i which could be time dependent (for example, lagged shares), then (6) suggests that $P_A = \left(\Pi_{i=1}^{n} \theta_i^{\omega_i}\right) P_{GDP}$. At the aggregate level, we do not have information on the individual hedonic characteristics making up the θ_i parameters for particular products. However, if we can find relevant information on particular ICT innovations we can presume that these correlate with improved quality of individual attributes and construct an overall quality adjustment factor θ, as designated by (5) as an approximation to $\Pi_{i=1}^{n} \theta_i^{\omega_i}$.

In the current research, (5) is used as the point of entry for examination of downward shifts in the Engel Curve for food as a result of ICT innovations. Applying (5) to (4), the CHI-MAIDS Engel Curve for food is:

$$s_1 = \frac{(\alpha - \beta\eta \ln\theta) + \beta\eta \ln\left(c / P_{GDP}\right)}{(1 - \eta\ln\theta) + \eta\ln\left(c / P_{GDP}\right)} + \varepsilon_1 \tag{7}$$

A useful way to interpret (7) is to write it in two components:

$$s_1 = \frac{(\alpha - \beta\eta\ln\theta)}{(1 - \eta\ln\theta) + \eta\ln\left(c / P_{GDP}\right)} + \frac{\beta\eta\ln\left(c / P_{GDP}\right)}{(1 - \eta\ln\theta) + \eta\ln\left(c / P_{GDP}\right)} + \varepsilon_1 \tag{8}$$

and to note from the discussion following (5) that $\ln\theta \le 0$. The parameters α, β and η are all positive (or, at least, non-negative). Hence, in the denominator of the share equation, the ‘intercept’,

$1-\eta\ln\theta$, is positive. So too is the numerator. The first term on RHS (8) is a hyperbola that asymptotes to zero. The second term asymptotes to β. The first term dominates when c/P_{GDP} is low (near unity). The second term begins to have more influence as c/P_{GDP} rises. In the case of the food share, Engel's Law should be reflected in parameter estimates satisfying $\alpha > \beta$.

Specifications for the individual food price elasticities in the two price indexes

In the previous sub-section it was argued that the parameter θ defined in (5) will be falling as advances in technology occurred that are not fully reflected in official prices. This also has implications for the specification of the individual food price elasticities α and β. To investigate these implications, observe that another way to write (7) is to define a bounded real expenditure indicator:

$$Z = \frac{\eta\ln\left(c/P_{GDP}\right)}{(1-\eta\ln\theta)+\eta\ln\left(c/P_{GDP}\right)} \qquad (9)$$

and hence rewrite (7) as:

$$s_1 = \frac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}(1-Z)+\beta Z \qquad (10)$$

Then, with further re-arrangement we can write the pseudo-'linear' form:

$$s_1 = \frac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}+\frac{\beta-\alpha}{1-\eta\ln\theta}Z \qquad (11)$$

where of course the 'linearity' is due to the construction of Z.

In (11), the intercept $\dfrac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}$ is a proper weighted average of α and β, and is greater than β since $\alpha > \beta$ in the case of the food share. It is also apparent that:

$$\partial\left(\frac{\alpha-\beta\eta\ln\theta}{1-\eta\ln\theta}\right)/\partial\ln\theta = \frac{(\alpha-\beta)\eta}{(1-\eta\ln\theta)^2} > 0 \qquad (12)$$

and consequently the intercept in (11) will be falling as θ falls, cet. par.

Extensive experimentation with specifications like (11), undertaken as background to the research reported in this paper, shows that in the (s, Z) space the Engel Curve for food is flattening out over time. In (11), the intercept is falling and the slope is also falling in absolute value. The curve is pivoting about β on the $Z = 1$ upper bound axis. β itself may or may not be constant, but it is certainly small, though difficult to estimate with precision because the upper bound axis $Z = 1$ in (s, Z) space is approached with substantial extrapolation (that is, as $c/P_{GDP} \to \infty$). However, it is also apparent that the intercept in (11) may vary over time for reasons other than the fall in θ.

In this research we treat η as a constant parameter. However, we should at least investigate the possibility that α and β are variable. As the discussion following (4) pointed out, P_A has an interpretation as a cost of living indicator. Given that, it might be reasonable to suppose that its individual price elasticities could vary with changes in preferences. While it is not necessary for α to fall over time in order to observe a fall in the intercept in (11), this could occur and so not all of the flattening of the pseudo-linear Engel Curve (11) might be attributable to the cost reduction effects of technological advances incorporate in θ. This motivates our decision to specify α as a variable parameter function in its own right. After initial experimentation in which a variety of possible influences on changes in α were considered, the specification finally chosen was simply:

$$\alpha_t = \psi s_{1,t-1} + (1-\psi) s_{R,t-1} \tag{13}$$

where ψ is a freely estimated parameter. The specification (13) means that the price index P_A is being continually reweighted with updated (one-period-lagged) share weights, compatibly with its interpretation in (4) as a cost of living indicator. The lower ψ, however, the less rigidly current preferences are linked to immediate past behaviour.

It is also possible in principle to model β as a function of time. In the event, it proved to be difficult to obtain statistically significant estimates of β. This is really a reflection of the fact that β is the long run food share as real expenditure tends to infinity. It is an extrapolated value well outside the bounds of experience. To pre-empt a later result, we have found that there is no significant difference to modelling results if β is treated as effectively zero. This means that P_B will be effectively a function of all other prices, with no influence coming from the price of food. It turns out that this result does not affect the remainder of the modelling and is simply a reflection of the ultimate unimportance of the food share in the limit. For generality in formulas that might be applied in principle to shares other than that for food, in what follows we retain β_t as a potential time varying parameter in the described specification. However, in the empirical application we set this parameter to zero.

The food share Engel Curve in a cross-country context

An issue investigated in this research is the degree to which innovative Internet-based public sector IT infrastructure, obtained for government by the contracting out of problems for solution by research oriented private sector firms, leads to reduced costs, generates quality improvements in services, and ultimately leads to increased consumer welfare. The parameter estimates required for this investigation are based on examination of actual consumer behaviour and need to be obtained in that context. With limited aggregate time series data covering a period of ICT innovation, the dataset needs to be extended in another way.

In the discussion above we have presented a simplified variant of the final estimating form, which we now need to generalise slightly to allow for a country specific effect in pooled time series/cross section estimation. In the pooled data context, the need for a country specific effect is in part related to different data definitions for food across countries. In addition to this issue, however, the need to allow for a country specific effect can also be given a purchasing power parity interpretation. These two concerns are of course related. One reason for differences in purchasing power parity is incompatible data definitions across countries. Another reason is differences in the provision of public infrastructure, the services of which might be consumed as a public good complementary to consumption of any purchased product. This difference can apply even with compatible product definitions. It reflects different public sector infrastructure provision and different taxation arrangements for the funding of such provision.

No adjustment for differences in purchasing power has been made in the data, and it is possible to interpret an additional country specific parameter γ, now to be introduced, as controlling for these differences. Instead of making arbitrary adjustments to the data prior to estimation, our procedure effectively endogenises the purchasing power parity (PPP) adjustment. This would appear to be more in spirit with the compelling arguments on an appropriate approach to PPP adjustments put by Pant and Fischer (2007). To allow for this, the IUF (1) can be generalised slightly. Consider (1) in a multi-country context with an additional country specific scaling parameter initially applied to total expenditure:

$$V(c,p) = \left(\frac{c/\tilde{\gamma}}{P_B}\right)^{\eta} \ln\left(\frac{c/\tilde{\gamma}}{P_A}\right) \tag{14}$$

This is equivalent to:

$$V(c,p) = \tilde{\gamma}^{-\eta}\left(\frac{c}{P_B}\right)^{\eta}\left[\ln\left(\frac{c}{P_A}\right) - \ln\tilde{\gamma}\right] \tag{15}$$

Since utility is ordinal and we are not intending to attempt inter-country utility comparisons, without loss of generality the country-specific scaling constant $\tilde{\gamma}^{-\eta}$ can be ignored. However, the adjustment term $-\ln\tilde{\gamma}$ within the square brackets in (15) is a non-monotonic transformation of utility in the context of MAIDS preferences and thus it does affect the form of the share equations. For convenience we redefine this parameter as $\gamma = \ln\tilde{\gamma}$ and write the cross-country variant of MAIDS as:

$$V(c,p) = \left(\frac{c}{P_B}\right)^{\eta}\left[\ln\left(\frac{c}{P_A}\right) - \gamma\right] \tag{16}$$

Re-applying Roy’s Identity to (16) and following through the previous steps from MAIDS to CHI-MAIDS, the stochastic specification of the CHI-MAIDS food share Engel Curve now becomes a slight extension of (7), *viz.*:

$$s_{1t} = \frac{\left[\alpha_t - \beta_t\eta\ln\theta_t\right] + \beta_t\eta\left[\ln\left(c_t / P_{GDP,t}\right) - \gamma\right]}{\left[1 - \eta\ln\theta_t\right] + \eta\left[\ln\left(c_t / P_{GDP,t}\right) - \gamma\right]} + \varepsilon_{1t} \tag{17}$$

where the additional parameter γ is fixed over time but varies across countries and where explicit time subscripts have been added for all variables as well as for the time varying parameters previously discussed.

Time varying parameter specification for the cost reduction effect

In order to estimate (17), it is necessary to parameterise the functional form for θ. In the empirical component of this research, the time varying θ_t parameter is specified to investigate the influence of the Internet-based public sector IT infrastructure of interest as well as other controls, especially spillover effects from other economies. Two forms of the latter are accommodated:

i) externalities that are available consistently over time but to a greater degree to those economies that have the most opportunity to gain costlessly, having not invested heavily in their own R&D; and *ii)* general spillovers from technological leader economies, available to all economies due to globalisation, but that are time varying depending on the historical context. After a good deal of experimentation the chosen specification is:

$$\theta_t = \theta_{1,t} + \theta_{2,t} = \frac{INNOV_t}{INNOV_b + OTHER_b} + \frac{OTHER_t}{INNOV_b + OTHER_b} \qquad (18)$$

$$INNOV_t = 1 + \theta_{1,C} \frac{AVGIT\%GDP_t}{1 + AVGIT\%GDP_t} \qquad (19)$$

where AVGIT = annualised value of government IT contracts (USD m.) awarded to high research intensive firms for development of innovative solutions to the provision of Internet-based public IT infrastructure. AVGIT%GDP is this value expressed as a percentage of GDP.

By construction in (18), $\theta_t = 1$ in the base period (denoted by subscript $t = b$). The explicit cost reduction effect due to AVGIT is controlled by a parameter $\theta_{1,C}$ which represents the key cost reduction effect of contracted Internet-based public sector IT innovations. With limited time series data on AVGIT for any country (indeed, no information for some), a common cost reduction parameter is estimated for a pooled cross-country time series dataset.

The variable OTHER primarily relates to spillover effects, either of ICT innovations or of other technological advances that may lead to quality improvements in various countries without being reflected in a reduction in the quality-adjusted prices of consumer products. One measure of this effect is captured by a parameter $\theta_{2,E}$ in (20) below, which is attempting to catch spillover effects applicable for countries whose level of e-readiness is below that of the United States in the base period. Another annually varying measure, meant to capture world-wide innovations in a globalised economy, is represented by the set of specific year dummies with associated parameters $\theta_{2,year}$. The specification is shown for an estimation period running from 2001 to 2008, with 2001 treated as the base period.

$$OTHER_t = \theta_{2,E} \max\left\{1 - \frac{EREADY_t}{EREADY_{US,b}}, 0\right\} + \sum_{year=2002}^{2008} \theta_{2,year} DUM_{year} \qquad (20)$$

Data and data construction

The model represented by the estimating form (17) was estimated by pooling time series data from 2001 to 2008 across 31 countries, using the non-linear estimation routine NL in Shazam. As (17) indicates, this requires data on the food share s_1, total consumption expenditure c, the GDP deflator P_{GDP} and the sundry variables making up the variable parameter specifications θ_t (cf. eqns. (18)-(20)). Because of the use of lagged food shares in construction of α_t, data on the food share is required from 2000 onwards. The food share, total consumption and GDP deflator data are available from official sources over the full range of 31 countries examined in this research. Attention here is concentrated on the special data constructed for the purposes of this research. Effectively, this is the data defined in discussion of (18)-(20)). Of this, the year and country dummy variables are the usual constructions. The EREADY series is directly taken from publications of country specific e-readiness indicators prepared by the Economist Intelligence Unit. The main task here is to describe the key AVGIT (annualised value of government IT) contracts data that enters the $\theta_{1,t}$ component of the specification. This data has been constructed by the author from announcements of major contracts by governments for the awarding of IT solutions contracts. The actual announcements database is the proprietary data of Datamonitor Pty Ltd, and interested readers will need to consult the provider to obtain access to the original data. For the purposes of this research the announcements of expenditures over a given number of years have been annualised by dividing the announced contract value by the stated length of the contract. For any given country and year, the value recorded in AVGIT will represent an aggregation of work on all contracts that are current at that time.

There are a number of important qualifications that should be understood about the background data and the specific AVGIT data construction process. First, the background proprietary data consist generally of announcements prior to commencement of a project, with information provided on the contracting parties, the estimated contract length and value, as well as some detail on the nature of the contract. Generally, no follow-up information is available on whether the contracts actually ran to budget. Second, to construct AVGIT from the contract announcements data, this author has allocated the estimated contract value evenly over the announced life of the contract. Third, it is implicitly assumed that from the perspective of consumers' welfare, the value due to the project actually comes on stream in direct proportion to funds spent, and at the time that they are assumed to have been spent. Fourth, while information is available in some cases where projects have been abandoned, no detailed information is available on success of most of the contracts from a project management perspective. While some will have been managed well, others may not have had effective government oversight. The results should be indicative of average economy-wide returns for a range of public sector IT infrastructure projects of differing quality, and should be used cautiously in considering the potential returns for any given project. Fifth, there is a whole class of ICT activity, namely that related to telecommunications, that is missing from the current data, which relates to IT only. Given the strong linkage between telecommunications and IT, evidenced by the growth of the Internet, this is a serious gap.

As a result, the AVGIT figure for any given year and country should be thought of simply as an indicator of the new stock of publicly funded IT infrastructure coming on line at any time for some general mix of consumer and producer usage. Despite its limitations, it seems worthwhile to link this data to a consumer demand study to investigate whether it really does seem to make a difference to consumer behaviour. If it does so, this can be taken as indirect evidence of an impact due to the ICT economy. After processing by the author in the manner described above, it is impossible to reconstruct the original contracts data from the AVGIT data series. Consequently, as suggested above, the interested reader should contact the data provider to access the original data. On the positive side, the constructed AVGIT data, being divorced after construction from the proprietary contracts data series, can be made freely available with this paper (see Table 1). Using it or other relevant data, alternative modelling that can produce comparisons with the results reported in this paper is invited.

In the analysis, we have attempted to include as many as possible of the 34 current OECD member economies. Of these, three (Chile, Slovenia and Israel) were not members in the period under investigation but have nevertheless been included in the modelling. However, three current smaller member economies of the OECD (Estonia, Iceland, Luxembourg) were not included in the analysis because of a lack of compatibly defined economic data available to the author at the time of database construction.

Table A18. Annualised and aggregated public sector IT contracts data (USD m.)

	Canada	Denmark	Italy	Switzerland	Slovakia
2001	81.4	1.1	21.5	0	0
2002	130.8	11.2	118.3	1.1	4
2003	173.1	26.5	152	1.5	1.1
2004	176.4	23	196.4	0.4	2.9
2005	268.7	53.3	144.2	0.9	0.8
2006	252.7	122.4	245.4	2	2.7
2007	362.9	151.7	293.6	2	7.3
2008	408.5	160.8	387.6	2	11
	Mexico	Finland	Netherlands	Turkey	Australia
2001	3	0	6.8	0	68.4
2002	4	8.9	82.9	0	119.2
2003	7.9	22.9	105	0	197
2004	12.1	48.7	121.2	31.2	231.5
2005	11.6	37.7	79.2	32.8	440.2
2006	10.6	65.5	110.6	0	530.9
2007	13.4	72.7	121.7	14.7	621
2008	12.9	88.7	121.6	51.8	742.9
	United States	France	Norway	United Kingdom	Japan
2001	8547.3	6.1	98.3	1 261.2	0
2002	10 865.5	13.1	90.7	1 608.1	0
2003	14 260.5	58.3	31.2	2 448.4	0.2
2004	20 101.5	138.9	67.4	3 694.3	16.7
2005	24 761.4	217.9	85.8	5 476.5	10.5
2006	30 151.9	167.1	145.3	7 297.9	19.3
2007	3 6328	224.1	235.8	7 991.9	38.7
2008	43 302.6	256.7	197.9	8 853.3	48.4
	Chile	Germany	Portugal	Czech Rep.	New Zealand
2001	0	0	0	0	12
2002	0	25.2	0	0	14.6
2003	0	133.3	0	0.3	23.5
2004	3.2	209.5	0	0.8	33.3
2005	5	182.3	0	3	17.4
2006	1.8	173.6	3.1	2.7	20.3
2007	0.5	1 118.1	3.4	13.4	18.2
2008	0.5	1 101.9	3.4	18.1	21.6
	Austria	Greece	Spain	Hungary	Korea
2001	0	5.8	7.3	2.5	0
2002	0	2.9	138.9	10.7	0
2003	0.3	159.5	169.8	22.7	0
2004	23.1	195.6	85.8	31.9	0
2005	26	10.1	18.8	25.1	0
2006	12.2	13.3	46	15.3	0
2007	0	24.1	98.1	15.5	18.4
2008	0	44.9	190.2	15.7	29.8
	Belgium	Ireland	Sweden	Poland	Israel*
2001	0	0.2	12.7	13.8	0
2002	2.5	7.6	68.8	15.6	0
2003	73.3	13.1	103.6	9	0
2004	153.3	27.3	208.2	0.1	0.7
2005	209.7	8.7	271.7	7.3	7.1
2006	205.8	7.9	204.5	15.2	15.2
2007	168.8	13.9	184.2	8.5	20.4
2008	174	59.5	176.6	5.8	24.5

Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Source: Cooper (2012)

Table A18 provides the constructed AVGIT data for 30 of the 31 countries included in the analysis. One country included in the econometric modelling, Slovenia, had no recorded public sector IT contracts announcements in the Datamonitor database. The fact that Slovenia has no AVGIT data does not prevent it being included in the pooled time series cross-country database for estimation of the full set of parameters that describe preferences. All countries have been assumed to share a common cost-reduction-due-to-IT-innovation parameter $\theta_{1,C}$. Many of the countries have low or erratic values of AVGIT and this is largely responsible for the need to estimate a common pooled parameter. Given the common $\theta_{1,C}$ parameter, Slovenia can be included along with all the other countries in counterfactual experiments. The simple assumption is that, had it undertaken AVGIT expenditure, this would have had similar effects as for other countries which have other economic variables (total expenditure, official prices, e-readiness) in a similar range.

To put the AVGIT data in perspective it is helpful to also present it as a proportion of GDP for each country over time. This is the form in which it appears in the model, as the variable AVGIT%GDP. Table A19 presents the annualised and aggregated IT contracts data in this form.

Table A19: Annualised public sector IT contract values as a proportion of GDP (%)

	Canada	Denmark	Italy	Switzerland	Slovakia
2001	0.01142	0.00069	0.00192	0.00000	0.00000
2002	0.01785	0.00644	0.00971	0.00040	0.01634
2003	0.02004	0.01244	0.01009	0.00046	0.00332
2004	0.01784	0.00943	0.01138	0.00011	0.00688
2005	0.02379	0.02059	0.00812	0.00024	0.00168
2006	0.01990	0.04432	0.01319	0.00052	0.00485
2007	0.02539	0.04984	0.01400	0.00048	0.00977
2008	0.02708	0.04917	0.01660	0.00042	0.01156
	Mexico	Finland	Netherlands	Turkey	Australia
2001	0.00048	0.00000	0.00170	0.00000	0.01833
2002	0.00062	0.00659	0.01894	0.00000	0.02856
2003	0.00124	0.01394	0.01951	0.00000	0.03695
2004	0.00177	0.02583	0.01990	0.00844	0.03583
2005	0.00151	0.01932	0.01256	0.00724	0.06106
2006	0.00127	0.03123	0.01657	0.00000	0.06967
2007	0.00148	0.03036	0.01591	0.00248	0.06907
2008	0.00140	0.03319	0.01410	0.00835	0.07876
	United States	France	Norway	United Kingdom	Japan
2001	0.08439	0.00046	0.05767	0.08751	0.00000
2002	0.10378	0.00090	0.04741	0.10185	0.00000
2003	0.13010	0.00324	0.01390	0.13451	0.00001
2004	0.17201	0.00674	0.02619	0.17105	0.00036
2005	0.19915	0.01022	0.02864	0.24523	0.00023
2006	0.22852	0.00744	0.04389	0.30544	0.00044
2007	0.26044	0.00887	0.06178	0.28840	0.00089
2008	0.29857	0.00965	0.04456	0.34665	0.00098
	Chile	Germany	Portugal	Czech Rep.	New Zealand
2001	0.00000	0.00000	0.00000	0.00000	0.02331
2002	0.00000	0.00125	0.00000	0.00000	0.02442
2003	0.00000	0.00546	0.00000	0.00033	0.02950
2004	0.00335	0.00763	0.00000	0.00073	0.03426
2005	0.00423	0.00653	0.00000	0.00241	0.01602
2006	0.00123	0.00597	0.00159	0.00189	0.01945
2007	0.00031	0.03388	0.00154	0.00786	0.01510
2008	0.00029	0.02981	0.00141	0.00839	0.01876
	Austria	Greece	Spain	Hungary	South Korea
2001	0.00000	0.00430	0.00120	0.00469	0.00000
2002	0.00000	0.00190	0.02024	0.01607	0.00000
2003	0.00012	0.08012	0.01923	0.02690	0.00000
2004	0.00788	0.08249	0.00822	0.03123	0.00000
2005	0.00852	0.00398	0.00167	0.02274	0.00000
2006	0.00377	0.00478	0.00374	0.01354	0.00000
2007	0.00000	0.00746	0.00693	0.01136	0.00194
2008	0.00000	0.01194	0.01098	0.01018	0.00360
	Belgium	Ireland	Sweden	Poland	Israel[3]
2001	0.00000	0.00019	0.00573	0.00725	0.00000
2002	0.00099	0.00620	0.02824	0.00787	0.00000
2003	0.02365	0.00834	0.03406	0.00415	0.00000
2004	0.04272	0.01484	0.05962	0.00004	0.00057
2005	0.05627	0.00433	0.07602	0.00240	0.00538
2006	0.05210	0.00360	0.05325	0.00445	0.01066
2007	0.03764	0.00540	0.04162	0.00205	0.01265
2008	0.03451	0.02263	0.03740	0.00094	0.01227

Source: Table A18 and GDP in current USD millions. Figures are proportions expressed as a percentage – eg AVGIT for Canada in 2001 was just over 81 USD m. with GDP approx 722,444 USD m. giving AVGIT%GDP just over 0.0001 or 0.01 of 1 % of GDP.

3 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Estimation results

Table A20 summarises maximum likelihood estimates and t-statistics for the various parameters making up components of the complete time varying parameter θ under three alternative modelling assumptions: *i)* that the same ICT cost reduction parameter, $\theta_{1,C}$, applies to all countries; *ii)* that the common cost reduction parameter applies to all countries except the United States, which has its own parameter $\theta_{1,USA}$; *iii)* that, in addition to the United States, the United Kingdom also has its own parameter $\theta_{1,UK}$.

Table A20: Cost reduction parameter estimates

	Model 1		Model 2		Model 3	
	estimate	t-statistic	estimate	t-statistic	estimate	t-statistic
$\theta_{1,C}$	-0.05	-2.5	-0.05	-2.6	-0.05	-2.5
$\theta_{1,USA}$			5.69	0.6	5.77	0.6
$\theta_{1,UK}$					0.25	0.6
$\theta_{2,E}$	-0.11	-2.1	-0.13	-3.1	-0.13	-2.8
$\theta_{2,2002}$	-0.05	-4.1	-0.06	-4.9	-0.06	-4.7
$\theta_{2,2003}$	-0.12	-6.2	-0.13	-7.0	-0.13	-6.7
$\theta_{2,2004}$	-0.10	-4.9	-0.11	-5.6	-0.11	-5.5
$\theta_{2,2005}$	-0.05	-2.5	-0.06	-3.2	-0.06	-3.2
$\theta_{2,2006}$	-0.03	-1.3	-0.04	-1.9	-0.04	-1.9
$\theta_{2,2007}$	-0.06	-2.3	-0.07	-3.0	-0.07	-2.9
$\theta_{2,2008}$	-0.05	-2.0	-0.06	-2.7	-0.07	-2.7

These results have very substantial implications. Setting aside the United States and United Kingdom results as special cases, there is clear evidence that the awarding of contracts for provision of Internet-based public sector IT infrastructure leads to an overall reduction in costs. This is despite the fact that the econometric results allow for other general effects (technology improvements over time via the year dummies) that can also explain substantial cost reductions as well as spillover effects from technological innovators to other economies, especially to those that are lagging in their own e-readiness and stand to benefit from quality improvements in products that generally circulate through trade, even though they may not have invested in the R&D required to produce the innovative products. These 'θ_2' effects are of course competing in explanation for the same cost reductions as the 'θ_1' effects.

It is arguable that the United States and the United Kingdom are sufficiently different from other countries as to require separate specification of the public sector IT innovation cost reduction effect. This is because these countries engage in so much more public sector contracting out of IT solutions than does any other country. In addition, in the United States in particular, so much more of these contracts relate to military requirements and, further, a substantial amount of this expenditure takes place in other countries. Arguably, the benefits from this expenditure will not flow as directly to quality advances in products of interest to domestic consumers whose preferences we are examining.

To allow for this possibly different impact on preferences, Model 2 specifies a separate parameter $\theta_{1,USA}$ which replaces, for the case of the United States alone, the otherwise common cost reduction parameter $\theta_{1,C}$. The estimated result is unexpectedly positive, but it is insignificant, and changes in other parameter estimates between Models 1 and 2 are minimal. Model 3 extends this approach to allocate a separate parameter for the United Kingdom. This is also positive and insignificant. Again, the other parameters do not change to any appreciable degree. In principle this process could be extended to allow a separate cost reduction parameter to be estimated for each country. However, the very small, not uncommonly zero, values for AVGIT%GDP in many countries, and the erratic nature of the data due to their compilation by aggregation of a small number of infrequently announced contracts, suggests that this process is not sustainable at the present level of available data. Rather, it is necessary to pool information across countries to have any real chance of determining the average size of the cost reduction effect at this stage.

Table A21 completes the summary of information from the alternative models by exhibiting the remaining Engel Curve parameters and overall fit statistics. In interpreting these results the reader should note that only the t-statistics for the parameter estimate of the MAIDS parameter η are constructed for the test against the null hypothesis that the true parameter value is zero. In the case of ψ, the parameter controlling the degree of influence of past food shares on the elasticity of the aggregate cost of living index P_A with respect to food prices, the null hypothesis is that $\psi = 1$, which reflects complete dependence on the lagged food share. In the case of the country specific γ parameters, since these relate to adjustments for purchasing power parity and/or other differences in food data definitions, the test is for the difference between the country specific estimate of γ and the average value of γ across all countries, which is 3.42, 3.41 and 3.41 for Models 1, 2 and 3 respectively.

Table A21: Engel curve parameter estimates and overall fit statistics

	Model 1		Model 2		Model 3	
	estimate	t-statistic	estimate	t-statistic	estimate	t-statistic
η	1.41	7.6	1.43	7.4	1.44	7.4
ψ	0.99	-6.3	0.99	-6.7	0.99	-7.0
γ_{Canada}	3.44	0.6	3.44	0.9	3.44	0.9
γ_{Mexico}	3.48	2.2	3.48	3.5	3.48	3.4
γ_{USA}	3.49	2.9	3.39	-0.6	3.39	-0.6
γ_{Chile}	3.45	1.0	3.45	1.3	3.45	1.3
$\gamma_{Austria}$	3.41	-0.4	3.40	-0.3	3.40	-0.3
$\gamma_{Belgium}$	3.44	0.6	3.43	0.8	3.43	0.8
$\gamma_{Denmark}$	3.40	-0.8	3.39	-0.8	3.39	-0.8
$\gamma_{Finland}$	3.45	0.8	3.44	1.0	3.44	1.0
γ_{France}	3.39	-0.9	3.38	-1.1	3.38	-1.0
$\gamma_{Germany}$	3.41	-0.5	3.40	-0.4	3.40	-0.4
γ_{Greece}	3.42	-0.1	3.41	-0.1	3.41	-0.1
$\gamma_{Ireland}$	3.41	-0.4	3.40	-0.4	3.40	-0.3
γ_{Italy}	3.39	-1.1	3.38	-1.1	3.38	-1.1
$\gamma_{Netherlands}$	3.38	-1.2	3.37	-1.5	3.37	-1.4
γ_{Norway}	3.37	-1.4	3.37	-1.4	3.37	-1.4
$\gamma_{Portugal}$	3.36	-2.0	3.36	-2.0	3.36	-1.9
γ_{Spain}	3.40	-0.5	3.40	-0.5	3.40	-0.5
γ_{Sweden}	3.44	0.6	3.43	0.8	3.43	0.7
$\gamma_{Switzerland}$	3.40	-0.9	3.39	-0.8	3.39	-0.8
γ_{Turkey}	3.46	1.2	3.46	1.4	3.46	1.4
γ_{UK}	3.44	0.6	3.43	0.8	3.41	0.0
$\gamma_{Czech\ Republic}$	3.36	-1.6	3.35	-1.7	3.35	-1.7
$\gamma_{Hungary}$	3.39	-1.0	3.38	-1.0	3.38	-1.0
γ_{Poland}	3.42	0.1	3.42	0.2	3.42	0.3
$\gamma_{Slovakia}$	3.39	-0.7	3.38	-0.8	3.38	-0.8
$\gamma_{Slovenia}$	3.37	-1.3	3.36	-1.5	3.36	-1.5
$\gamma_{Australia}$	3.42	0.0	3.42	0.1	3.42	0.2
γ_{Japan}	3.51	4.1	3.51	5.1	3.51	4.8
$\gamma_{New\ Zealand}$	3.38	-1.1	3.37	-1.2	3.37	-1.2

	Model 1		Model 2		Model 3	
	estimate	t-statistic	estimate	t-statistic	estimate	t-statistic
$\gamma_{South\ Korea}$	3.49	2.3	3.49	2.8	3.49	2.8
γ_{Israel}	3.50	3.9	3.50	4.9	3.50	4.7
$\gamma_{average}$	3.42		3.41		3.41	
R^2	0.96		0.97		0.97	
DW-statistic	1.86		1.84		1.84	
Log-likelihood	1299.08		1308.14		1308.63	

Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Table 4 shows that the MAIDS parameter η is highly significant and compatible across all specifications. This is consistent with strongly non-homothetic preferences.

The parameter Ψ appears as part of the determination of the time varying parameter α as defined in (13). The role of specification (13) is to allow the parameter α to vary over time in a manner consistent with past behaviour. As the food share s_1 typically falls over time, the same characteristic can be captured by α ,according to (13), as long as ψ is greater than 0.5. The parameter ψ can be interpreted as an indicator of the importance of recent past preferences on current preferences. Its estimated value of 0.99 is obviously close to unity, but it is very precisely measured and it is in fact statistically significantly below unity.

The actual values of α are not only time varying but they also vary across countries. While they are not reported in detail here, the estimates of the time-varying parameter α typically range from about 0.045 down to about 0.03 over time in most countries. With β set to zero and the results for θ reported in the previous table, this suggests a gradual flattening out of each country's Engel Curve over time. Specification (13), which relates α to lagged shares, is also successful in mopping up residual autocorrelation, as suggested (to an approximation, in the context of this non-linear model) by the very satisfactory Durbin-Watson statistic which is 1.86, 1.84 and 1.84 across the three alternative models reported in Table A21.

The γ parameters have been estimated to allow a country-specific effect. This is necessary to allow for differences that may be due to varying data definitions with respect to food across countries and possibly to differences in purchasing power parities. The differences are not substantial in most cases, and there are only four out of 31 cases where the country specific effect is consistently statistically different from the average (the cases of Mexico, Japan, South Korea and Israel). The United States is also statistically different from the average in the case of Model 1, where the change in its value relative to Models 2 and 3 is almost certainly due to the forced commonality of the θ_C parameter in Model 1.

The log-likelihood values, when compared via a likelihood ratio test, suggest that the Model 2 dominates the other two models. On the other hand, the additional coefficient in Model 2 relative to Model 1, $\theta_{1,USA}$, is not statistically significant on the standard t-test. As Tables 3 and 4 demonstrate, all other parameter estimates are very similar in the two models. Given the insignificance of the country-specific public sector IT contract expenditure effects for the United States and the United Kingdom in Models 2 and 3, and the very compatible nature of other parameter estimates and overall fit statistics we continue from this point with Model 1.

Approach to welfare evaluation

Even when measured real *per capita* GDP has not necessarily risen, (17) allows an avenue for the share of food in the budget to fall following an innovation in ICT through the effect of a time varying parameter θ_t in the level of the Engel Curve. This is an important effect to measure because it is an indicator of the 'hidden productivity' of ICT, where advances in ICT induce changes in consumer behaviour. These changes in behaviour may be construed as indirect indicators of welfare improvements, even though official statistics such as real GDP *per capita* (proxied in this model by c / P_{GDP}) may show no change associated with the ICT innovation.

Of course there may be a variety of influences affecting θ_t, quite apart from the innovation of interest. As described in detail in (18), we write

$$\theta_t = \theta_{1,t} + \theta_{2,t} \tag{21}$$

where $\theta_{1,t}$ represents an ICT effect of specific interest and $\theta_{2,t}$ controls for all other influences on θ_t, *viz.* other events that are not necessarily related to the ICT event of interest but that might have led to quality advances and/or quality-adjusted price reductions that have also failed to be recorded at the appropriate time in official price statistics. In what follows, for notational convenience we use the same symbols for estimated values of parameters as have been used above in describing the 'true' population parameters in the model. We apply (21) to (17), drop the disturbance term, and represent a predicted share form of (17) as:

$$\hat{s}_{1t} = \frac{\left[\alpha_t - \beta_t \eta \ln(\theta_{1,t} + \theta_{2,t})\right] + \beta_t \eta \left[\ln\left(c_t / P_{GDP,t}\right) - \gamma\right]}{\left[1 - \eta \ln(\theta_{1,t} + \theta_{2,t})\right] + \eta \left[\ln\left(c_t / P_{GDP,t}\right) - \gamma\right]}$$

A model-consistent evaluation of the welfare generated at this point in time makes use of the same estimated parameters to construct the predicted utility consistent with the model's IUF, *viz.*:

$$u_t = \left(\frac{c_t}{P_{B,t}}\right)^{\eta} \left[\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma\right] \tag{22}$$

At this point we have no way of constructing the necessary time series estimates of the price index $P_{B,t}$ in (22) because although we can construct estimates of the time varying parameters α_t (and also of β_t in principle, if it is specified as non-zero) following estimation, this is all done for the current model without information on the individual prices $p_{1,t}$ and $P_{R,t}$ that are necessary ingredients of $P_{B,t}$. Despite this we now propose a method that avoids this lack of data and nevertheless allow us to consider two counterfactual questions.

Compensating variation

Firstly, we can ask:

Suppose that a certain proportion of the ICT innovation implied by the parameter value $\theta_{1,t}$ had not occurred. The counterfactual situation is one in which $\theta_{1,t,counterfactual}$, say, is greater than $\theta_{1,t}$ due to θ_1 not falling so much from its previous value $\theta_{1,t-1}$. This reflects the fact that some degree of innovation has not occurred in the counterfactual situation. Hence $\theta_{1,t,counterfactual} = \theta_{1,t} + \theta_{1,S}$ where $\theta_{1,S} > 0$. In this circumstance, by how much would a consumer's total consumption expenditure c have to be increased (*i.e.* from c_t to c_t^C, say) in order for us to predict that they could attain the welfare level u_t, *cet. par*.?

This amount of increase, say $c_t^{CV} \equiv c_t^C - c_t$, is the 'compensating variation' required to allow generation under the counterfactual conditions (absence of the innovation) of the utility predicted as achievable in time t in the presence of the innovation that actually did occur. It is therefore a money metric measure of the *per capita* value of the innovation. Relative to the *per capita* expenditure required to achieve the innovation, it would then give a measure of the return on the innovation.

From (22), the relevant new consumption level c_{t+1}^C under these circumstances can in principle be found as the solution of:

$$u_t = \left(\frac{c_t^C}{\tilde{P}_{B,t}} \right)^{\eta} \left[\ln c_t^C - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma \right] \qquad (23)$$

where $\tilde{P}_{B,t}$ denotes the value achieved by the (unobservable) price index P_B under the counterfactual circumstance in which $\theta_{t,counterfactual} = \theta_{1,t} + \theta_{1,S} + \theta_{2,t}$.

In order to calculate c_t^C, we need to eliminate the unobservables u_t and $\tilde{P}_{B,t}$ from (23). We can begin by combining (22) and (23). In ratio form, these imply:

$$1 = \left(\frac{c_t^C / c_t}{\tilde{P}_{B,t} / P_{B,t}} \right)^{\eta} \frac{\ln c_t^C - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma} \qquad (24)$$

A difficulty in using this equation to solve for c_t^C is that it contains the unknown price index P_B. A reasonable assumption is required to eliminate this term. We may note from (5) and (21) that $P_{A,t} = (\theta_{1,t} + \theta_{2,t}) P_{GDP,t}$. It is therefore natural to define:

$$\tilde{P}_{A,t} = (\theta_{1,t} + \theta_{1.S} + \theta_{2,t}) P_{GDP,t}.$$

Now this implies

$$\tilde{P}_{A,t} / P_{A,t} = (\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) / (\theta_{1,t} + \theta_{2,t}) \tag{25}$$

Thus $\tilde{P}_{A,t} > P_{A,t}$ in the counterfactual situation under examination.

But what about $\tilde{P}_{B,t} / P_{B,t}$? As the interpretation surrounding (3) and (4) indicates, P_B could be interpreted as a price index more relevant to a wealthy society than is the case for the current cost of living price index P_A. In a cross-sectional analysis, if there is no 'digital divide' it might be reasonable to assume that $\tilde{P}_{B,t} / P_{B,t} = \tilde{P}_{A,t} / P_{A,t}$. More generally, in a time series analysis, if there is a digital divide but it is likely to be gradually eliminated we might at least expect that $\tilde{P}_{B,t} / P_{B,t} \le \tilde{P}_{A,t} / P_{A,t}$ but that $\tilde{P}_{B,\tau} / P_{B,\tau} \to \tilde{P}_{A,\tau} / P_{A,\tau}$ as $\tau \to \infty$ following a one-off shock at time t. In any event, in a counterfactual experiment involving a lower degree of innovation, we would certainly expect $\tilde{P}_{B,t} / P_{B,t} \ge 1$. In general, we could assume that $\tilde{P}_{B,t} / P_{B,t}$ lies between unity and $\tilde{P}_{A,t} / P_{A,t}$. Using (25) we could specify:

$$\tilde{P}_{B,t} / P_{B,t} = (1-\phi) + \phi\,(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) / (\theta_{1,t} + \theta_{2,t}) \tag{26}$$

for some parameter $0 \le \phi \le 1$ with the value of ϕ perhaps depending upon the type of ICT innovation, upon its likely effects on different sectors of society, and upon the perceived degree of permanence of its transformative technology. This parameter could conceivably be related to the degree of e-readiness in the economy. However, it is not possible to recover a probable value of this parameter simply from estimation of the food share equation without the aid of further rather arbitrary assumptions. In this paper we present an evaluation of the welfare effects in summary form for three possible values of this parameter: 0, ½ and 1. The degree of sensitivity of the results with respect to alternative settings is evident from this. We then focus on the most conservative results for detailed presentation. Determination of the most appropriate value for ϕ in any given welfare experiment invites further research.

It is convenient to rewrite (26) as

$$\tilde{P}_{B,t} / P_{B,t} = \frac{(1-\phi)(\theta_{1,t} + \theta_{2,t}) + \phi\,(\theta_{1,t} + \theta_{1,S} + \theta_{2,t})}{\theta_{1,t} + \theta_{2,t}} = \frac{\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t}}{\theta_{1,t} + \theta_{2,t}} \tag{27}$$

Then, given (27), we can now use (24) to solve for $\ln c_t^C$. We have an implicit expression:

$$\exp\left(\eta \ln c_t^C\right)\left(\frac{\theta_{1,t} + \theta_{2,t}}{(\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t})c_t}\right)^{\eta} \frac{\ln c_t^C - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma} = 1 \tag{28}$$

from which c_t^C can be calculated numerically for any given choice of ϕ.

Equivalent variation

On the other hand, a second counterfactual question that can be asked is:

Given that the innovation did occur, by how much could a consumer's total expenditure be reduced so that they would feel no noticeable change in the utility from that which could have been achieved had the innovation not have occurred?

To answer this question, we first need to compute a utility level that would be compatible with the innovation not having occurred in circumstances where expenditure c_t was available. This hypothetical utility level is:

$$\tilde{u}_t = \left(\frac{c_t}{\tilde{P}_{B,t}} \right)^{\eta} \left[\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma \right] \qquad (29)$$

However, given that the innovation did occur, this utility level $\tilde{u}_t$ could have been reached if an alternative expenditure level, $\tilde{c}_t$ say, had been allocated to achieve:

$$\tilde{u}_t = \left(\frac{\tilde{c}_t}{P_{B,t}} \right)^{\eta} \left[\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma \right] \qquad (30)$$

From the ratio of (30) to (29) we can obtain an implicit expression for the hypothetical expenditure level $\tilde{c}_t$, viz:

$$1 = \left(\frac{\tilde{c}_t / c_t}{P_{B,t} / \tilde{P}_{B,t}} \right)^{\eta} \frac{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} \qquad (31)$$

Using (27) we can eliminate the unobservable $P_{B,t} / \tilde{P}_{B,t}$ and rewrite this as:

$$\exp\left(\eta \ln \tilde{c}_t\right) \left(\frac{\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t}}{(\theta_{1,t} + \theta_{2,t}) c_t} \right)^{\eta} \frac{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln c_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} = 1$$

(32)

which we note that, for a given selection of ϕ, can be solved numerically for $\tilde{c}_t$.

With this level of $\tilde{c}_t$ defining an expenditure level that would have given utility level $\tilde{u}_t$ in the presence of the innovation, we can now reframe our second counterfactual question as:

By how much could a consumer's total expenditure be reduced from the level $\tilde{c}_t$, given that the innovation did occur, and still allow achievement of a further hypothetical utility level, u_t^E, say that would have been achievable with expenditure of $\tilde{c}_t$ in the absence of the innovation?

This amount, say $c_t^{EV} \equiv \tilde{c}_t - c_t^E$, is the 'equivalent variation'. To find c_t^E, we need to compare two equivalent ways of obtaining the counterfactual utility level u_t^E. These are:

$$u_t^E = \left(\frac{\tilde{c}_t}{\tilde{P}_{B,t}} \right)^{\eta} \left[\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma \right] \tag{33}$$

which gives the utility associated with $\tilde{c}_t$ if the innovation had not occurred, and which needs to be equated to:

$$u_t^E = \left(\frac{c_t^E}{P_{B,t}} \right)^{\eta} \left[\ln c_t^E - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma \right] \tag{34}$$

which implicitly defines c_t^E as the expenditure that would have given the equivalent utility in the actual presence of the innovation.

From the ratio of (34) to (33) we now obtain:

$$1 = \left(\frac{c_t^E / \tilde{c}_t}{P_{B,t} / \tilde{P}_{B,t}} \right)^{\eta} \frac{\ln c_t^E - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} \tag{35}$$

Once again using (26) with $\phi = 1$, we can eliminate the unobservable price indexes to get an expression that can be solved implicitly for $\ln c_t^E$:

$$\exp\left(\eta \ln c_t^E \right) \left(\frac{\theta_{1,t} + \phi\theta_{1,S} + \theta_{2,t}}{(\theta_{1,t} + \theta_{2,t})\tilde{c}_t} \right)^{\eta} \frac{\ln c_t^E - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{2,t}) - \gamma}{\ln \tilde{c}_t - \ln P_{GDP,t} - \ln(\theta_{1,t} + \theta_{1,S} + \theta_{2,t}) - \gamma} = 1 \tag{36}$$

To summarise, to compute the compensating variation $c_t^{CV} \equiv c_t^C - c_t$ we make use of actual expenditure c_t and the solution of (28) for c_t^C. To compute the equivalent variation $c_t^{EV} \equiv \tilde{c}_t = c_t^E$ we first find $\tilde{c}_t$ from (32) and then calculate c_t^E from (36).

Results of the welfare experiment

In this section, parameter estimates from the model are used to calculate the compensating variation $c_t^C - c_t$ and the equivalent variation $\tilde{c}_t - c_t^E$ by solving (28) and (36) respectively under the following scenario. The ratio of AVGIT to GDP is increased by an amount equal to 0.001 of a percent. This experimentally small increase is needed for realism because, as Table 2 attests, AVGIT is either non-existent or a tiny proportion of GDP in most countries. With zero values in a number of cases, the experiment cannot be conducted in terms of a reduction in IT innovation. Therefore the experiment is conducted as an increase in public sector IT innovation contracts rather than the decrease used in the previous section to describe the welfare calculations. Consequently the signs on the variations are reversed from the formulas given in the previous section to calculate the compensating and equivalent variations. In the model, c_t is total nominal consumer expenditure in *per capita* terms. To give a reasonable quantitative estimate of the welfare effect, the compensating and equivalent variations are reported as returns per dollar of expenditure. Let x_t denote the actual increase in AVGIT in current USD *per capita* required to move AVGIT%GDP, which is expressed as a percentage, up by 0.001. Allowing for the experimental direction reversal, we calculate

$$CVR = \left[-(c_t^C - c_t) - x_t \right] / x_t \quad \text{and} \quad EVR = \left[-(\tilde{c}_t - c_t^E) - x_t \right] / x_t \qquad (37)$$

The results are thus in units of USD returns per dollar of public sector IT contracts expenditure.

Table A22 gives the results in the final year of the estimation/simulation period, 2008, under the scenario described above. The final two columns (EV return and CV return) were obtained using (37), solving (28) for c_t^C, (32) for $\tilde{c}_t$ and (36) for c_t^E, in each case using the NL command in Shazam. For each of the 31 member countries of the OECD that have been included in the analysis, the table gives *i)* AVGIT in current USD millions*; ii)* AVGIT%GDP prior to the experiment (these are the figures that are increased by the amount of 0.001 in the experiment); *iii)* the aggregate increase in AVGIT required for the experimental scenario (*i.e.* x_{2008} times population); *iv)* the *per capita* increase in AVGIT, x_{2008}; *v)* the EVR and *vi)* the CVR as defined in (37).

Table A22. Evaluation of a small public infrastructure IT innovation in 2008

Country	AVGIT	AVGIT %GDP	$\Delta AVGIT$	$\frac{\Delta AVGIT}{POPN}$	EV return	CV return
	(USDm.)	(%)	(USDm.)	(USD)	(USD)	(USD)
Canada	408.5	0.027	15.1	0.45	53.43	40.84
Mexico	12.9	0.001	9.2	0.08	522.15	416.99
United States	43 302.6	0.299	145.0	0.48	-0.22	-0.37
Chile	0.5	0.000	1.7	0.11	680.68	500.00
Austria	0.0	0.000	4.2	0.51	682.25	513.06
Belgium	174.0	0.035	5.0	0.49	37.94	28.43
Denmark	160.8	0.049	3.3	0.60	20.87	15.64
Finland	88.7	0.033	2.7	0.51	41.37	30.06
France	256.7	0.010	26.6	0.42	189.77	143.72
Germany	1 101.9	0.030	37.0	0.45	47.06	35.46
Greece	44.9	0.012	3.8	0.35	165.95	117.92
Ireland	59.5	0.023	2.6	0.63	74.04	53.06
Italy	387.6	0.017	23.4	0.40	104.19	80.01
Netherlands	121.6	0.014	8.6	0.52	126.86	95.54
Norway	197.9	0.045	4.4	0.96	25.37	18.56
Portugal	3.4	0.001	2.4	0.23	526.68	407.83
Spain	190.2	0.011	17.3	0.41	179.85	127.35
Sweden	176.6	0.037	4.7	0.52	33.43	24.76
Switzerland	2.0	0.000	4.8	0.63	622.07	474.96
Turkey	51.8	0.008	6.2	0.08	237.87	169.17
United Kingdom	8 853.3	0.347	25.5	0.42	-0.4	-0.53
Czech Rep.	18.1	0.008	2.2	0.21	242.94	166.17
Hungary	15.7	0.010	1.5	0.16	196.68	139.46
Poland	5.8	0.001	6.2	0.16	663.06	450.68
Slovakia	11.0	0.012	1.0	0.17	184.2	123.15
Slovenia	0.0	0.000	0.6	0.28	737.03	524.54
Australia	742.9	0.079	9.4	0.45	8.84	6.46
Japan	48.4	0.001	49.5	0.39	535.91	434.38
New Zealand	21.6	0.019	1.2	0.28	88.65	67.91
South Korea	29.8	0.004	8.3	0.17	397.56	289.37
Israel	24.5	0.012	2.0	0.28	144.76	113.18

Note: The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Table A22 suggests that a small amount of additional innovative public sector IT expenditure in 2008 would have generated very large returns in most countries. The only countries where returns would have been negative are the United States and the United Kingdom. Both of these countries were already engaging in these expenditures to a degree far exceeding all other countries and this suggests that diminishing returns may have set in for these two cases. However, it should also be noted that these two countries are special cases in another respect. The proportion of contracts that are of a military type are much higher in the United States than for any other country, and a substantial number of contracts actually relate to spending outside the United States. In the case of the United Kingdom, it has been the leader in overall IT contract expenditure by government for many years and its expenditure as a proportion of GDP is substantially higher even than the United States. For example, the United Kingdom expenditure as a proportion of GDP is a factor of 7 higher than that of Denmark, greater than 20 times that of the Netherlands and almost a thousand times that of Switzerland. It is not too difficult to conjecture that diminishing returns may have set in for the United Kingdom and the United States even while there are substantial returns still available for other countries. The results reflect this, with the highest returns available to those countries that have not so far availed themselves of this source of potential gains from provision of publicly supported IT infrastructure.

In Table A22, the EV return is uniformly higher than the CV return. The differences reflect the non-homotheticity of preferences in the MAIDS model. While this is an important design feature aimed to address the empirical facts, it creates some ambiguity in reporting numerical results. In what follows we concentrate on the more conservative CV return. Following the comparison of AVGIT%GDP expenditures in the United Kingdom compared to Denmark, the Netherlands and Switzerland, it is interesting to note that the calculated return on the dollar in these countries is approximately USD 15, 95 and 475 respectively. The lowest positive return is USD 6 in the dollar for Australia. Correspondingly, it may be noted that the baseline AVGIT%GDP for Australia is 0.079, well below the United Kingdom at 0.347 but also considerably above Denmark at 0.049, the Netherlands at 0.014 and of course Switzerland at effectively zero.

There are many interesting comparisons that can be made from the table. For example, comparing Spain and Portugal it can be seen that the return per dollar from this experiment in Spain is calculated to be USD 127 whereas for Portugal it is calculated to be a much higher USD 407. To attempt to explain the difference we could note that Portugal is coming from a much lower base in terms of baseline expenditure by government on innovative IT solutions compared to Spain. AVG%GDP for Portugal is 0.001 whereas it is ten times that value for Spain.

These results are startling. Yet they are conservative based on modelling that has attempted to control for a variety of other influences that might have been reducing costs quite apart from the programmes of public sector IT innovation covered by the contracts database. These other effects include the year dummy variables which allow for a global reduction in costs regardless of source and the spillover variable that allocates an explanation for cost reductions due to countries' opportunities, for example through trade linkages, to benefit from quality advances in products even though they have not necessarily spent funds on development of their own e-readiness to the same extent as the ICT innovators.

Of course, there could be many other missing factors whose influence might be mistakenly attributed to a cost reduction effect due to the AVGIT variable. However, the results are so startling that they invite much more investigation. It should also be noted that these are estimated economy-wide returns, implied by the behaviour of consumers in what appears to be a substantially welfare increasing situation due to innovations in ICT. These returns are not available to private sector providers. They might be expected to be much higher than returns that can be privately captured in the market, because of special features of ICT such as network effects, spillovers and the permeation of ICT advances throughout the economy.

One reason why the results reported in Table A22 might be unrealistically high is because they have been computed on the assumption that the parameter ϕ is unity in (27). One way of interpreting a value of unity for this parameter is that it means that cost of living reductions due to ICT advances are judged by consumers to have permanent effects. Hence, the long run high income price index P_B is assumed to be affected by the ICT advance to the same extent as the short run or current cost of living index P_A. At the other extreme, we could set $\phi = 0$. This would effectively mean that the long run price index P_B would not be influenced by the innovation considered in the experiment. This could be interpreted as having welfare effects confined to the short run. An intermediate case would be obtained by setting $\phi = 0.5$. Table 6 presents the CV returns for the experiment described above repeated under these alternative parameter settings. For convenience of comparison, the original results obtained for the case $\phi = 1$ are repeated in this table and some of the columns in Table A22 that describe the experimental scenario are also repeated.

Table A23. Comparison of results for 2008 under alternative parameter settings

Country	AVGIT	$\Delta AVGIT$	$\frac{\Delta AVGIT}{POPN}$	CV return $\phi=1$	CV return $\phi=0.5$	CV return $\phi=0$
	(USDm.)	(USDm.)	(USD)	(USD)	(USD)	(USD)
Canada	408.5	15.1	0.45	40.84	34.57	28.30
Mexico	12.9	9.2	0.08	416.99	366.42	315.85
United States	43 302.6	145.0	0.48	-0.37	-0.45	-0.53
Chile	0.5	1.7	0.11	500.00	412.55	325.12
Austria	0.0	4.2	0.51	513.06	431.51	349.96
Belgium	174.0	5.0	0.49	28.43	23.69	18.95
Denmark	160.8	3.3	0.60	15.64	13.03	10.42
Finland	88.7	2.7	0.51	30.06	24.42	18.77
France	256.7	26.6	0.42	143.72	120.93	98.15
Germany	1 101.9	37.0	0.45	35.46	29.68	23.90
Greece	44.9	3.8	0.35	117.92	94.07	70.21
Ireland	59.5	2.6	0.63	53.06	42.60	32.15
Italy	387.6	23.4	0.40	80.01	67.99	55.98
Netherlands	121.6	8.6	0.52	95.54	79.99	64.45
Norway	197.9	4.4	0.96	18.56	15.16	11.77
Portugal	3.4	2.4	0.23	407.83	350.33	292.83
Spain	190.2	17.3	0.41	127.35	101.28	75.22
Sweden	176.6	4.7	0.52	24.76	20.44	16.11
Switzerland	2.0	4.8	0.63	474.96	404.01	333.06
Turkey	51.8	6.2	0.08	169.17	135.16	101.14
United Kingdom	8 853.3	25.5	0.42	-0.53	-0.60	-0.67
Czech Rep.	18.1	2.2	0.21	166.17	128.11	90.05
Hungary	15.7	1.5	0.16	139.46	111.08	82.70
Poland	5.8	6.2	0.16	450.68	346.87	243.09
Slovakia	11.0	1.0	0.17	123.15	92.80	62.46
Slovenia	0.0	0.6	0.28	524.54	421.49	318.46
Australia	742.9	9.4	0.45	6.46	5.27	4.08
Japan	48.4	49.5	0.39	434.38	385.81	337.24
New Zealand	21.6	1.2	0.28	67.91	57.60	47.28
South Korea	29.8	8.3	0.17	289.37	236.25	183.13
Israel[4]	24.5	2.0	0.28	113.18	97.55	81.91

Previously we reported in Table A22, looking at Denmark for example, that the CV return would have been about USD 15 per dollar invested if the cost reduction passed fully through from current prices to prices in the long run, that is if $\phi=1$ in (27). Now Table A23 shows that if $\phi=0$ so that there is no effect on long-run prices, then the CV return for Denmark would have been USD 10, or two thirds of the return previously predicted. Looking at the final three columns of Table A23, this finding is uniform. From this point we will again take the conservative option and look at the CV

4 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

returns for the parameter setting $\phi = 0$. By doing so, we are allowing for the possibility that the failure of official statistics to record a quality-adjusted price is only temporary. However, as Table A23 attests, while the returns are lower under this assumption, they are still substantial.

It could be argued that the experimental scenario is too constrained, involving a very small change in public sector expenditure on innovative IT solutions, for which the marginal return might be high, but that over a more substantial change in expenditures the average effect could be much lower. The experimental results reported in Tables A22 and A23 were based on a scenario in which the innovation involved expenditures of an average of USD 0.38 per person across all countries. This varied across countries, as the experiment was based on a uniform change in expenditure relative to GDP. The expenditure change scenario in *per capita* terms is given in the column headed $\Delta AVGIT / POPN$. It ranges from a low of ISD 0.08 in Mexico and Turkey up to USD 0.96 in Norway. However, the extremes are to some extent an artifact of the data presentation, which is in US dollars at current exchange rates, although they also reflect differences in the relative wealth of the countries. As an average, the figure of USD 0.38 per person is a reasonable indicator of the small but realistic size of the experiment. However, in order to investigate a possible bias upwards in results because of the size of the experiments, Table A24 presents the results for the most conservative case above, the CV return under parameter setting $\phi = 0$, and compares this with two alternatively size experiments, an experiment with an ICT innovation shock ten times as large and another experiment with a shock one hundred times as large.

Table A24: 2008 CV returns for parameter setting $\phi = 0$ and alternative-sized shocks

	$\Delta AVGIT\%GDP = 0.001$		$\Delta AVGIT\%GDP = 0.01$		$\Delta AVGIT\%GDP = 0.1$	
country	$\frac{\Delta AVGIT}{POPN}$	CV return	$\frac{\Delta AVGIT}{POPN}$	CV return	$\frac{\Delta AVGIT}{POPN}$	CV return
	(USD)	(USD)	(USD)	(USD)	(USD)	(USD)
Canada	0.45	28.30	4.54	22.70	45.41	7.14
Mexico	0.08	315.85	0.84	182.54	8.41	34.25
United States	0.48	-0.53	4.77	-0.55	47.67	-0.65
Chile	0.11	325.12	1.06	180.51	10.56	32.40
Austria	0.51	349.96	5.12	192.06	51.16	34.11
Belgium	0.49	18.95	4.85	15.65	48.47	5.28
Denmark	0.60	10.42	5.96	8.93	59.62	3.32
Finland	0.51	18.77	5.10	15.43	50.95	5.10
France	0.42	98.15	4.15	68.06	41.53	16.11
Germany	0.45	23.90	4.49	19.40	44.88	6.27
Greece	0.35	70.21	3.51	50.16	35.07	12.41
Ireland	0.63	32.15	6.33	25.15	63.26	7.41
Italy	0.40	55.98	4.02	41.97	40.16	11.42
Netherlands	0.52	64.45	5.18	47.18	51.81	12.24
Norway	0.96	11.77	9.56	9.99	95.63	3.59
Portugal	0.23	292.83	2.26	169.30	22.60	31.73
Spain	0.41	75.22	4.14	53.09	41.35	12.86
Sweden	0.52	16.11	5.22	13.43	52.20	4.62
Switzerland	0.63	333.06	6.27	185.84	62.66	33.56
Turkey	0.08	101.14	0.82	68.74	8.19	15.71
United Kingdom	0.42	-0.67	4.19	-0.67	41.91	-0.74
Czech Rep.	0.21	90.05	2.11	61.21	21.12	13.93
Hungary	0.16	82.70	1.55	57.76	15.52	13.77
Poland	0.16	243.09	1.61	138.33	16.11	25.33
Slovakia	0.17	62.46	1.75	44.38	17.45	10.79
Slovenia	0.28	318.46	2.75	174.83	27.46	30.99
Australia	0.45	4.08	4.49	3.62	44.90	1.42
Japan	0.39	337.24	3.89	192.08	38.93	35.49
New Zealand	0.28	47.28	2.76	36.07	27.59	10.16
South Korea	0.17	183.13	1.71	112.93	17.13	22.68
Israel[5]	0.28	81.91	2.81	58.78	28.08	14.78

Table A24 shows that the average return does in fact fall off for larger shocks. However, it falls off initially at a fairly modest rate. For example the results from three alternatively sized shocks are summarised in Table A24. For comparison, the shock size previously examined, averaging (across the

5 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

economies) an expenditure of about USD 0.38 *per capita*, is recorded again in the first two columns of figures in Table A24. Then follow, in the middle two columns, results for a shock ten times larger. There is a fall off in average returns, but it is not substantial. Of course, the fall off does become substantial for very large shocks. However, even if one looks at what might be, for political reasons, shocks that are far too large to be countenanced, such as those reported in the two far right columns of Table A24 that correspond to a shock one hundred times larger than that summarised in the left two columns of figures, the returns are still impressive.

It is difficult, in the face of these results, to conceive of a reasonably sized innovation that produces small returns except of course for the cases of the United States and the United Kingdom which are different for reasons previously discussed. The results remain remarkable both for their size and their robustness to alternative assumptions.

Conclusion

In response to the Internet economy measurement problem, this approach has been to utilise an economic model that looks at the end result – observations on changes in the pattern of consumer spending behaviour – and econometrically estimates the extent of the link between these behavioural changes and some of their drivers: traditional economic stimuli as well as changes in the economic environment due to advances in technology and improved provision of public sector IT infrastructure. Counterfactual simulations with the estimated model provide money-metric measures of the welfare benefits of innovations in Internet-based public sector IT infrastructure in a variety of OECD economies.

The model and the experiment undertaken have necessarily been limited by the availability of data. The results on the implied impact of the Internet can reasonably be described as startling. However, in view of model and data limitations some caveats are in order. The CHI-MAIDS model seeks to measure an effective (quality adjusted) cost reduction effect due to advances in Internet-based technology, with special reference to the provision of public sector IT infrastructure. An important caveat concerns the need to control for other influences on quality adjusted cost reduction. In the model, these effects are partially allowed for by the inclusion of year dummy variables that allow for worldwide technology improvements over time. These effects are statistically significant. A useful next research step would be to attempt to replace these crude dummy variables with explicit data on competing explanations for the cost reduction effect. Indeed, this research process probably should continue until the crude dummy variables are no longer statistically significant. This could then be accepted as some evidence towards the proposition that other effects have been adequately controlled for.

Although the model developed and used in this research is highly aggregative and cannot trace out the precise process of transmission of IT productivity enhancements, it nevertheless corroborates the hypothesis of a positive end result for the macro-economy, implicit in the views of Huttner (2007), quoted in the Introduction. In the same opinion piece, she also documented what she suggested is the more complex, and possibly hidden, intermediate demand for the Internet: 'What is perhaps less apparent is that Internet-based applications underlie major advances in science, business organisation, environmental monitoring, transport management, education and e-government.' These are the outcomes of IT developments that are implemented at the micro level. Not all such R&D comes to fruition, but the promise of just some of the possible breakthroughs remains nothing short of amazing. Some might argue that the ICT revolution is spent, and that while extremely high returns may be possible at the introduction of any new general purpose technology, these types of returns are unlikely to be available for further advances in the same technology in the future. Against this, in 2008, the final year of the data period examined in this research, substantial innovations seemed to be just around the corner. Sydney Morning Herald Science Editor Deborah Smith reported at the time the invention, by a team of Australian, Dutch and Chinese researchers, of a device with the potential to speed up the Internet 100 times. ‘The device, a photonic integrated circuit, could overcome the gridlock that occurs when information travelling along optical fibres at the speed of light has to be processed by slow, old-fashioned electronic components’ (SMH, July 10 2008, p. 3). If just a small part of some potential IT innovations is achieved, further IT induced productivity surges are highly likely.

In the spirit of the desirability of evidence-based policy, this approach has sought to measure the impact of micro-level IT productivity advances in terms of an improvement in the standard of living at the macro level. The study has examined the hypothesis that innovative IT solutions are welfare enhancing through econometric estimation and subsequent counterfactual simulation of a model that links announcements of specific Internet-based public sector IT contracts to changes in a measure of the standard of living. The results are intriguing and invite further research, verification and extension.

REFERENCES

Andersen, T., J. Bentzen, C.-J. Dalgaard and P. Selaya (2011), “Does the Internet Reduce Corruption? Evidence from U.S. States and across Countries”, World Bank Economic Review, 25 (3).

Arvanitis, S. and E. N. Loukis (2009), Information and communication technologies, human capital, workplace organization and labour productivity: A comparative study based on rm-level data for Greece and Switzerland. *Information Economics and Policy* 21 (1), 4361.

Atkinson, R., D. Correa, and J. Hedlund (2008), "Explaining International Broadband Leadership," Information Technology & Innovation Foundation (ITIF), Washington, DC, 1 May 2008, available at: *http://archive.itif.org/index.php?id=142*

Atrostic, B. K., P. Boegh-Nielsen, K. Motohashi, and S. Nguyen (2002), IT, Productivity and Growth in Enterprises: Evidence from new international micro data. Manuscript prepared for OECD Workshop on ICT and Business Performance.

Baily, M. N. (2002), The New Economy: Post Mortem or Second Wind? Distinguished Lecture on Economics in Government. *Journal of Economic Perspectives* 16 (2), 322.

Baily, M. N. and R. Z. Lawrence (2001), Do We Have a New E-Conomy? American Economic Review 91 (2), 308312.

Bapna, R., W. Jank, and G. Shmeuli. (2008), “Consumer Surplus in Online Auctions.” Information Systems Research 19(4), pp. 400 – 416.

Bargh, J. A., K. McKenna, and G. M. Fitzsimons, (2002), “Can you see the real me? Activation and expression of the “true self” on the Internet”, *Journal of Social Issues*, 58 (1).

Bargh, J. and K. McKenna (2004), “The Internet and Social Life”, *Annual Review of Psychology*, Vol. 55, No. 1, pp. 573-590.

Barro, R.J., (1991) “Economic Growth in a Cross Section of Countries.” *Quarterly Journal of Economics*, 106 (2):

Barro, R. J. (1999), Notes on Growth Accounting. *Journal of Economic Growth* 4 (2), 119137.

Basu, S. and J. G. Fernald (2007), Information and Communications Technology as a General-Purpose Technology: Evidence from US Industry Data. *German Economic Review* 8 (2), 146173.

Basu, S., J. G. Fernald, N. Oulton, and S. Srinivasan (2003), The Case of the Missing Productivity Growth, or Does Information Technology Explain Why Productivity Accelerated in the United States but Not in the United Kingdom? NBER Macroeconomics Annual 18.

Bauer, S., D. Clark, and W. Lehr (2010), Understanding Broadband Speed Measurements, MITAS Working Paper, June 2010, available at: *http://mitas.csail.mit.edu/papers/Bauer_Clark_Lehr_Broadband_Speed_Measurements.pdf*

Baye, M., J. Morgan and P. Scholten. (2006), "Information, Search, and Price Dispersion." In Handbook of Economics and Information Systems (T. Hendershott, ed.), Elsevier Press: Amsterdam.

BCG (Boston Consulting Group) (2010), The Connected Kingdom, How The Internet Is Transforming the UK Economy, BCG, Boston, USA, www.connectedkingdom.co.uk/downloads/bcg-the connected-kingdom-oct-10.pdf (accessed 29 March 2012).

BCG (Boston Consulting Group) (2011), Turning Local: From Madrid to Moscow, the Internet is Going Native, BCG, Boston, USA, *www.bcg.de/documents/file84709.pdf* (accessed 29 March 2012).

BEA (US Bureau of eConomic Analysis) (2009), *Industry Economic Accounts*, US Dep. Of commerce, Washington DC.

Bertschek, I., D. Cerquera, and G. Klein (2011), More Bits - More Bucks? Measuring the Impact of Broadband Internet on Firm Performance. SSRN eLibrary No 1852365.

Bosworth, B. P. and J. E. Triplett (2003), Services Productivity in the United States: Griliches' Services Volume Revisited. Manuscript prepared for: CRIW Conference in Memory of Zvi Griliches .

Bosworth, B. P. and J. E. Triplett (2007), The Early 21st Century U.S. Productivity Expansion is Still in Services. International Productivity Monitor 14, 319.

Bresnahan, T. F. and M. Trajtenberg (1995), General purpose technologies 'Engines of growth'? Journal of Econometrics 65 (1), 83106.

Bresnahan, T. F., S. Stern, and M. Trajtenberg (1997), Market segmentation and the sources of rents from innovation: personal computers in the late 1980s. RAND Journal of Economics 28 (0), 1744.

Brynjolfsson, E. and A. Saunders (2010). Wired for Innovation: How Information Technology Is Reshaping the Economy. Cambridge, MA: MIT Press.

Brynjolfsson, E. and L. M. Hitt (1995). Information Technology as a Factor of Production: The Role of Dierences Among Firms. Economics of Innovation and New Technology 3 (3), 183200.

Brynjolfsson, E. and L. M. Hitt (1998), "Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending," Management Science.

Brynjolfsson, E. and L. M. Hitt (2000), Beyond Computation: Information Technology, Organizational Transformation and Business Performance. *Journal of Economic Perspectives* 14 (4), 2348.

Brynjolfsson, E. and S. Yang (1996), Information Technology and Productivity: A Review of the Literature. Working Paper, MIT Sloan School of Management.

Brynjolfsson, E., M. D. Smith, and Y. Hu (2003),"Consumer Surplus in the Digital Economy: Estimating the Value of Increased Product Variety at Online Booksellers" *Management Science*, Vol. 49, No. 11, November.

Cappelli, P. (2010). The Performance Effects of IT-Enabled Knowledge Management Practices. National Bureau of Economic Research Working Paper Series No. 16248.

Carlaw, K. I., R. G. Lipsey, and R. Webb (2007), "The past, present and future of the GPT-driven modern ICT revolution." Report commissioned by Industry Canada.

Chinn, M. and R. Fairlie (2007), “The Determinants of the Global Digital Divide: A Cross-country Analysis of Computer and Internet Penetration”, Oxford Economic Papers, Vol. 59, No. 1, pp. 16-44.

Colecchia, A. and P. Schreyer (2002a), “The Contribution of Information and Communications Technologies to Economic Growth in Nine Countries”, OECD Economic Studies No. 34, pp. 153-171, OECD, Paris.

Colecchia, A. and P. Schreyer (2002b), ICT Investment and Economic Growth in the 1990s: Is the United States a Unique Case? A Comparative Study of Nine OECD Countries. *Review of Economic Dynamics* 5, 408442.

Cooper, R. (2012), Measuring the Impact of Innovations in Public IT Infrastructure on the Standard of Living in OECD Economies, OECD Digital Economy Working Paper, OECD, Paris.

Cooper, R. and K. McLaren (1992), ‘An empirically oriented demand system with improved regularity properties’, *Canadian Journal of Economics* 25: 652-67.

Cooper, R. and K. McLaren (1996), ‘A system of demand equations satisfying effectively global regularity conditions’, Review of Economics and Statistics 78: 359-64.

Crafts, N. (2002), The Solow Productivity Paradox in Historical Perspective. SSRN eLibrary No 298444.

Crandall, R., W. Lehr and R. Litan (2007), The Economic Impact of Broadband on Growth: A Simultaneous Approach, Issues in Economic Policy No. 6., The Brookings Institution, Washington, DC.

Czernich, N., O. Falck, T. Kretschmer and L. Woessmann, (2009), “Broadband Infrastructure and Economic Growth”, *Economic Journal, Royal Economic Society*, Vol. 121, No. 552, pp. 505-532.

David, P. A. (1990), The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox. *American Economic Review* 80 (2), 355361.

David, P. A. and G. Wright (1999), General Purpose Technologies and Surges in Productivity: Historical Reections on the Future of the ICT Revolution. Manuscript prepared for the International Symposium on Economic Challlenges of the 21st Century in Historical Perspective.

Deaton, A. and J. Muellbauer (1980), ‘An Almost Ideal Demand System’, *American Economic Review* 70: 312-326.

Dedrick, J., V. Gurbaxani, and K. L. Kraemer (2003), Information Technology and Economic Performance: A Critical Review of the Empirical Evidence. ACM Computing Surveys 35 (1), 128.

Deloitte (2011), The Connected Continent, How the Internet is Transforming the Australian Economy, Deloitte Access Economics, Sydney.

Diewert (1971), 'An Application of the Shephard Duality Theorem: A Generalized Leontief Production Function', *Journal of Political Economy*, 79: 481-507.

Draca, M., R. Sadun, and J. M. van Reenen (2006), Productivity and ICT: A Review of the Evidence. CEP Discussion Paper No 749 .

Dutz, M., J. Orszag and R. Willig (2009), "The Substantial Consumer Benefits of Broadband Connectivity for US Households." Mimeo.

Eisenach, J. A. and T. M. Lenard (1998a), Antitrust in Software Markets published in Competition, innovation, and the Microsoft monopoly: antitrust in the digital Marketplace, Kluwer Academic Publishers.

Eisenach, J.A. and T.M. Lenard (1998b), Competition, Innovation, and the Role of Antitrust in the Digital Marketplace, Kluwer Academic Publishers, Boston, United States.

EIU (2010), "Digital economy rankings 2010: Beyond e-readiness," Economist Intelligence Unit (EIU), London, 2010, available at: http://graphics.eiu.com/upload/EIU_Digital_economy_rankings_2010_FINAL_WEB.pdf

Ellison, N. B., C. Steinfield, and C. Lampe, (2007), "The benefits of Facebook "friends:" Social capital and college students' use of online social network sites. *Journal of Computer-Mediated Communication*, 12(4), article 1. *http://jcmc.indiana.edu/vol12/issue4/ellison.html*, last accessed on 4 June 2012.

Forman, C. and N. van Zeebroeck (2010), From wires to partners: How the Internet has fostered R&D collaborations within firms. SSRN eLibrary No 1725780.

Franklin, M., P. Stam, and T. Clayton (2009), "ICT Impact Assessment by Linking Data," *Economic and Labour Market Review*, 3(10), 18-27

Gibson, R.K. and I. McAllister (2009), Revitalising Participatory Politics? The Internet, Social Capital and Political Action, APSA 2009 Toronto Meeting Paper, *http://ssrn.com/abstract=1451462* (accessed 29 March 2012).

Gilchrist, S., V. Gurbaxani, and R. Town (2001), Productivity and the PC Revolution. Working paper University of California, Irvine .

Gordon, R. J. (2000), Does the New Economy Measure up to the Great Inventions of the Past? *Journal of Economic Perspectives* 14 (4), 4974.

Gordon, R. J. (2003), Exploding Productivity Growth: Context, Causes, and Implications. Brookings Papers on Economic Activity 2003 (2), 207279.

Gordon, R. J. (2010), Revisiting U. S. Productivity Growth over the Past Century with a View of the Future. National Bureau of Economic Research Working Paper Series No. 15834.

Greenan, N. and J. Mairesse (2000), Computers and Productivity in France: Some Evidence. Economics of Innovation and New Technology 9 (3), 275315.

Greenstein, S. and R. McDevitt (2011), “The Broadband Bonus: Estimating Broadband Internet’s Economic Value,” *Telecommunications Policy*, Vol. 35, No. 7, pp. 617-632.

Greenstein, S. and R. McDevitt (2012), “Measuring the Broadband Bonus in Thirty OECD Countries”, OECD Digital Economy Papers, No. 197, OECD Publishing, available at: *http://dx.doi.org/10.1787/5k9bcwkg3hwf-en* , last accessed on 4 June 2012.

Grimes, A. and C. Ren (2009), “The Need for Speed: Impacts of Internet Connectivity on Firm Productivity”. SSRN eLibrary No 1604247.

Guerrieri, P. and P.-C. Padoan, eds. (2007), “Modelling ICT as a General Purpose Technology: Evaluation Models and Tools for Assessment of Innovation and Sustainable Development at the EU level.” Report prepared for the European Commission, Collegium 35, College of Europe, Bruges, Belgium.

Hamilton Consultants (2009), Economic Value of the Advertising-Supported Internet Ecosystem, Internet Advertising Board report, Hamilton Consultants, Shrewsbury, United Kingdom, *www.iab.net/media/file/flyin09-deighton.pdf* (accessed 29 March 2012).

Hausmann, R., C. Hidalgo, S. Bustos, M. Coscia, S. Chung, J. Jimenez, A. Simoes, and M. Yildirim (2011), The Atlas of Economic Complexity: Mapping Paths To Prosperity, MIT, September 2011, available at: *http://atlas.media.mit.edu/*

Holt, L. and M. Jamison (2009), Broadband and contributions to economic growth: Lessons from the US experience. Telecommunications Policy 33 (10-11), 575581.

Hormby, T. (2010), “The Story Behind Apple’s Newton”, Gizmodo, 19 January 2010, *http://gizmodo.com/5452193/the-story-behind-apples-newton*

Huttner, S. (2007), “The Internet Economy: Towards a Better Future”, *OECD Observer*, November, *www.oecdobserver.org/news/fullstory.php/aid/2330/* (accessed 29 March 2012).

Inklaar, R., M. P. Timmer, and B. van Ark (2008), Market services productivity across Europe and the US. Economic Policy 23 (53), 139194.

ITU (2011), Measuring the Information Society: the ICT Development Index (IDI), International Telecommunications Union (ITU), Geneva, 2009 (available at: *www.itu.int/ITU-D/ict/publications/idi/2011/Material/MIS_2011_without_annex_5.pdf*).

Jorgenson, D.W. (2001), "Information Technology and the U.S. Economy," *American Economic Review*, Vol. 91, Number 1 (March) 1-33.

Jorgenson, D. W. (2005), Accounting for Growth in the Information Age. In P. Aghion and S. N. Durlauf (Eds.), Handbook of Economic Growth, Vol 1A, pp. 743815. Amsterdam: Elsevier B. V.

Jorgenson, D. W. (2007), Industry Origins of the American Productivity Resurgence. Economic Systems Research 19 (3), 229252.

Jorgenson, D. W., M. S. Ho, and K. J. Stiroh (2008), A Retrospective Look at the U.S. Productivity Growth Resurgence. *Journal of Economic Perspectives* 22 (1), 324.

Jovanovic, B. and P. L. Rousseau (2005), General Purpose Technologies. In P. Aghion and Durlauf Steven N. (Eds.), Handbook of Economic Growth, Vol. 1B, pp. 11811224. Amsterdam: Elsevier B. V.

Katz, M.L., and Shapiro, C. (1986), "Technology Adoption in the Presence of Network Externalities", *Journal of Political Economy*, Vol. 94.

Kiiski, S. and M. Pohjola, (2002), "Cross-Country Diffusion of the Internet", Information Economics and Policy, Vol. 14, No. 2, pp. 297-310.

Koutroumpis, P. (2009), "The Economic Impact of Broadband on Growth: A Simultaneous Approach" Telecommunications Policy, Vol. 33, No. 9, pp. 471-485.

Krueger, A. and M. Lindahl (2000), Education for Growth: Why and For Whom?, NBER Working Paper No. 7591, National Bureau of Economic Research, Cambridge, USA.

Leff, N. H. (1984), Externalities, Information Costs, and Social Benefit-Cost Analysis for Economic Development: An Example from Telecommunications. Economic Development and Cultural Change 32 (2), 255276.

Lehr, W. (2012), Measuring the Internet: The Data Challenge, OECD Digital Economy Papers, No. 194, OECD, Paris, *http://10.1787/5k9bhk5fzvzx-en*

Lehr, W. and F. Lichtenberg (1999), "Information Technology and Its Impact on Productivity: Firm-level Evidence from Government and Private Data Sources, 1977-1993," *Canadian Journal of Economics*, vol 32, no 2 (April 1999) 335-362

Lehr, W., S. Bauer, M. Heikkinen, and D. Clark (2011),"Assessing broadband reliability: Measurement and policy challenges," 39th Research Conference on Communications, Information and Internet Policy (www.tprcweb.com), Alexandria, VA, September 2011

Lenhart, A., Simon, M., and Graziano, M. (2001), "The Internet and education: Findings of the Pew Internet and American Life Project," Pew Research Center, Volume: 20036(202).

Levy, S. (2009), "Secret of Googlenomics: Data-Fueled Recipe Brews Profitability." WIRED Magazine: 17.06. Retrieved from *www.wired.com/culture/culturereviews/magazine/17-06/nep_googlenomics* on 25 August, 2012.

Lichtenberg, F. R. (1995), The Output Contributions of Computer Equipment and Personnel: A Firm-Level Analysis. Economics of Innovation and New Technology 3 (3), 201218.

Majumdar, S.K., O. Carare, and H. Chang (2009), "Broadband Adoption and Firm Productivity: Evaluating the Benefits of General Purpose Technology", Industrial and Corporate Change, Vol. 19, No. 3, pp. 641-674.

McAfee, A. and E. Brynjolfsson, (2007), "Dog Eat Dog: Industries that Buy a lot of Technology are Becoming a Cutthroat at those that Produce Technology", *Wall Street Journal*, 28 April 2007.

McKinsey (2011), Internet Matters: The Net's Sweeping Impact on Growth, Jobs and Prosperity, McKinsey Global Institute, www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/Internet_matters (accessed 29 March 2012).

Melville, N., K. L. Kraemer, and V. Gurbaxani (2004), Review: Information Technology and Organizational Performance: An Integrative Model of IT Business Value. *MIS Quarterly* 28 (2), 283322.

Morton, F.S. (2006), "Consumer Benefit from Use of the Internet", A.B. Jaffe, J. Lerner and S. Stern (eds.), Innovation Policy and the Economy, Vol. 6, National Bureau of Economic Research (NBER), Cambridge, United States.

Nelson, P. (1974), "Advertising as Information." *Journal of Political Economy* 82(4), pp. 729 – 754.

Nielsen NetView (2010), What Americans Do Online: Social Media And Games Dominate Activity, summary available at: http://blog.nielsen.com/nielsenwire/online_mobile/what-americans-do-online-social-media-and-games-dominate-activity/

Norton, S. W. (1992), Transaction Costs, Telecommunications, and the Microeconomics of Macroeconomic Growth. Economic Development and Cultural Change 41 (1), 175196.

OECD (2006), *Understanding National Accounts*, OECD Publishing. doi: 10.1787/9789264027657-en

OECD (2008a), The Seoul Declaration for the Future of the Internet Economy, Ministerial session, 18 June 2008, Available at: http://www.oecd.org/internet/consumerpolicy/40839436.pdf (accessed 29 March 2012).

OECD (2008b), "ICT Use and Educational Scores: Preliminary Results from PISA", internal working document, OECD, Paris.

OECD (2010a), *OECD Information Technology Outlook 2010*, OECD Publishing. doi: 10.1787/it_outlook-2010-en

OECD (2010b), "Greener and Smarter: ICTs, the Environment and Climate Change", *OECD Green Growth Papers*, No. 2010/01, OECD Publishing. doi: 10.1787/5k9h3635kdbt-en

OECD (2011a), *OECD Guide to Measuring the Information Society 2011*, OECD Publishing. doi: 10.1787/9789264113541-en

OECD (2011b), *OECD Communications Outlook 2011*, OECD Publishing. doi: 10.1787/comms_outlook-2011-en

OECD (2012a), "Big data and Statistics: Understanding the Proliferation of Data and Implications for Official Statistics and Statistical Agencies", internal working document, OECD, Paris.

OECD (2012b), *OECD Internet Economy Outlook 2012*, OECD Publishing. doi: 10.1787/9789264086463-en

OECD (2012c), "ICT Applications for the Smart Grid: Opportunities and Policy Implications", *OECD Digital Economy Papers*, No. 190, OECD Publishing. doi: 10.1787/5k9h2q8v9bln-en

Oliner, S. D. and D. E. Sichel (2000), The Resurgence of Growth in the Late 1990s: Is Information Technology the Story? *Journal of Economic Perspectives* 14 (4), 322.

O'Mahony, M. and M. Vecchi (2005), Quantifying the Impact of ICT Capital on Output Growth: A Heterogeneous Dynamic Panel Approach. Economica 72 (288), 615633.

Ou, G. (2009), "Understanding Deep Packet Inspection (DPI) Technology," a White Paper from Digital Society, October 2009, available at: *www.digitalsociety.org/files/gou/DPI-Final-10-23-09.pdf*

Oz, E. (2005), Information technology productivity: in search of a definite observation. Information & Management 42 (6), 789798.

Pant, H. and B. Fisher (2007), 'Alternative Measures of Output in Global Economic-environmental Models: Purchasing Power Parity or Market Exchange Rates? - Comment', Energy Economics, 29:375-389.

Pilat, D. (2004), The ICT Productivity Paradoix, Insights from Micro Data, OECD Economic Studies No. 38,

Polder, M., G. van Leeuwen, P. Mohnen and W. Raymon (2009), Productivity Effects of Innovation Modes, Discussion Paper, Statistics Netherland, The Hague.

Qiang, C.,Z. and C. M. Rossotto with K. Kimura (2009), "Economic Impacts of Broadband" published in "Extending Reach and Increasing Impact," 2009 Information and Telecommunications for Development, World Bank.

Savage, S. J. and D.M. Waldman, (2004), "United States Demand for Internet Access." Review of Network Economics 3(3): Pp. 228-247

Savage, S. J. and D. M. Waldman (2009), Ability, location and household demand for Internet bandwidth. International Journal of Industrial Organization 27 (2), 166174.

Scholten, P. (2012), Measuring the Internet Economy: Economic arguments and Evidence for Consumer Surplus, OECD Digital Economy Working Paper, forthcoming.

Scholten, P. A., Livingston, J. A., Chen, S. (2009), Do Countercyclical-Weekend Effects Persist in Online Retail Markets? Electronic Commerce Research and Applications, 8 (4).

Schreyer, P. and D. Pilat (2001), Measuring Productivity. OECD Economic Studies 33 (2), 127170.

Sen, S., J. Yoon, J. Hare, J. Ormont, and S. Banerjee (2011), "Can you hear me now?: a case for client-assisted approach to monitoring wide-area wireless networks," Internet Measurement

Conference (IMC'11), Berlin Germany, November 2-3, 2011 (available at: http://pages.cs.wisc.edu/~suman/pubs/wiscape.pdf

Shah, D.V., N. Kwak and R.L. Holbert (2001), "'Connecting' and 'Disconnecting' with Civic Life: Patterns of Internet Use and the Production of Social Capital, Political Communication, Vol. 18, No. 2, pp. 141-162.

Spiezia, V. (2010), "Does Computer Use Increase Educational Achievements? Student-level Evidence from PISA", OECD Journal: Economic Studies, vol. 2010, No. 1, www.oecd.org/dataoecd/5/0/49849896.pdf (accessed 29 March 2012).

Stiroh, K. and M. Botsch (2007), "Information Technology and Productivity Growth in the 2000s," German Economic Review, Verein für Socialpolitik, vol. 8, pages 255-280, 05

Stiroh, K. J. (1998), Computers, Productivity, and Input Substitution. Economic Inquiry 36 (2), 175191.

Stiroh, K. J. (2002a), Are ICT Spillovers Driving the New Economy? Review of Income and Wealth 48 (1), 3357.

Stiroh, K. J. (2002b), Information Technology and the U.S. Productivity Revival: What Do the Industry Data Say? American Economic Review 92 (5), 15591576.

Stiroh, K. J. (2005), Reassessing the Impact of IT in the Production Function: A Meta-Analysis and Sensitivity Tests. Annales D'Économie et de Statistique 79/80, 529561.

Tesfatsion, L., and K. Judd (2006), Handbook of computational economics: Agent-based computational economics, North Holland: New York.

Triplett, J. E. and B. P. Bosworth (2006), Baumol's Disease"' Has Been Cured: IT and Multifactor Productivity in U.S. Services Industries. In D. W. Jansen (Ed.), The New Economy and Beyond: Past, Present, and Future, pp. 3471. Cheltenham, United Kingdom: Edward Elgar.

UNCTAD (United Nations Conference on Trade and Development) (2006), Information Economy Report 2006: The Development Perspective, UNCTAD, Geneva, www.unctad.org/en/docs/sdteecb20061ch4_en.pdf (accessed 29 March 2012).

van Ark, B. and R. Inklaar (2005), Catching Up or Getting Stuck? Europe's Troubles to Exploit ICT's Productivity Potential. Research Memorandum Groningen Growth and Development Centre 79.

Varian H., R. E. Litan, A. Elder, J. Shutte (2002), "The Net Impact Study, The Projected Economic Benefits of the Internet In the United States, United Kingdom, France and Germany," available at: www.itu.int/wsis/stocktaking/docs/activities/1288617396/NetImpact_Study_Report_Brookings.pdf, last accessed on 4 June 2012.

Varian, H. (2009), "Online Ad Auctions." *The American Economic Review*, 99(2).

Venturini, F. (2009), The Long-Run Impact of ICT. Empirical Economics 37 (3), 497515.

Wallsten, S. (2008), "Understanding International Broadband Comparisons," Technology Policy Institute Working Paper, Washington, DC, May 2008, available at: *www.techpolicyinstitute.org/files/wallsten_international_broadband_comparisons.pdf*

Wallsten, S. and J. Riso. (2010), "Residential and Business Broadband Prices, Part 1: An Empirical Analysis of Metering and Other Price Determinants," Technology Policy Institute Working Paper. Available at *www.techpolicyinstitute.org/publications/type/1.html*

Waverman, L. (2011), Connectivity Scorecard 2011, a study prepared for Nokia-Siemens Networks, available at: *www.connectivityscorecard.org*

Wolff, E. N. (2002), Productivity, Computerization, and Skill Change. National Bureau of Economic Research Working Paper Series No. 8743.

WWW Foundation (2011), The World Wide Web Index, World Wide Web Foundation (W3C), available at: *www.webfoundation.org/projects/the-web-index*