Measuring the Digital Economy: State-of-the-Art Developments and Future Prospects

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■ Introduction: The Economic Consequences of Measuring the Digital Economy

The quality of economic data is important for building an economic information infrastructure, especially in a changing environment. For example, the frequent releases of GDP statistics are monitored by policymakers and financial analysts and are interpreted as a barometer of the economy's wealth. Economic statistics play a vital role in public policy decisions:

"as well as in forecasting the economy’s potential for future growth, in conducting monetary policy and managing the tradeoffs between inflation and full employment, in projecting tax revenues and conducting fiscal policy, and finally in building long-term forecasts" (MOULTON 2000).

To reach these goals, economic indicators must be constantly improved and refined to challenge rapidly evolving economies and societies. The major change experienced by developed countries, and the US economy in particular, is a combination of historic long-range growth and a rather massive circulation of Information and Communication Technologies (ICT) throughout the economy and society. The relation between ICT diffusion and productivity growth has been intensely discussed among experts since Solow’s "productivity paradox" (1) was first introduced. There is now widespread evidence that "productivity growth and the massive use of information technology is not a coincidence" (US DOC, 2000). We are

(1) The “productivity paradox” refers to Robert M. Solow's statement in 1987 that “we can see the computer age everywhere but in productivity statistics”.

currently faced with the problem of whether or not this ICT-based economy, or digital economy, constitutes a fundamental and lasting change in the overall structure of the economy. The answer to this question is important because if this change is real and likely to last then it will have major implications for a large set of issues such as:

- understanding the sources of growth and productivity,
- the increase of personal and household wealth,
- the improvement of tax and spending projections,
- funding and allocating state and local development programmes,
- the management of technological policy, regulations, laws and tax rules affecting savings, investment in physical and human capital, R&D, financial markets.

This paper presents the state-of-the-art developments related to this important question and mainly draws on US data and research conducted both at public and private level since it needs to be recognized that this country has made a greater effort to address this concept than Europe. We first look at the measurement of digital economy infrastructure and output and then, we deal with measuring the digital economy as an input at macroeconomic, sectoral and firm level.

■ Measuring Digital Economy Infrastructure and Output: the ICT Sector and Internet-based Electronic Commerce

Defining and measuring the ICT (or digital) sector is important if we want to assess the significance of digital activities as an output in economies. We present the key approaches that have been adopted in the USA, the OECD and Europe in relation to the ICT sector and classification, as well as to the measurement of e-commerce and Internet activities.

Digital activities, the ICT sector and classification

The OECD's measurement of the ICT sector

The OECD commenced its work on measuring the ICT sector at the beginning of the 80s through the ICCP (Information, Computer and Communication Policy) Committee, which created the Working Party on Indicators for the Information Society (WP/IIS) in 1997. The group's task was to develop statistical indicators and also to coordinate work with Eurostat and the Voorburg group [2]. In 1997, the latter group presented its first approach to the definition of the ICT sector. This approach was pragmatic in the sense that the ICT sector was built from existing ISIC rev/3 and NACE rev/1 classifications. The creation of an ICT sector based on three activities emerged from this group:

- computer hardware manufacturing,
- telecommunications hardware and services, software,
- information (content) activities (press, editing, television, etc.).

The OECD's ICCP committee now considers this approach as being the first step to building more universal indicators for the information society, including electronic commercial relations.

In 2000, the OECD presented an important international study on the ICT sector in OECD countries. The principles underlying the definition of the ICT sector for the OECD (2000a) are the following.

For manufacturing industries, products must be intended to fulfill the function of information processing and communication including transmission and display, they must use electronic process to detect, measure and/or record physical phenomena or to control a physical process (OECD, 2000a, p. 7).

For services: services must be intended to enable the function of information processing and communication by electronic means (OECD, 2000a, p. 7).

The OECD's definition of the ICT sector is based on the industrial classes in revision 3 of the International Standard Industrial Classification (ISIC) and includes both manufacturing and service activities (see appendix 1).

One of the most significant things about this OECD report is that it gives an indication of how important the ICT sector is to OECD members and therefore develops an original measurement of ICT intensity. ICT intensity is created by comparing the size of the ICT sector with the size of the business enterprise sector in regard to four economic indicators: employment, added value, R&D and total trade.

[2] The Voorburg group is an informal group of international statisticians in charge of examining the question of measuring services statistics.

This approach gives four measures of ICT intensity (see appendix 2 for the main results), which are broken down into three groups containing approximately the same number of countries: high, medium and low classes. The four indicators are brought together to form groups by giving equal weight to each set of indicators.

Table 1: ICT intensity in major OECD countries

High ICT intensity	Medium ICT intensity	Low ICT intensity
Finland	Austria	Belgium
Ireland	Denmark	Germany
Korea	France	Portugal
Sweden	Greece	Spain
United Kingdom	Italy	
United States	Japan	
	Netherlands	

Source: OECD, 2000a

The measurement of the ICT sector in this important OECD document refers to standard manufacturing equipment including TV and industrial process control and most of the standard service activities directly linked to hardware (e.g. rental). The document does not examine the broader definition of "information activities" as defined in the proposed "information sector" of the NAICS.

The US ICT sector and the new information sector in the NAICS

In the USA (DOC, 2000), digital activities appear as Information Technology Industries in the 1987 SIC classification manual published by the Office of Management and Budget (OMB). The activities covered by this industry are hardware, software and services and communications.

The hardware industry includes suppliers that provide (both by wholesale and retail sales) computers and equipment, office machines and other electronic equipment for measurement. This part of ICT does not generally pose any particular problems as far as measuring is concerned.

The software and services industry includes industries that provide pre-packaged software and computer-related services. Measurement of the software industry is only partial in this definition because the software loaded in mainframe computers for business and the government is not covered.

The real output of this industry is underestimated. An effort has recently been made to deal with this problem in the US statistical system. In particular, the latest (1999) revision of the National Income and Production Account (NIPA) accounts for business and government software expenditure as fixed investments (3). Moreover, this change in the accounting of software is consistent with the approach used in most developed countries and especially in Europe. We will see below that this modification has important consequences when it comes to calculating the share of digital activities in GDP.

Communication equipment and service industries include suppliers that provide the material and non-material "infrastructure" enabling connections between computers and servers upon which the development of the Internet and electronic commerce is based. As for computer hardware and software, the material side of this activity is generally better covered by statistics than the non-material one.

Two major difficulties are underlined in most American studies concerning the measurement of the ICT sector.

The first comes from the difficulty to strictly define the borders of an ICT industry because many ICT products and services are incorporated into non-ICT industry. As a consequence, a great deal of governmental and private bodies have their own definition of the ICT industry and sometimes include it in a larger classification of the high-tech industry. This is particularly the case with the Bureau of Economic Analysis (BEA) which adds a portion of the defence industry's high-tech suppliers to computers and equipment. Moreover, as stated in DOC 2000, industry associations like the American Electronic Association (AEA) and the Information Technology Institute (ITI) have their own definition based on the interests of their members (4).

The second problem stems from the relationship between the "material" and "non-material" side of the digital economy and the emergence and measurement of an "information economy". This last measurement constitutes one of the US' principal innovations in its effort to elaborate a new classification system. The current SIC system is going to be replaced by the Census Bureau's North American Industry Classification System (NAICS), and one of the major innovations proposed in this system for 2002

(3) The NIPA considers, along with BEA, that software, like other assets traditionally included in fixed investments, produces a flow of services for more than one year.

(4) Appendix 1 page 21 of (DOC, 2000) provides a useful list of industries selected as IT (or high-tech) by different public and private organizations in the US.

is the creation of a new Information Sector that is focused on industries that provide ICT-based information rather than on industries that provide ICT hardware.

The Information Sector (sector N° 51 of the proposed NAICS for 2002) originates from the question of the emergence of a specific "information economy". The sector is divided into 34 industries (20 are new and 14 come from a revision or a reorganization of the SIC classification) producing and disseminating information as well as cultural products and processing data. The information sector comprises establishments primarily engaged in producing and distributing cultural information, providing the means to transmit or distribute these products as well as data or communications and processing data (NAICS, 1999). It should be noted that many of the industries in the NAICS Information Sector are engaged in either producing, manipulating or distributing products protected by copyright law. The major innovations proposed in the seven "three digit" sub-sectors of the NAICS concerning the digital economy are the following (see appendix 3 for a more detailed presentation of the seven sub-sectors of sector N° 51 of NAICS).

Software publishing is included in the publishing activities sub-sector (511) because this activity is equivalent to the creation of processes for other types of intellectual production. One should note that the reproduction of pre-packaged software is treated in NAICS as a manufacturing activity.

A new sub-sector (516) Internet publishing and broadcasting is created to take account of the difference between traditional and Internet-based publishing and broadcasting.

The revised telecommunication sub-sector (517) is primarily engaged in operating, maintaining, and/or providing access to facilities for transmitting voice, data, sound, and full motion picture video between network termination points. It does not produce information or cultural content.

A new sub-sector (518) accounts for Internet service providers, web search portals and data processing services. This new sub-sector is subdivided into two groups. The ISP and web search portals industry group includes establishments that provide access to the Internet or provide the means to search for information on the web. The data processing, hosting and related service industry group includes establishments that process data for others (mainframe time-share facilities and web hosting establishments).

The creation of this new sector in the US classification system will help this country to elaborate a better measurement of what is generally considered as being one of the most dynamic sectors of developed countries' economies.

It should be noted that the Census Bureau has developed a definition of Electronic Economy with three components: Electronic business, electronic commerce and e-business infrastructure (ATROSTIC, GATES & JARMIN, 2000):

- Electronic business is: Any process that a business organization (including non-profit and government) conducts over computer-mediated network channels.
- Electronic commerce is: Any transaction completed over a computer-mediated network that transfer ownership of, or right to use, goods or services.
- E-business infrastructure: is The economic infrastructure used to support electronic business processes and conduct electronic commerce transactions.

The authors first present a set of questions concerning the size and characteristics of the e-economy and then make a very useful assessment of the information needed and of the measurement challenge.

The European approach: EUROSTAT and SINE

Eurostat's work on the measurement of the digital economy is part of the e-Europe project. A digital economy "task force" was created at the beginning of 2000 and proposals were put forward at the end of the same year. It will propose a definition of e-Europe's key indicators.

A group is working on the question of measurement in the Nordic European countries (Norway, Denmark, Iceland, Sweden, Finland), and a programme has been designed for 2000-2002. In Norway, Denmark and Finland, a study on the use of ICT in business has been conducted and another study on government use of ICT in 2001 is underway.

EPROS (European Plan for Research in Official Statistics) recognizes the need for a review of existing classifications of economic activities (NACE, see appendix 4), products (CPA/CPS), trade (the harmonized system) and occupations (ISCO) for digital and knowledge-based activities. The SINE (Statistical Indicators for the New Economy) work programme 2000 (Eurostat 2000) has put forward a few proposals for taking into account the technological characteristics and knowledge content of entities to be listed in classifications. One major issue would be the inclusion of a comparison between the relative merits of a classification based on product/commodities and a classification based on industry. This would take into account the fact that an increasing volume of ICT-related goods and services is produced outside traditionally defined ICT industries. An underlying classification issue would be based on the concept of "embedded intangibility" due to the existence of an increasingly nebulous boundary between tangible and intangible goods, between goods and services, visible and invisible trade, knowledge-based occupations and others.

The SINE initiative enables us to examine some of the conceptual, statistical and definition-related issues via input-output matrices that trace the ICT production process and its intermediate and final consumption. Similarly, satellite accounts would provide the flexibility needed to examine concepts such as intangibility, added value, productivity etc, without abandoning the exploitation of existing macroeconomic data.

Measuring digital economy output: e-commerce and the Internet economy

Measuring e-commerce

Much attention has been focused on the electronic-commerce (e-commerce) aspect of the digital economy and e-commerce, mainly over the Internet, is obviously a new way of conducting business. The development of e-commerce along with the development of the World Wide Web at the beginning of the 90s is the result of a combination of technological innovations and regulatory reforms.

The measurement of the infrastructure needed for the development of e-commerce is based on data that been harmonized and updated by the OECD's recent work.

Table 2: E-commerce infrastructure and development

	Japan	European Union	United States
Internet hosts per 1,000 inhabitants 1999	19 (*)	30 (**)	160 (*)
Secure web servers per million inhabitants 2000	15 (*)	25 (**)	170 (*)
Installed PC base per 100 inhabitants 1997	20 (**)	21 (**)	50 (**)
Employees using e-commerce-enabling technologies 1999 (%)	60 (**)	49 (***)	65 (**)
Cellular mobile subscribers 1999 (%)	45 (**)	40 (**)	30 (**)

(*) *Source: OECD (2000e)*
(**) *Source: ANDERSON (2000)*
(***) Average of France, Germany, Italy and the United Kingdom

This measurement can be supplemented by available data on the "physical geography of Internet traffic" as a component of more general data on telecommunications traffic. Research on international Internet traffic has been undertaken by various sources and in particular by the ITU (International Telecommunication Union), Tele-geography and the Internet Software Consortium. Relevant traffic indicators include (ABRAMSON, 2000):

- web servers by country,
- internet-connected host computers by domain names,
- country by country Internet user counts by aggregation of national surveys.

The measurement of e-commerce is generally restricted to two important elements: Business-to-Consumer e-commerce (B-to-C) and Business-to-Business e-commerce (B-to-B). It should be noted that electronic relations are much broader than B-to-C and B-to-B since these also include relations between the Government, Business and Consumers (G-to-B and G-to-C) and even direct relations between consumers (e. g. electronic auctions). A broader figure of e-relations is presented later.

E-commerce concerns the trade of "non-digital" and "digital" goods and services. Non-digital products must be physically distributed to consumers by physical networks (e.g. books) and the electronic aspect of this commerce mainly resides in ordering and paying. E-commerce of digital products (e.g. on-line software sales) is able to bypass the wholesale, retail and physical transport network.

Estimations of the value of e-commerce transactions vary widely on account of the different scales and definitions used (OECD, 2000e). Consulting groups provide estimates for e-commerce transactions but it is difficult to make comparisons because their estimates are based on surveys for which we do not have the questions. Meanwhile, figure 3 gives some recent estimates of worldwide e-commerce.

Table 3: Consultant estimates of worldwide e-commerce ($ billion)

	1999	2003	Average annual growth (%)
e-marketer	98.4	1224	89
IDC	111.4	1317	85
Actimedia	95	1324	93
Forrester low (*)	70	1800	125
Forrester high (*)	170	3200	108
Boston Consulting Group	1000	4600	46

(*) includes Internet-based EDI

Sources: e-marketer (2000) and Boston Consulting Group (1999 b) in OECD (2000e)

The bulk of e-commerce is B-to-B since this accounts for 70 to 85% of e-commerce overall, and it is growing much more rapidly than B-to-C. This brisk growth is mainly due to the migration of transactions from the previously expensive and closed EDI (Electronic Data Interchange operated through private networks) to the Internet.

All the measurements show that B-to-C transactions only account for a small portion of total retail sales (appendix 5). The US Census Bureau's 'estimate of retail Internet sales is based on the results of an additional question in its retail survey which measures the sale of goods from B-to-C, be this through brick and mortar outlets or by mail order, phone or the Internet. It does not include sales of services to consumers such as travel services. According to this estimate, only 0.64% of US retail sales are e-commerce sales (LANDEFELD & FRAUMENI, 2000). In Europe, the estimate falls to 0.2% despite the fact that some countries (Sweden, Netherlands and United Kingdom) show similar results to the US (OECD, 2000e). There is obviously something very particular about the use of e-commerce in Scandinavian countries (table 4).

Table 4: Electronic commerce in Scandinavia and Western Europe for 1998

	Internet trading (% of population)	B-to-C turnover Per capita ($)	B-to-B turnover Per capita ($)	Total turnover Per capita
Denmark	1.6	317	864	1181
Finland	2.9	489	778	1267
Sweden	2.9	525	835	1360
Western Europe	1.2	223	454	677

Source: Danish Ministry of Research and Information Technology in FALCH & HELTEN (2000)

Considerable effort is being made to provide a better estimate of e-commerce in the US. E-commerce sales should be covered by the Census Bureau's economic censuses and surveys, but there has been no attempt to systematically divide up sales by sales method. Meanwhile, the Bureau of Economic Analysis, in coordination with the Census Bureau, is pursuing an initiative to better identify e-business. Furthermore, it plans to include the question in its annual retail survey to collect this information so that e-commerce retail sales can be measured. BEA suggests measuring e-business through the use of national, industrial, international and regional accounts. Not only is its goal to "measure the volume of e-business but also to measure how it is distributed across industries and across regions, as well as its effects on other businesses, such as traditional retailers, wholesalers and transportation services. This information will further help to estimate the effects of e-business on overall growth in GDP, productivity and income" (LANDEFELD & FRAUMENI, 2000).

In addition, a great deal of interest is being shown in B-to-B business measurement and the trading of digital goods and services in particular, and there is currently no way of estimating sales delivered to consumers electronically in comparison to traditional methods.

It should be noted that the Census Bureau (ATROSTIC, GATES & JARMIN, 2000) is doing a lot to improve data on electronic business and electronic commerce and has made recommendations regarding short-term and long-term enhancements in this field.

In Europe, the development of e-commerce is generally far less advanced than in the US. A few restrictive regulations and exclusive commercial agreements are considered as having delayed the process in sectors like car distribution or pharmaceutics. In the service area, "some limitations on the activities of regulated professions (lawyers, architects) are considered as obstacles to e-commerce" (EEC, 1999).

Measuring the Internet economy

A major study on the Internet economy has been conducted by the University of Texas (funded by Cisco) (University of Texas, 2000) and is based on data collected from 2,380 US firms. The most original feature of this study is the way that the Internet economy is broken down into four layers.

• *The Internet infrastructure indicator (layer 1).* Consists of telecommunications companies, ISPs, Internet backbone carriers, last mile access companies and manufacturers of end-user networking equipment.

• *The Internet applications infrastructure indicator (layer 2).* Consists of the software products and service companies needed to facilitate web transactions. This level includes the consultants and service companies that design, build and maintain all types of web sites, ranging from portals to full e-commerce sites.

• *Internet intermediary indicator (layer 3).* Companies that operate at this level are predominantly pure Internet players. They generally do not generate revenues directly from transactions, since their web-based business creates revenues through advertising, membership subscription fees and commissions. Many of these layer 3 companies are purely web content providers, while others are market makers or market intermediaries. This is an important group of companies that is likely to have a significant impact on the efficiency and performance of electronic markets. (e.g. Yahoo) in time.

• *The Internet commerce indicator (layer 4).* Companies conducting web-based commerce transactions (e.g. Amazon). Many other studies on e-commerce include layer 3 firms in this group. This layer includes a wide variety of vertical industries, as well as a few small shops generating a revenue stream.

In this study, total sales by the Internet economy were initially estimated at $331 billion in 1998, adjusted to $301 billion (adjustment for sales counted twice between Internet layers). This kind of sales-based estimate is appropriate in many cases but problems arise when comparing GDP or GDP growth (LANDEFELD & FRAUMENI, 2000). The data must be adjusted to reflect intermediate sales to all firms and not just inter-company sales between Internet economy firms. Using input-output tables for 1996, BEA's estimation of the contribution to GDP amounts to $159 billion (1.8 % of GDP rather than the 3.5% implied by CISCO's $301 billion sales figure).

Table 5: University of Texas and Cisco estimates of Internet economy adjusted to GDP concepts (1998)

Layer description	Estimated Internet revenues in $ billion (*)	GDP share (**) (%)	Contribution to GDP in $ billion (***)
Infrastructure	115	0.37%	43.1
Applications	56.3	0.60%	34
Intermediary	58.2	0.18%	10.3
Commerce	101.9	0.70%	71.4
Total	301.4		158.8

(*) University of Texas & Cisco estimate
(**) GDP shares from the 1996 annual input-output accounts. For each layer, commodities were selected from the 1996 input-output accounts and an average share of the total sales of commodities to GDP was calculated by BEA
(***) Internet revenues times GDP share (2) X (3)

Source: University of Texas & Cisco (2000)

The 2001 report from University of Texas and Cisco gives the following data for Internet revenues:

Table 6: Internet revenue indicators (1998-2000)

Layer description	Revenues 1998	Quarter 1 1999	Quarter 2 1999	Quarter 3 1999	Quarter 4 1999	Quarter 1 2000	Quarter 2 2000
Infrastructure	115	37.2	44.8	55.8	59.8	67.6	75.2
Applications	56.3	19.9	22.8	27.4	31.1	33.9	38.9
Intermediary	58.2	17.2	20.7	30.9	27.8	27.2	36.7
Commerce	101.9	36.5	36.2	46.7	51.9	60.3	66.9
Total	**301.4**	**104.1**	**121.6**	**141.6**	**156.4**	**173.6**	**200.2**

Source: University of Texas and CISCO (2001)

■ Measuring Digital Economy Input

Macroeconomic Level: Measuring ICTs' Contribution to Growth and Productivity

Direct and indirect contribution to growth

The direct contribution of the digital economy to growth is estimated by looking at the impact of digital goods and services on real GDP and GDP growth. The first difficulty (see above) lies in the absence of detailed and uniform product categories for high-tech goods. However, it is usually easy to find estimates of the direct contribution of "high-tech products" (computers, software and telecommunications) to real GDP growth. In particular, the OECD (SCHREYER, 2000) gives international data about the contribution of ICT equipment to output growth (table 7) in the major industrialized countries. However, harmonized data does not extend beyond 1996 and does not take into account the late 90s where it played an important role in the American economy.

Table 7: Contribution of IT to output growth (%)

	United States	Canada	Japan	France	Germany (West)	Italy	United Kingdom
1980-85	0.28	0.25	0.11	0.17	0.12	0.13	0.16
1985-90	0.34	0.31	0.17	0.23	0.17	0.18	0.27
1990-96	0.42	0.28	0.19	0.17	0.19	0.21	0.29

Source: SCHREYER, 2000

In the US, and as far as BEA is concerned, the contribution of ICT for 1995-99 averaged 24% or 0.9 percentage point of the 3.8% growth in real GDP (LANDEFELD & FRAUMENI, 2000). It should be noted that this data includes audio, video products and cable TV.

Table 8: Contribution of IT to real GDP growth (%)

Percentage change at annual rate	1995	1996	1997	1998	1999	Before 1995-1999
GDP total growth	2.7	3.6	4.2	4.3	4.2	3.8
Contribution from computers and software (*)	0.62	0.76	0.71	0.86	0.80	0.75
Contribution from telecommunications (**)	0.11	0.14	0.08	0.13	0.13	0.12
Total information technologies	0.73	0.90	0.80	0.99	0.92	0.87

(*) Includes audio and video products

(**) Includes cable TV

These approaches are generally focused on the direct contribution of ICT products and services but do not capture the major indirect contribution and impact of the computer and telecommunications software used in designing, ordering and manufacturing on the price (and output) of other (traditional) goods and services.

To cope with the limitations of this "product side" approach, two major sets of studies have focused on the indirect contribution of ICT goods and services to growth (and generally productivity). The first set (CORRADO & SLIFMAN, 1999; GULLICKSON & HARPER, 1999; JORGENSON & STIROH, 1999; DOC, 1999) uses industry and gross output-by industry data to analyze the effects of ICT products and services on technical change and on growth and productivity in industry and service activities. These studies generally find that the industries the most closely related to high-tech have above-average productivity growth. Using Census Bureau sales, BEA and GPO-by-industry data, the Department of Commerce and Industry (DOC, 1999) estimates that high-tech industries accounted for more than one third of real GDP growth in 1995-1998.

The second set of studies estimates both the direct and indirect contributions of computer hardware to GDP growth by using a variety of growth accounting models (GORDON, 1999; MACROECONOMIC ADVISORS, 2000; WHELAN, 2000; OLINER & SICHEL, 2000; JORGENSON & STIROH, 2000). They all find a positive correlation between the use of computer hardware and the trend in growth of real GDP and productivity (table 9).

In all cases (1995-1998 or 1995-1999), the contribution of computer hardware to US GDP growth is at least twice that of the contribution during the earlier period (and roughly equivalent to the contribution of all IT goods and services in the OECD study in table 7). The distinction between direct and indirect effects is not clear in these studies. GORDON (1999) suggests that impact is mainly achieved through the direct effect of high-tech products on GDP rather than through indirect effects. Likewise, JORGENSON & STIROH (2000) find no empirical evidence of a significant indirect impact, mainly on account of measurement difficulties.

BEA calculates the direct effect of computers on measured GDP growth using its "contribution to percent change methodology". In the case of computers, the contribution is approximated by simply excluding computer components in the various sectors of GDP (producers durable equipment, personal consumption expenditures, government gross investment, etc;) and comparing the growth rate minus computers to the growth rate of real GDP (table 10).

Table 9: Contribution of computer hardware to annual real output or GDP growth (%)

	Previous period		Current period	
	Years covered	Annual real contribution	Years covered	Annual real contribution
JORGENSON & STIROH (2000)	1991-95	0.19%	1996-99 1996-98	0.49% 0.46%
Macroeconomic advisers (1999)	1994-95	0.20-0.30%	1996-99 1996-98	0.50-0.70% 0.50-0.60%
OLINER & SICHEL (2000)	1991-95	0.25%	1996-99 1996-98	0.63% 0.59%
WHELAN (2000)	1990-95	0.33%	1996-98	0.82%

Source: LANDDEFELD & FRAUMENI, 2000

Table 10: Real GDP, GDP minus final sales of computers in percent change from preceding year

	1988	1990	1992	1994	1996	1998
GDP	3.8	1.2	2.7	3.5	3.4	3.9
GDP minus final sales of computers	3.6	1.2	2.5	3.4	2.9	3.3
Difference	0.2	0	0.2	0.1	0.5	0.6

Source: MOULTON, 1999

It is worth noting that these studies generally focus on the direct effects of computer hardware on GDP and GDP growth. This is usually due to the fact that the deflator used for computer hardware is considered as being plausible. This is not the case, however, even if major improvements are made for software and telecommunication equipment (see below) (JORGENSON & STIROH, 2000; GORDON, 2000).

The introduction of business and administration expenditures for software in US GDP is an important part of the 1999 revision of the National Income and Product Accounts (NIPA). In business, the purchase of software was considered as an intermediate input and omitted from the calculation of GDP. It is now added to fixed investment and added to GDP (own-account software will be measured as the sum of the cost of production). As far as the government is concerned, the purchase of software is reclassified from government expenditure to gross government investment and then to GDP.

Taking into account changes in quality and price: methodological problems

The sharp decrease in price and increase in quality of computer hardware is estimated using a hedonic price index. The problem of a price index for computers was resolved in the US by the governmental agency (BEA) cooperating with industry. The quality-adjusted price index (hedonic) was introduced in US national accounts in December 1985 and showed a multi-decade decline in prices and growth in output of computers and peripheral equipment. The US national accounts (NIPA) also capture nominal spending on computers, peripherals and software and deflate using hedonic indexes that adjust to rapid technical change in those products. The diffusion of the quality-price index is very slow in major industrial countries' statistics. One way of diffusing it is to build a national hedonic price index (as in France for microcomputers) or to use the US hedonic index that is adjusted to the exchange rate (as in Denmark and Sweden).

Work on quality-adjusted indexes has been extended to other information products (semiconductors, telephone switching equipment) in the US since 1985. BEA has recently worked on developing improved price indexes for certain types of software, which it plans to introduce in its revision of the national economic accounts of October 2000.

As far as software is concerned, only pre-packaged items are deflated in the US using a combination of hedonic and matched-model indexes through 1997 and an adjusted version of the PPI index for "pre-packaged software-applications software".

For telecommunications equipment and services, including Internet services, BEA uses an index developed by HAUSSMAN (1999) to deflate cellular services. However, there are other areas where the price indexes used for deflation do not fully capture the advances in quality, speed, convenience, and reduction in cost per minute associated with a number of communication products.

Price indexes are not hedonic for video and audio, but LIEGEY & SHEPLER (1999) suggest that the use of a hedonic index for VCRs may have little impact on growth and productivity.

Another improvement in statistics, which is not directly linked to the digital economy, is the elimination of the substitution bias (tendency of indexes with fixed weights to overstate growth). In the US, BEA adopted chain-type quantity and price indexes (indexes in which the weights are continually updated rather than fixed) in January 1996. A significant number of developed countries have now adopted chain-type quantity and price indexes which generally correct the upward bias in GDP growth.

These changes are embedded in the general transition of national accounts from the 1968 System of National Accounts (SNA 68) to the SNA 93 developed under the United Nations, and from the 1979 European System of national Accounts (ESA 79) to ESA 95, which is designed to be consistent with SNA 93. Both SNA 93 and ESA 95 recommend greater use of chain-weighted price indexes. The changeover to the new system will lead to greater international comparability of productivity measurements, although at present, this changeover has made measuring complicated, and not only across countries, but also over time in some cases because implementation has been gradual and is not uniform (table 11).

Table 11: Evolution of national accounts in major OECD countries

Country	Hedonic price	Chain weighted	Benchmark year base	Expenditure accounts
United States	Yes	Yes	1996	NIPA
Canada	Yes	Yes	1992	SNA 93
Japan	Yes	No	1995	SNA 68
Belgium	No	No	1995	ESA 95
Denmark	Yes (2)	No	1990	ESA 95
France	Yes (1)	Yes	1995	ESA 95
Germany	No	No	1995	ESA 95
Ireland	No	No	1995	ESA 95
Italy	No	No	1995	ESA 95
Netherlands	No	Yes	1995	ESA 95
Norway	No	Yes	1996	SNA 93
Spain	No	No	1995	ESA 95
Sweden	Yes (2)	No	1995	ESA 93

(*) Used for microcomputers only

(**) Use US hedonic index, exchange rate adjusted

Source: GUST & MARQUEZ (2000)

Digital economy and productivity growth

The discussion on the role of information technology as an explanation for recent US productivity growth and the supposed diffusion of this dynamic to other developed countries has motivated an important number of studies and survey papers (GORDON, 2000; OLINER & SICHEL, 2000; JORGENSON & STIROH, 2000; OECD, 2000). The growth of labour productivity depends upon the rate of "capital deepening" and the growth of "multifactor productivity" (see GUST & MARQUEZ, 2000, p. 666) for a synthetic presentation of productivity measurement). Capital deepening refers to an increase of the ratio capital to labour in the production function while "multifactor productivity" refers to an increase of the productive capacity of an economy, which is not due to contributions to labour and capital. Increases in multifactor productivity may reflect advances in technology (both information and non-information technologies) but also other changes in production such as the reorganization of tasks (organizational innovations) or improvements in the distribution channels used to deliver goods and services. In either case, an acceleration in multifactor productivity allows labour to be more productive even if the capital-labour ratio is fixed. The measurement of productivity and multifactor productivity supposes that capital, and IT capital in particular, is well calculated. The main results of the comparison of labour and multifactor productivity for major industrialized countries are the following (table 12).

Table 12: Average growth rate of labour and multifactor (MFP) productivity (%)

	1981-1989	1990-1995	1996-1999
United States (OECD data)			
Labour productivity	1.59	1.47	2.57
MFP	0.86	0.79	1.47
Canada			
Labour productivity	1.42	1.34	0.92
MFP	0.14	0.26	0.27
France			
Labour productivity	3.41	2.26	1.61
MFP	2.26	0.89	1.12
Germany			
Labour productivity		2.26	2.14
MFP		1.02	1.07
Italy			
Labour productivity	2.33	2.72	0.67
MFP	1.45	1.32	- 0.14
United Kingdom			
Labour productivity	3.37	1.78	1.47
MFP	2.90	1.12	0.95

Source: OECD and GUST & MARQUEZ (2000)

The figure shows a slowdown in labour and multifactor productivity in major developed countries except the US. The differences between these trends lie in economic cyclical considerations as well as those pertaining to methodology and measurement. Methodological considerations refer to the rate at which new national accounts and quality changes (see above and table 8) are implemented and also to the measurement of the IT diffusion process. While the contribution of IT goods is well covered in the US, at least as far as computers and semiconductors are concerned, this data is non-existent in many other countries. The contribution of Internet-type technologies and the creation of network effects are far from being included in these approaches.

Other measurement problems

• *Measuring the output of services.* Among the industries that are the most intensive users of IT products and services are wholesale trade, finance, banking, insurance and business services. It is generally acknowledged that the output of these industries is difficult to measure and that improvements are needed. Although the service industry produces intermediate services that are purchased by other businesses:

"mismeasurement of their output leads to a misstatement of the allocation of GDP and productivity changes by industry, but does not affect growth in overall GDP. But if their output is sold to final consumers, error in measuring output will affect the measure of overall GDP" (MOULTON, 2000).

• *Accounting for capital stock.* One aspect of IT that contributes to the difficulty of measuring its effects on the economy is the fact that it often enters the production process in the form of capital equipment. Important components of capital may not be adequately captured in the measurement of capital. Intellectual property in software, inventions, patents… have been important omissions. R&D and other intellectual property are presently not treated as capital investment in national accounts.

• *The need for expanded and updated surveys.* It is generally recognized that surveys need to be implemented if we wish to gain a better understanding of the digital economy. The US Census Bureau is working to expand and modernize its surveys in order to better track businesses involved in e-commerce and measure transactions conducted via the Internet, monitor new firms that enter the e-commerce sphere and measure the increase in spending on equipment and services supporting web-based commerce. It is important to know whether output is being consumed by end-users (so it enters GDP) or if it is being consumed as intermediate input (not directly added to GDP). The rapid growth of the Internet may change some of the assumptions that have historically supported BEA's estimates and the Census Bureau's surveys. For example, there have been:

"substantial increases in direct sales by manufacturers to households, to other businesses, and to foreigners" (MOULTON 2000).

For the Brookings Institution (BROOKING, 2000) some of the changes will have to take the form of new service sector surveys, but there is just as much need, if not more, to extend research on the types of questions that have to be asked. How should we define the output of these industries and how should we distinguish between changes in prices and the quality of service? This suggests that statistical agencies need to expand their research in order to resolve more measurement issues. This work must also be coordinated with the industries concerned since their co-operation is of critical importance if a common set of definitions and an agreement on a feasible measurement programme is to be found.

Measuring the consequences of the digital economy on market structure and behaviour

Although a lot of data and studies exist to help us assess the macroeconomic impact of the digital economy, the consequences of ICT on markets and their structure are analyzed far less frequently. It is important for policymakers to assess this impact to be able to measure the actual and potential changes in markets, market structures and behaviour.

As regards market structures, it is important to evaluate the ability for small firms to compete on more markets due to cheaper access to these markets. Web-enabled e-commerce changes the way buyers and suppliers interact with each other. Moreover, the availability of low cost hardware and software reduces the cost of locating activities a long way from consumers.

The Internet gives consumers more power to compete on the marketplace by making information on the price and quality of goods and services more accessible. Thus, price competition may be substantially enhanced by the ability of buyers to search for alternative suppliers of goods and services on the Internet. It is important to deal with the degree of substitution occurring between goods and services purchased through e-commerce and similar goods purchased through traditional channels.

This substitution may be considerable in the case of "digital" goods and services and has potentially major implications for wholesalers, retailers and transporters. Data collected at firm and industry level and surveys can help us compare how the structure of industries using digital technologies changes over time against industries using fewer digital technologies.

In the US, data on where businesses are located, the industry in which they operate and their scale of distribution is available in federal statistical agencies. The Standard Statistical Establishment List (SSEL) is maintained by the Census Bureau but it is an under-utilized source that could be put to much more efficient use - for example, if there is some sense that e-commerce reduces entry barriers and allows small businesses to compete. The SSEL:

> "gives a dynamic picture of business which can be used to track the impact of the Digital Economy on small business (there is an ongoing collaborative project between Small Business Administration and Census to track the dynamics of small versus large business)" (HALTIWANGER & ARMIN, 2000).

Use of the SSEL for this type of analysis poses something of a challenge. The quality of data for new businesses is low and this causes problems for the digital economy and the large number of start-ups. In addition, while the NAICS offers much greater detail in the information sector, it is important to add codes. For example, there is now a plan to classify businesses that primarily sell by e-commerce (actually grouped with mail order houses) in a separate category.

The importance of the effect of digital technologies on competitive behaviour can be tracked by collecting information about the pricing of goods and services sold via e-commerce and the Internet and the same sold via traditional methods. It would be interesting to quantify how price-cost markups have changed and how dispersion across sellers of the same product or service varies by method of selling and delivery.

Measuring the digital economy at firm level

Aggregate industry data may not accurately reflect the value of variety, timeliness, customization and other intangibles, and underestimate the effects of computers on productivity if the benefits of computerization are oriented toward intangible values (BOSKIN et al., 1997). Firm-level data may better reveal the computer's contributions when consumers consider intangible benefits at the time of making their purchasing decision. However, investments in computers may have little direct contribution to the overall performance of a firm or the economy until they are combined with complementary investments in working practices, human capital and firm restructuring (DAVID, 1990; GREENWOOD & JOVANOVICH, 1998; HALL, 2000; HAMMER, 1992). This may lower the apparent contribution of the computer in the short term but result in substantial contributions in the long term.

Research on the effects of the computer on firm-level productivity has been constrained by data availability and has produced mixed results. LEVEMAN (1990) and BARUA KRIEBEL & MUKHOPADHYAY (1995) found no evidence that computers contributed positively to output when they examined a data set of 60 business units in the early 80s. In contrast, studies using more recent firm-level data have found a correlation between levels of computer investments and productivity level. For example, (BRYNJOLFSON & HITT, 1995 & 1996, and LICHTENBERG, 1995) estimated the production function for 350 large firms from 1988 –1992 and found high output elasticity for computers exceeding their capital costs. The results at industry level are more mixed. MORISSON (1996) founds a zero or even negative correlation between computers and productivity while SIEGEL (1997) found a positive relationship after correcting error in input and output quantity.

The major and more recent contribution to the relationship between the use of information technologies and a firm's productivity can be found in BRYNJOLFSON & HITT, 2000. The paper estimates computers' contribution to the growth of firms and evaluates one of the mechanisms that drives this relationship: the role of organizational co-investments. The authors examine the relationship between growth in computer spending and growth in output for 600 large firms over the 1987-1994 period.

The data used in this study is a combination of a database of computer capital stock provided by Computer Intelligence InfoCorp (CII), the International Data Group's (IDG) database and economic and financial information from Standard and Poor's Compusat II database. CII has conducted a series of surveys, involving the interviewing of information systems managers in the 1,000 largest US firms. It should be noted that CII only provides information on computers and does not include software and telecommunications equipment. The Compusat II database gives information on sales, labour expenses, capital stock, employment and R&D spending for all the firms in the CII database.

When the firms' output growth exceeds a "normal" rate, and after accounting for the growth of other factors, the authors conclude that computers contribute to productivity growth. Since the study is conducted with a variation in the time horizon, the authors found that the computer's short run contribution to output is approximately equal to the direct user cost of computer capital. In the long run, they find that the contribution of computers rises by a significant margin and their interpretation is that computers complement organizational changes. This study is a very good example of what can be done to measure the multidimensional aspect of introducing digital technologies at firm level.

■ Conclusion

To fully capture the nature of the digital economy, many changes in the statistical system are needed. At macroeconomic level, much of the work has already been done and only a few improvements and a touch of harmonization are needed. The main difficulties lie at sectoral, micro and, overall, societal level.

The digital economy is part of a broader knowledge economy so indicators of the nature, the strengths, weaknesses and trends of the skill base are required, together with measurements of the level, production, distribution and utilization of intellectual capital. We also need indicators that are designed to measure the impact on employment, the effect of substituting traditional jobs and the effects of social inclusion/exclusion on the labour market.

In addition, it seems important to measure the environmental aspects of the digital economy, and conceptual work and indicators are needed on the matter of the dematerialization of industrial and business processes, for example.

We can also look for social indicators to estimate the emergence of the digital society. These include economic and social demography indicators, lifelong learning/training indicators, living standards and lifestyle indicators, cultural indicators, social inequality indicators, technology penetration indicators, Internet penetration indicators and time use.

Appendix 1

Information and Communication Technologies in OECD (2000a) (ISIC rev/3 classification)

Manufacturing
3000 - Office accounting and computing machinery
3130 - Insulated wire and cable
3210 - Electronic valves and tubes and other electronic components
3220 - Television and radio transmitters and apparatus for line telephony and line telegraphy
3230 - Television and radio receivers, sounds or video recording or reproducing apparatus, and associated goods
3312 - Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process equipment
3313 - Industrial process control equipment

Services
5150 - Wholesaling of machinery, equipment and supplies (ICT)
7123 - Renting of office machinery and equipment (including computers)
6420 - Telecommunications
72 - Computer and related activities

Appendix 2

ICT sector intensity rating in major OECD countries

	Employment	**Added-value**	**R&D**	**Trade**
	Share of ITC (%) And ranking	Share of ITC (%) And ranking	Share of ITC (%) and ranking	Share of ITC (%) and ranking
Austria	4.9 high	6.8 low	na	6.6 medium
Belgium	4.3 medium	5.8 medium	20.1 low	7.1 low
Denmark	5.1 high	na	21.1 medium	10.4 medium
Finland	5.6 high	8.3 high	51 high	18.1 high
France	4 medium	5.3 low	26.4 medium	10.2 medium
Germany	3.1 low	6.1 medium	20.1 low	9.8 medium
Greece	na	na	46.9 high	7.6 medium
Ireland	4.6 medium	na	47.7 high	33.1 high
Italy	3.5 medium	5.8 medium	26.5 medium	6.3 low
Netherlands	3.8 medium	5.1 low	19.6 low	15.6 high
Portugal	2.7 low	5.6 low	23.5 medium	7.5 medium
Spain	na	na	21.4 medium	7 low
Sweden	6.3 high	9.3 high	27.9 high	14.6 medium
United Kingdom	4.8 high	8.4 high	21.8 medium	14.9 high
United States	3.9 medium	8.7 high	38 high	15.9 high

Source: OECD, 2000a

Appendix 3

The new Information Industries (51) sector of the NAICS system

511 Publishing industries (excluding Internet)
This sub-sector include both newspapers, periodicals, directory and mailing lists and software publishers. Software publishing is included here because this activity is equivalent to the creation of process for other types of intellectual production. The reproduction of pre- packaged software is treated in NAICS as a manufacturing activity. These distinctions arise because of the different ways that software is created, reproduced and distributed.

512 Motion picture and sound recording industries

515 Broadcasting (except Internet)
Telecommunications and Broadcasting are different sub-sectors due to the fact that the production and distribution of information or cultural content is significantly different from the creation of the infrastructure used in distribution.

516 Internet publishing and broadcasting
The NAICS 2002 recognize the differences between traditional and Internet publishing and broadcasting. This unique combination of text, audio and video and interactive features justifies the creation of a new sub-sector.

517 Telecommunications
The new telecommunication sub-sector is primarily engaged in operating, maintaining, and/or providing access to facilities for transmitting voice, data, sound, and full motion picture video between network termination points. It does not produce information and cultural content.

518 Internet services providers, web search portals and data processing service
This new sub-sector in the NAICS is subdivided into two groups. The ISP and web search portals industry group includes establishments that provide access to the Internet or that provide the means to search information on the web. The data processing, hosting and related service industry group includes establishments that process data for others (mainframe time-share facilities and web hosting establishments).

519 Other information services

These 7 three-digit sub-sectors are further divided in 16 four-digit and 5 five-digit activities.

Appendix 4

Information technologies in the NACE (rev 1) system (ISIC rev/3 correspondence)

30	Manufacture of office machinery and computers (30)
30.0	Manufacture of office machinery and computers
30.01	Manufacture of office machinery
30.02	Manufacture of computers and other information processing equipment
31.3	Manufacture of insulated wire and cable (313)
31.30	Manufacture of insulated wire and cable
32	Manufacture of radio, television and communication equipment and apparatus
32.1	Manufacture of electronic valves and tubes and other electronic components (321)
32.10	Manufacture of electronic valves and tubes and other electronic components
32.2	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy (322)
32.20	Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy
32.3	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods
32.30	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods
33.2	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment (3312)
33.20	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
33.3	Manufacture of industrial process control equipment (3313)
33.30	Manufacture of industrial process control equipment
51.43	Wholesale of electrical household appliances and radio and television goods
51.64	Wholesale of office machinery and equipment
51.65	Wholesale of other machinery for use in industry, trade and navigation
52.45	Retail sale of electrical household appliances and radio and television goods
64.2	Telecommunications
71.33	Renting of office machinery and equipment, including computers (7123)
72	Computer and related activities
72.1	Hardware consultancy
72.10	Hardware consultancy
72.2	Software consultancy and supply
72.20	Software consultancy and supply
72.3	Data processing
72.30	Data processing
72.4	Database activities
72.40	Database activities
72.5	Maintenance and repair of office, accounting and computing machinery
72.50	Maintenance and repair of office, accounting and computing machinery
72.6	Other computer related activities
72.60	Other computer related activities
92.1	Motion picture and video activities
92.11	Motion picture and video production
92.12	Motion picture and video distribution
92.13	Motion picture projection
92.2	Radio and television activities
92.20	Radio and television activities

Appendix 5

Estimation of B-to-C e-commerce in selected OECD countries

	Value of transactions US$ billion	Value of transaction growth rate 1999/1998	Penetration rate % of retail sales	Number of users buying online
United States	24 170	195	0.48	39
Japan	1 648	334	0.06	
Germany	1 199	200	0.30	13
France	345	215	0.14	8
Italy	194	145	0.09	12
United Kingdom	1 040	280	0.37	11
Austria	96	210	0.23	13
Belgium	82	420	0.16	11
Denmark	46	220	0.20	8
Finland	51	160	0.22	8
Greece				11
Ireland				13
Netherlands	182	210	0.34	13
Norway	61	200	0.26	10
Portugal	70	185	0.06	11
Spain	70	185	0.06	11
Sweden	232	170	0.68	10

Source: OECD, 2000e

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