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Characterizing and comparing the evolution of the major global economies in information and communication technologies ☆

Paul Desruelle, Juraj Stančík *

European Commission, Joint Research Centre – Institute for Prospective Technological Studies (JRC-IPTS), Edif. Expo, c/Inca Garcilaso 3, E-41092 Seville, Spain

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ABSTRACT

In this paper, we characterise and compare status and evolution of the ICT industry of the six major global economies in ICT: China, the EU, Japan, Korea, Taiwan and the USA. For this, we employ official data covering the period 2006–2009. Our analysis shows that although the EU is the largest economy of the world, it is the least ICT-specialised economy of all six major ICT economies. The USA is clearly the top global player in ICT in many respects. In both ICT Manufacturing and ICT Services it has the largest Value Added, BERD, BERD intensity and labour productivity. We further observe that China has, by far, the largest number of employees in both ICT Manufacturing and Services, while its level of ICT BERD remains low. China is however an emerging economy and economic indicators of its ICT sector have strongly grown from 2006 to 2009. Japan's ICT sector has a larger weight in the national economy than those of the USA, EU, and China. Moreover, it is the country from which the highest number of ICT patent applications originate. We also find that, of all six major global economies in ICT, Taiwan and Korea have the most ICT-specialised economies, with a strong orientation towards Manufacturing. Finally, we discuss selected results of our analysis and conclude the paper with tentative policy implications for the EU.

1. Introduction

In this paper, we characterise and compare, using most recent official macro-economic data, the evolution of the ICT industry of China, the European Union (EU), Japan, Korea, Taiwan and the USA, all major global players in this field. The Information and Communication Technologies (ICT) industry includes IT and telecom hardware manufacturers, telecom operators and software and computer service firms. It provides technologies and solutions necessary for the development of the digital economy and society. This analysis is particularly relevant for policy makers since the ICT industry and ICT-enabled innovation make an increasingly important contribution to economic growth.

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* Corresponding author.
E-mail addresses: Paul.Desruelle@ec.europa.eu (P. Desruelle), juraj.stancik@gmail.com (J. Stančík).

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1.1. Policy background

Europe 2020, the EU strategy for growth launched in 2010, set five ambitious objectives on employment, innovation, education, social inclusion and climate/energy to be reached by 2020.[1] One of them is the target to invest 3% of the EU's GDP in R&D by 2020, an achievement that "could create 3.7 million jobs and increase annual GDP by €795 billion by 2025".[2] The *Digital Agenda for Europe*[3] (DAE) is one the seven "flagship initiatives" of *Europe 2020*. The DAE aims at a doubling of both public funding of ICT R&D and business expenditures in R&D by the ICT industry. At the EU level, the most important public instrument for funding R&D, including R&D in ICT, has been the series of framework programmes for research and technological development. The EU launched in 2014 the *Horizon 2020* programme for research and innovation which will cover the period until 2020 with a total budget of €70 billion.

1.2. Research context

Quantitative evidence is needed on a regular basis in order to monitor progress and impact of policies and their instruments; and in order to guide their future development. As part of its mission to provide robust, evidence-based policy support, the Information Society Unit of JRC-IPTS regularly analyses the state of the ICT industry and of ICT R&D activities in the EU, under the PREDICT project, "*Prospective insights on R&D in ICT*".[4] The fifth edition of the PREDICT report was published in 2012 (Stančík and Desruelle, 2012). The research presented in this paper builds on the analyses developed so far under PREDICT. The PREDICT analysis, although clearly focused on the EU, benchmarks the performance of the EU ICT industry with that of the US and of other developed and emerging economies. For example the 2012 analysis observed a growing gap between the EU and the US, in terms of the size of the respective ICT sectors and of their R&D.

International benchmarking – going beyond just comparing the EU and US – was developed in PREDICT by analysing non-official data on R&D expenditures by the top worldwide R&D-investing ICT companies, and also by analysing patenting data (De Prato, Nepelski, Szewczyk, & Turlea, 2011a; Nepelski & Stancik, 2011; Turlea et al., 2009, 2010, 2011). PREDICT also analysed in details the performance of the ICT industry in several of the BRICS countries, in particular in Brazil, China and India (Simon, 2011a, 2011b).

The research presented in this paper complements the analyses developed so far by comparing and analysing the performance of the ICT industry of the most important global players in ICT (China, the EU, Korea, Japan, Taiwan and the USA), using a consistent set of indicators based on most recent official macro-economic data.

In the next sections of the paper, we first identify the major global players in ICT by comparing the economic weight of their ICT industry and their volume of Business Expenditures in R&D (BERD). We then analyse the specialisation and strengths of these economies in ICT Manufacturing and Services, examine main trends, and discuss selected results. We finally conclude with a brief summary for each of the six major global players in ICT and tentative policy implications for the EU.

2. Approach and data

The data analysed in this research (Value Added, Employment and BERD) was collected from official sources including OECD, US Bureau of Economic Analysis, NSF, METI, EUROSTAT, National Bureau of Statistics of China, Statistics Korea, and National Statistics of Taiwan. For patents we use EPO PATSTAT data. Our analysis covers four years, from 2006 to 2009. 2009 was the most recent year for which official data was available at the time when we did our research.

We followed as far as feasible the most recent definition of the ICT sector – i.e., ISIC 4/NACE Rev. 2 – adopted by the OECD in 2007.[5] For reasons of data availability, we had to slightly adapt this definition. The definition of the ICT sector used in this paper is provided in Box 1. In order to obtain comparable data from 2006 to 2009, we elaborated a transition methodology from the previous to the current definition.[6] We also developed correspondence tables to account for different ICT sector definitions in the analysed countries.[7] Data collection and methodological work were conducted jointly with the *Valencian Institute of Economic Research* (Ivie). Our data sets, indication of data sources, and methodological reports and notes are publicly available on the JRC-IPTS web site.[8]

[1] http://ec.europa.eu/europe2020.

[2] http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=why.

[3] http://ec.europa.eu/digital-agenda/en.

[4] The Institute for Prospective Technological Studies (JRC-IPTS) is one of the seven scientific institutes of the European Commission's Joint Research centre (JRC). For more information on PREDICT and for its publications, see http://is.jrc.ec.europa.eu/pages/ISG/PREDICT.html.

[5] See *OECD Information Economy – Sector definitions based on the International Standard Industry Classification (ISIC 4)*, Annex 1, p. 15. Available at: http://www.oecd.org/science/scienceandtechnologypolicy/38217340.pdf.

[6] *ICT Sector Definition Transition from NACE Rev. 1.1 to NACE Rev. 2: A Methodological Note*. Authors: Matilde Mas, Juan Carlos Robledo, Juan Pérez. Editors: Juraj Stančík, Geomina Turlea, Paul Desruelle. JRC Technical Report, EUR Number: 25690, Jan. 2013. Available at: http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=5919.

[7] 2006–2009 NACE REV. 2 ICT datasets methodological notes, December 2012. Available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/2da/documents/20062009NACE2_METHOD.pdf.

[8] http://is.jrc.ec.europa.eu/pages/ISG/PREDICT/2da/data2.html.

Box 1–Definition of the ICT sector.

ICT Manufacturing
261 Manufacture of electronic components and boards
262 Manufacture of computers and peripheral equipment
263 Manufacture of communication equipment
264 Manufacture of consumer electronics
ICT Services
5820 Software publishing
61 Telecommunications
62 Computer programming, consultancy and related activities
631 Data processing, hosting and related activities; web portals
951 Repair of computers and communication equipment

3. Data analysis

This section on data analysis is structured in three sub-sections. First, we identify and analyse the most important global economies in ICT, in terms of the size of their ICT sector and of R&D investment in the sector. Second, we look at specialisation inside the ICT sector of these major players. Finally, we observe main trends in these economies. We would like to stress that data analysis in this section is entirely factual, some interpretation of the results will be provided in the next section of the paper. Unless specified otherwise, this analysis is based on the situation up to 2009, for the reasons that were mentioned above.

3.1. Global players

We start by considering in Fig. 1 a sample of ten economies among the largest economies of the world in order to identify the major global players in ICT.[9] Fig. 1 presents the respective shares of Value Added (or production), Employment, and Business Expenditures in R&D (BERD) of the ICT sector in these ten economies. This initial analysis indicates that the USA, Japan, China and the EU were in 2009 the four world economies that contributed most to global ICT Value Added, Employment and BERD. With few exceptions (e.g. India with 14% share in terms of ICT Employment), the ICT sector of these four economies consistently contributed the most, on all three measures.

When comparing the contributions of the ICT sector of these four economies, it can be observed that the US ICT sector has the largest share in Value Added, and especially in ICT BERD, while its Employment share is lower than those of China and the EU. Compared to the US, the EU ICT sector has a Value Added share that is almost as important, a larger Employment share, and a significantly lower BERD share. Japan's ICT sector has a Value Added share that is about half that of the US or the EU, an Employment share that is about half that of the EU, and a BERD share that is similar to that of the EU. China's ICT sector has by far the largest Employment share, while its Value Added is lower than that of Japan, and its BERD share significantly lower. Those figures offer the first insight about the differences in labour productivity among these countries' ICT sectors. The USA has the highest labour productivity and China the lowest, as we will see in the next section. The large share of ICT BERD is another factor of strength for the USA.

Next in this figure the contributions of the ICT sectors of Korea and Taiwan can be observed, confirming that these two countries, in spite of the small size of their economy, play an important role in ICT on the global scale. For example, Korea's ICT BERD share was in 2009 the same as that of China.

As a result of this initial analysis, we focus in the remainder of the paper on the above mentioned six economies: the USA, EU, Japan, China, Korea and Taiwan.

Next, we analyse the weight of the ICT sector in each economy considering the relative shares of Value Added, Employment and BERD of the ICT sector in the country's or region's economy. These relative shares are shown in Fig. 2 for the six economies. A first observation confirms the importance of the ICT sector in the economy of Korea and Taiwan. Korea and Taiwan are clearly the most *ICT-specialised* economies for each individual measure (Value Added, Employment or BERD). The weight of the ICT sector in Taiwan is particularly strong: the share of ICT Value Added in total Value Added was almost 12% in 2009, in Employment the ICT industry share was more than 8% and in BERD more than 70%. By comparison, in the EU these shares were in 2009 almost 4% in Value Added, around 2% in Employment and 15% in BERD.

The weight of Japan's ICT sector in the national economy is also significant especially in terms of Valued Added (above 6%) and Employment (almost 4%). In terms of BERD, the next country after Taiwan and Korea is the USA with a share above 30%. The EU, the largest economy of the world, appears to be the least specialised in ICT of all six economies. It is only in terms of Employment that the EU share was above that of China and almost equal to that of the USA. And while the EU and

[9] Russian data was not available to us. The EU includes the 27 Member States part of the European Union in the period covered by the data analysis, prior to the recent accession of Croatia.

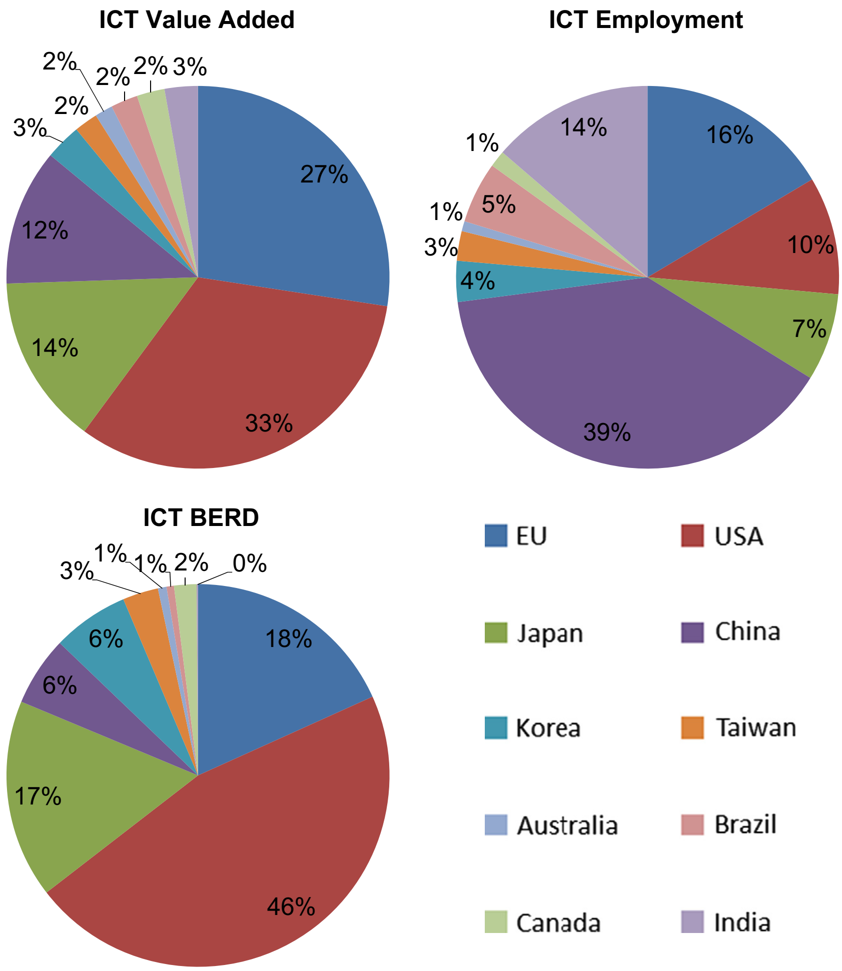

Fig. 1. Countries' shares in ICT Value Added, Employment and BERD (2009). Note: BERD – Brazil 2008, India 2007; Value Added – Canada 2008.

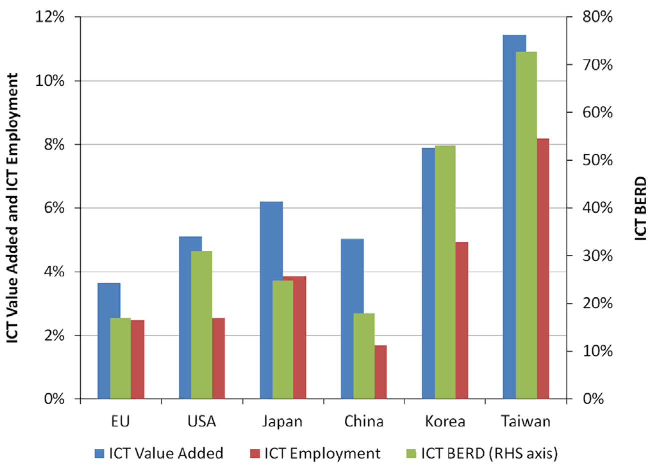

Fig. 2. Shares of ICT sector in countries' totals of Value Added, Employment and BERD (2009).

USA have the same ICT Employment shares, the share in ICT Value Added is much higher in the USA. In terms of Value Added, the relative weight of the US and China's ICT sector in their respective national economy is similar, while the ICT sector Employment share is higher in the US.

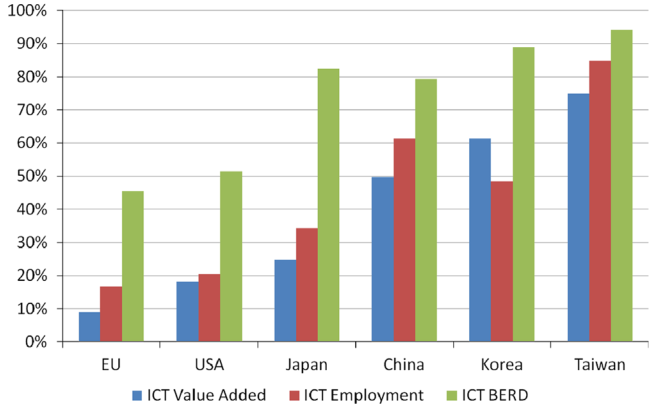

Fig. 3. Shares of ICT Manufacturing in ICT sector total Value Added, Employment and BERD (2009).

3.2. Specialisation and strengths of major ICT players

Having identified the major ICT global players, we look closer in this section at strengths and specialisation of their ICT sector, focusing mainly on differences between ICT Manufacturing and Services.

Fig. 3 provides an indication of the Manufacturing versus Services specialisation of the ICT sector of the six economies. The figure presents the shares of Manufacturing in Value Added, Employment and BERD of the ICT sector of these economies: the vertical bars in Fig. 3 represent the shares of Manufacturing, while the remaining parts up to the 100% represent the shares of Services (not show in the figure).

A first observation of Fig. 3 clearly shows that Taiwan's ICT sector is strongly specialised in Manufacturing both in terms of Value Added and Employment, and that the reverse is true for the ICT sectors of the EU, USA and Japan which are strongly specialised in ICT Services: ICT Services Value Added represented in 2009 more than 90% of the total ICT sector Value Added in the EU, more than 80% in the USA, and 75% in Japan. Employment in ICT Services is also significantly higher than in ICT Manufacturing in the EU, USA, and Japan.

In China, ICT Manufacturing Value Added is equal to ICT Services Value Added, but Employment in ICT Manufacturing is higher. In Korea, ICT Manufacturing Value Added is higher, like in Taiwan, but Employment in ICT Services is slightly higher than in ICT Manufacturing.

In terms of ICT BERD, specialisation in Manufacturing is strong in the four Asian countries, with percentages at or above 80% (95% in Taiwan). In the EU and US, percentages are about equal for Manufacturing and Services. The EU is the only economy – of the analysed six economies – in which ICT BERD was higher in Services than in Manufacturing in 2009. Finally, it is also interesting to observe that percentages of ICT Manufacturing BERD are consistently significantly higher than ICT Manufacturing Value Added and Employment percentages.

Fig. 4 presents a comparison of the same variables as Fig. 3, but in absolute terms rather than percentages, showing ICT Value Added, Employment and BERD in separate graphs, for both ICT Manufacturing and ICT Services. A first observation of the figure clearly shows the importance of size: as could be expected, in absolute terms, large economies dominate.

In terms of ICT Manufacturing Value Added, the top world ICT Manufacturing economies were the USA (€93 bn), China (€89 bn) and Japan (€56 bn) in 2009. The EU came fourth (€38 bn), closely followed by Korea (€29 bn) and Taiwan (€23 bn), two much smaller economies but strongly specialised in ICT manufacturing as observed above.

In terms of ICT Services Value Added, the importance of country size is even stronger than in Manufacturing, with in particular clear lead of the USA (€417 bn) and the EU (€389 bn), while ICT Services Value Added in China was still comparatively low in 2009 (€90 bn), given the size of the country's economy.

With more than 13 million people employed in the ICT sector in 2009, China is by far the largest employer, in spite of the fact that ICT sector Employment represents less than 2% of Chinese economy Employment, the lowest share in the six analysed economy (see Fig. 2). This number of 13 million employees includes more than 8 million working in ICT Manufacturing. ICT Employment is also very important in the EU, especially in ICT Services (4.6 million) where it reaches almost the level of China (5.1 million). Interestingly, ICT Employment is lower in the US than in the EU, while US ICT Value Added is higher, providing evidence of the USA leadership in ICT sector labour productivity.

In terms of ICT BERD, the US is also a clear leader in both Manufacturing and Services, with a total of €63 bn, compared to €25 bn for the EU and €23 bn for Japan. With €8 bn, China's ICT BERD was in 2009 lower than Korea's ICT BERD (€9 bn), but above Taiwan's ICT BERD (€4 bn). In terms of ICT Manufacturing BERD, the USA (€32 bn) and Japan (€19 bn) are leaders, followed by the EU (€11 bn) Korea (€8 bn), China (€6 bn) and Taiwan (€4 bn). The USA and the EU also have very large investments in ICT Services BERD (€31 bn and €13 bn respectively) while in the four Asian countries ICT BERD is highly concentrated in manufacturing.

While our analysis has so far only been considering individual variables, the remaining part of this section offers a complementary perspective by looking at ICT labour productivity and ICT BERD intensity. These two indicators are defined

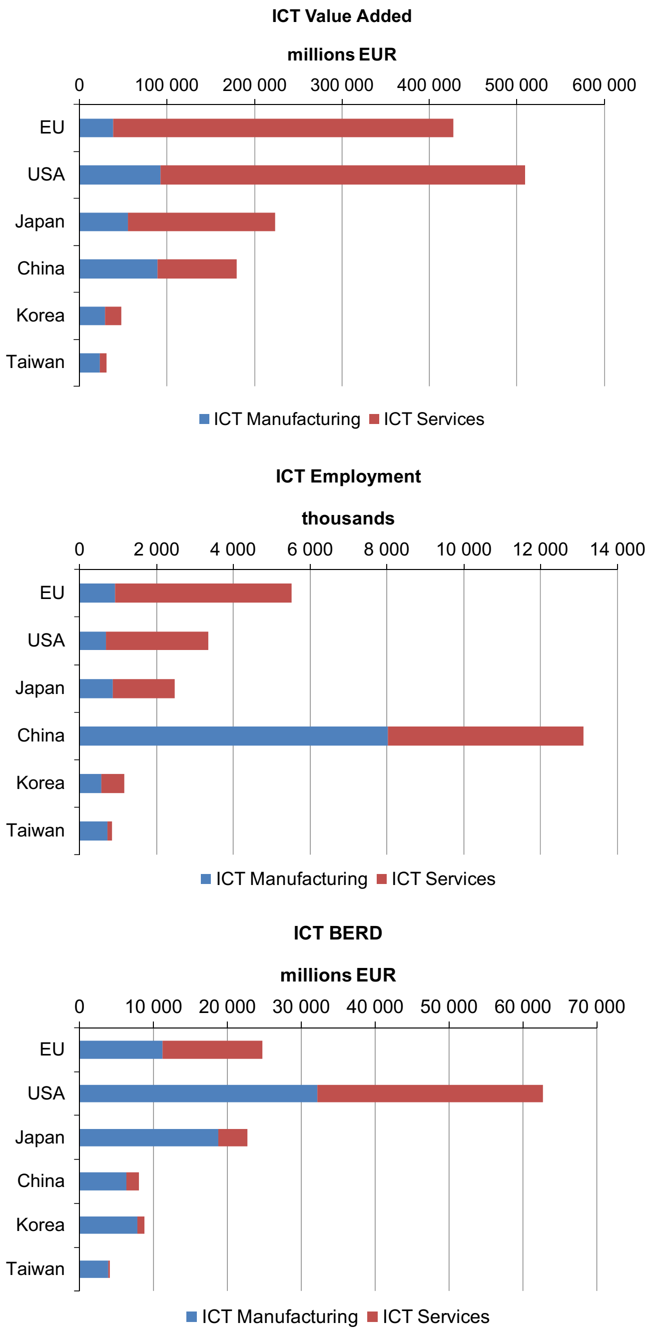

Fig. 4. ICT Value Added, Employment and BERD in Manufacturing and Services (2009).

respectively as the ratio of ICT Value Added over ICT Employment (ICT labour productivity), and the ratio of ICT BERD over ICT Value Added (ICT BERD intensity).[10]

Fig. 5 presents a comparison of labour productivity in the analysed economies, for the ICT sector, and for ICT Manufacturing and ICT Services confirming the insights provided in Fig. 1. With €152,000 per employee, the USA has the highest ICT sector labour productivity. Difference of labour productivity between ICT Manufacturing and ICT Services in the USA is not large (€135,000 and €157,000, respectively). Japan then follows (ICT sector labour productivity of €90,000) with a

[10] By looking at BERD intensity defined as the ratio of BERD and value added, it is assumed that all corresponding policies aim at increasing BERD, rather than reducing value added. BERD intensity is a useful indicator for comparing BERD across countries – small countries like Taiwan obviously cannot compete with giants like the EU or USA. This indicator is also used by the OECD, see for instance OCED, 2012.

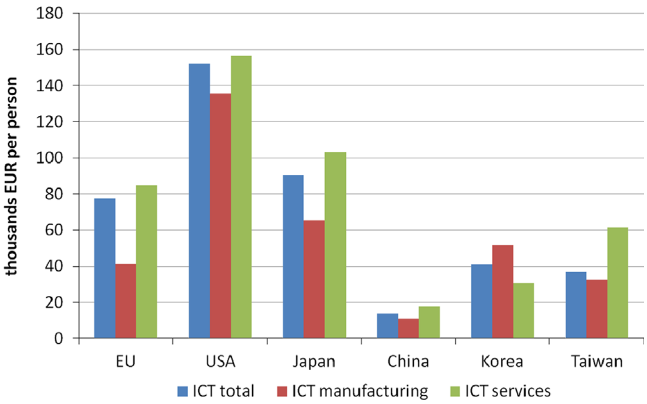

Fig. 5. Comparison of ICT sector Labour productivity (2009).

larger difference between Manufacturing and Services: €103,000 in Services vs. €65,000 in Manufacturing. The ICT sector labour productivity in the EU reached almost €80,000 per employee, half that of the US, and the double of that of Korea or Taiwan. EU ICT labour productivity is twice as high in ICT Services (€80,000) as in ICT Manufacturing (€40,000). In China, labour productivity in both ICT Manufacturing as ICT Services was below €20,000 per employee. Except in the case of Korea, labour productivity is higher in ICT Services than in ICT Manufacturing.

Fig. 6, the last figure of this section, presents a comparison of ICT BERD intensity in the analysed economies, for the ICT sector, and for ICT Manufacturing and ICT Services. In terms of ICT sector BERD intensity (blue bars in the figure), Korea and Taiwan are leaders with intensities of 18% and 13% respectively, closely followed by the USA (12%), and Japan (10%) while the EU and China have an ICT sector BERD intensity of 5%.

Overall, ICT Manufacturing (shown by the red bars) is much more R&D intensive than ICT Services (green bars). The USA, Japan, the EU and Korea have comparable levels of ICT Manufacturing BERD intensity, between 25% and 35%. Taiwan follows with 17% and China with 7%. In ICT Services, the leaders are the USA with 7% and Korea with 5%, while EU ICT services BERD intensity was 3% in 2009.

3.3. *Main trends*

While in the previous sections we discussed results for 2009 only, in this section we observe trends in the ICT sector of the analysed six economies over a period of four years (2006–2009).

We start our analysis with ICT BERD intensity (see Fig. 7). On the one hand, ICT BERD intensity significantly increased in Korea, Taiwan and China from 2006 to 2009. On the other hand, ICT BERD intensity in the EU, the USA and Japan hardly changed during this period. While Korea had the highest level of ICT BERD intensity already in 2006, Taiwan's ICT BERD intensity overtook that of Japan and the USA during the observed period. As observed above, China's ICT BERD intensity is the lowest of all six economies, but China is clearly the economy with the largest – almost exponential – growth in ICT BERD intensity. It seems likely that if the observed trends continue, ICT BERD intensity in China will reach the EU level in the next years.[11]

Next we compare trends in ICT sector Employment. As can be observed in Fig. 8, China is the only country where the number of employees working in ICT sectors substantially increased since 2006 (by more than 2 million), although this growth slowed down in 2008 and 2009. In the other five economies, ICT Employment remained close to its 2006 levels, with little variation during the period.

Our final trend comparison considers an R&D output indicator: ICT priority patent applications to patent offices worldwide. Fig. 9 shows ICT priority patent application data from the PATSTAT database.[12] As can be observed, there is a clear evidence of a strong recent increase of ICT patent applications by inventors from China.[13] The number of ICT patent applications from China overtook the number of applications by inventors from Korea in 2008 and became second after applications from Japan. The leading position of Japan remains, with almost 90,000 ICT patent applications in 2009.[14] China

[11] According to recent OECD numbers (OCED, 2014), China already surpassed the EU in the overall R&D intensity in 2012 (1.98% in China vs. 1.97% in the EU).

[12] The European Patent Office (EPO) develops and updates the EPO Worldwide Patent Statistical Database (known as the PATSTAT database), providing worldwide coverage of patent applications submitted to around 90 patent offices in the world. See De Prato et al. (2011a) for further discussion about analysis of patent applications data.

[13] In our analysis, patent applications are attributed to countries according to the physical location of the inventors.

[14] De Prato et al. (2011a) explain the case of Japan as a "world super-power in patenting". In 2009, the Japan Patent Office was reported to have issued almost 348,600 patents, the majority with domestic origins. Japanese patenting predominance lies in three major industry sectors: Chemicals & Materials, Electrical & Electronic, and Engineering. The high performance in terms of patent applications by inventors from Japan can be explained according to the literature (Goto, 2001; Kiyokawa, 2006; Motohashi, 2003, 2006) by several factors: firms' strategic behaviour, the gradual expansion of technology fields

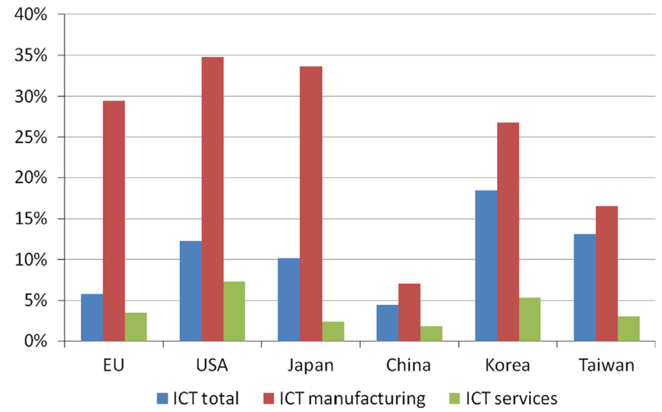

Fig. 6. Comparison of ICT BERD intensity (2009).

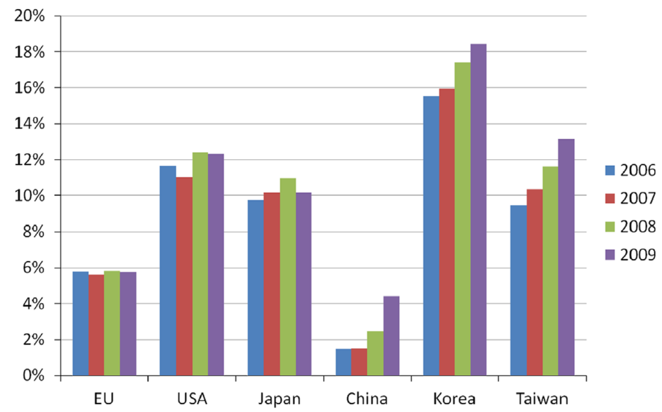

Fig. 7. ICT BERD intensity by countries (2006–2009).

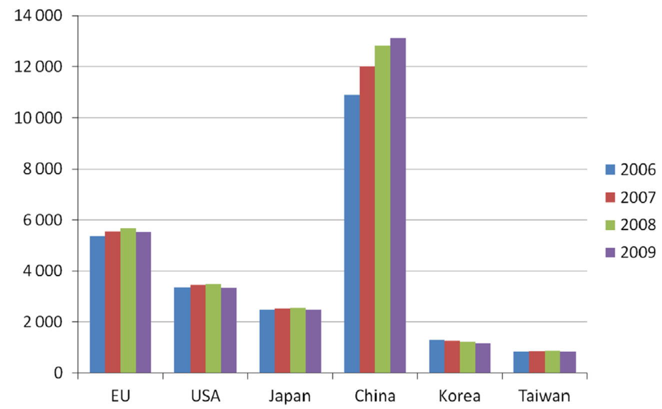

Fig. 8. ICT Employment by countries (2006–2009, thousands of employees).

is the only country with strong increasing trend in ICT patent applications. From 2006 the number increased by almost 20,000, reaching 52,000 in 2009. Besides China, only the EU and Taiwan showed a positive growth in number of ICT patent applications from 2006 to 2009, although in both cases there was a decline in the last analysed year.[15] In 2009, ICT patent applications from the EU and Taiwan amounted to around 15,000 and 11,000, respectively. Regarding the remaining three

(*footnote continued*)
covered by patent protection (especially with regard to ICT and pharmaceutical patents), and also the fast increase in R&D expenditure in the 1990s and the changes in the regulatory framework towards stronger support to intellectual property.

[15] This decline could be partly due to 2009 data not being fully updated yet in PATSTAT.

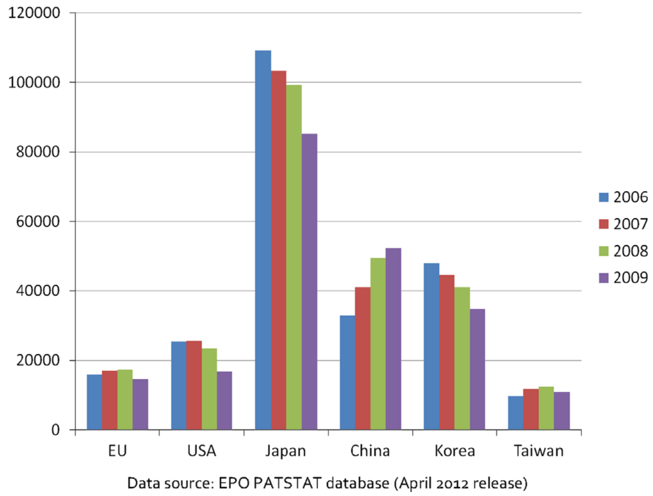

Fig. 9. ICT priority patent applications worldwide, based on location of inventors (2006–2009). Data source: EPO PATSTAT database (April 2012 release).

countries – the USA, Japan and Korea – there is a clear decline in ICT patent applications from 2006 to 2009, with the most prevalent drops especially in Japan (by almost 25,000 over the period 2006–2009) and Korea (almost 13,000).

4. Discussion of selected results

In this section we come back to some of the previous results and briefly discuss a selection of those we find particularly relevant for such a comparison of global players in ICT. First we discuss the levels of BERD and Employment observed in ICT Manufacturing in China. Then we compare the labour productivity and the BERD intensity in the US and EU ICT sectors, and finally we offer a comparison of ICT Manufacturing labour productivity in Taiwan and Korea. In each discussion, we attempt to identify potential factors behind the results. Detailed analysis of those factors is however beyond the scope of this paper and they are therefore offered here as suggestions for further research.

4.1. ICT Manufacturing BERD and Employment in China

4.1.1. ICT Manufacturing BERD

In 2009, ICT Manufacturing Value Added in China was as important as that in the USA (see Fig. 4). In spite of this, China still had in 2009 a comparatively low level of ICT Manufacturing BERD. While ICT Manufacturing Value Added in both countries was around €90 bn in 2009, ICT Manufacturing BERD in the USA was about five times higher than in China (€32 bn vs. €6 bn). As we observed in the previous section, as a result ICT Manufacturing BERD intensity was in 2009 much lower in China than in the US (red bars in Fig. 6).

A possible explanation for this difference may be the strong presence of foreign ICT manufacturing firms in China, and the hypothesis that foreign firms may do comparatively less R&D in China than Chinese firms do. This situation is illustrated in Fig. 10 where one can observe that while in 2011 foreign funded enterprises produced almost 50% of the overall Chinese ICT production, their R&D expenditures represented only slightly more than 20% of China's ICT manufacturing BERD. Foreign firms would therefore appear to essentially produce or assemble products developed by their parent companies abroad and do comparatively little R&D in China. This explanation would also be in line with the study of De Prato, Nepelski, and Stancik (2011b), which claims that "*ICT R&D expenditure in China is more focused on the development and applications side (observers estimate that less than 20% of ICT R&D expenditure is dedicated to basic research*)."

It is however necessary to stress again that the level of Chinese ICT BERD has been strongly growing in the observed period (2006–2009) and that the gap in ICT BERD intensity has been getting smaller. This trend is expected to continue beyond 2009.

4.1.2. ICT Employment

As also observed in the previous section, the high level of ICT Employment in China, and consequently low Labour Productivity, is striking compared to that of the other large economies covered in our analysis. In spite of similar levels of ICT Manufacturing Value Added in both China and the USA, China's ICT Manufacturing sector in 2009 employed almost twelve times as many employees as the US ICT Manufacturing sector (8 million vs. 0.7 million, see Fig. 4). In ICT Services, China employed in 2009 5.1 million employees compared to 4.6 million in the EU, while ICT services Value Added in the EU was four times as high as in China.

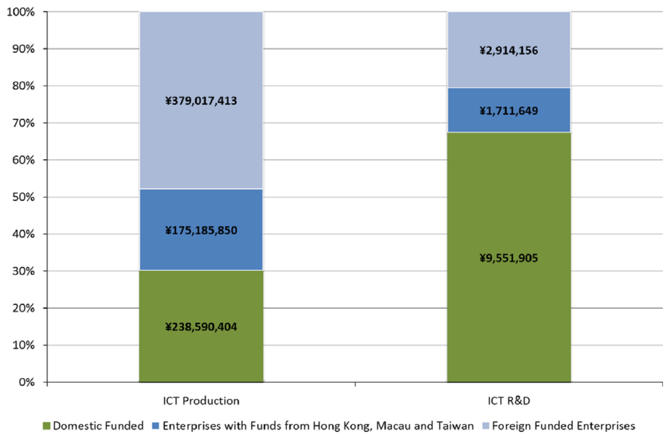

Fig. 10. China production and R&D in ICT Manufacturing sector, by ownership (2011).
Source: Chinese Academy of Science and Technology for Development – Ministry of Science and Technology (CASTED).

There are certainly several factors to explain such large differences. China was in 2009 and still is an emerging economy and furthermore it has a very large labour force. Although China is becoming more and more technologically advanced, its labour is still relatively less costly than capital and this may explain that a substantial part of manufacturing and services is still performed with a large labour contribution. Nevertheless, as China became the world's largest recipient of FDI, promising results come from a study of Liu, David, Vaidya, and Wei (2001) who claim that foreign presence in the Chinese electronics industry "*is associated with higher labour productivity*."

Another factor may be that prices are most likely lower in China than in developed economies like the EU, the USA or Japan, resulting in lower Value Added, and therefore lower measured Labour Productivity for a similar volume of production. An additional factor, when products are manufactured on a global scale, can also be the difference in the level of Value Added at various stages of the value chain, such as assembly versus design or marketing (see for instance Breznitz, Martin, Rouvinen, Zysman, and Ylä-Anttila (2011) or De Backer and Yamano (2012)). Here, these possible factors and others require further investigation.

4.2. Comparing the EU and US ICT sectors

There are a number of relevant ways to compare the EU and US ICT sectors. In this section we look at ICT labour productivity and at ICT BERD intensity.

4.2.1. ICT labour productivity

As we observed above, based on the analysed data, the US ICT sector was twice as labour productive as the EU ICT sector in 2009 (see Fig. 5). US ICT sector Value Added (€510 bn) was 20% higher than the EU ICT sector Value Added (€427 bn, see Fig. 4), while it employed 40% less people (3.3 million employees in the US ICT sector vs. 5.5 million employees in the EU). Thus, the US ICT sector produced about 20% more value than the EU ICT sector employing only 60% of labour force. The comparison is even stronger when we look closer at ICT Manufacturing. The manufacturing component of the US ICT sector produced almost 2.5 times more than its EU counterpart, employing 74% of labour force. Here again, there are certainly a number of different factors behind this large difference in labour productivity. Each of them impacts labour productivity from a different angle. We discuss next three possible factors.

First, it well may be that the US ICT sector is simply more technologically advanced and its employees are therefore able to produce more in the same amount of time. Or put otherwise, as suggested by Acemoglu, David, David, Hanson, and Price (2014), they are able to produce the same in less time. This technological advance is, however, not easy to quantify and such quantification is beyond the scope of this paper. Some insights can be found for instance in Timmer and van Ark (2005) or van Ark, O'Mahony, and Timmer (2008).

Second, the amount of US ICT Value Added may well be overestimated, not in the sense that it would be calculated wrongly, but rather that there may be many US ICT companies – or at least more US than EU companies – producing and assembling their products abroad at low cost and then putting a high mark-up to the price of their final products. This mark-up would then be accounted as part of Value Added in the US without the necessity of actually manufacturing these products in the USA and therefore to employ any ICT manufacturing employees. For example, when Apple introduced its 30 GB Video iPod in 2005, its manufacturing price was $144 but its wholesale price was almost 40% higher ($225) (Dedrick, Kraemer, & Greg, 2008). As a result, Apple – an ICT manufacturing company – accounted for an $80 ICT Value Added in the

US for each produced iPod without employing any ICT manufacturing employee in the US.[16, 17] Similarly, US ICT Service companies (mostly in software or internet business) are also often off-shoring work abroad at low cost, putting a high mark-up to the final products. Nevertheless, whether such off-shoring is done to a lesser extent by EU (versus US) companies is also a relevant question, which we are not able to answer here.

Another possible explanation for a lower ICT labour productivity in the EU vs. USA is the fact that using a head count approach for calculating employment may be inaccurate and to some extent misleading, particularly considering such distinct labour markets as those of the USA and the EU. After comparing statistics provided in the EU Labour Force Survey[18] and the US Current Population Survey,[19] we observed that US ICT employees actually spend more hours at work annually. While in 2009 US ICT employees spent on average 42.1 h per week at work, their EU counterparts spent 38.6 h, 8% less. This 3.5-h difference (half a day per week) is further amplified by the fact that US employees have on average 10 vacation days less than EU employees (including also public holidays).[20] Based on this, we reckon that US ICT employees spent on average almost 14% more hours per year at work than their EU counterparts. Mathematically, the US ICT sector therefore needs to employ less people than the EU ICT sector for the same amount of worked hours.

An interested reader can look into further discussion about the EU–US ICT productivity gap in a summarising study by Biagi (2013).

4.2.2. ICT BERD intensity

Another relevant aspect of the EU vs. US ICT sectors comparison is ICT BERD intensity, i.e., the ratio of ICT BERD in ICT Value Added. As mentioned above, 2009 US ICT sector Value Added was 20% higher than the EU ICT sector Value Added, while in terms of ICT BERD the EU ICT sector invested only 40% of the US level. This asymmetry is further analysed in the following paragraphs.

The difference in ICT Manufacturing BERD intensities between the EU and the USA was, in 2009, rather small (29% vs. 35%). In ICT Services, however, the EU ICT sector produced as much Value Added as the USA, while EU ICT Services BERD was only half of US ICT Services BERD, resulting in a large difference in BERD intensity. EU ICT Services BERD intensity in 2009 was only 3% compared to 7% in the USA, i.e. less than half the US level. Although these percentages look small, they have in fact a large impact on the difference in total ICT sector BERD intensity between the EU and US because of the strong weight of ICT services in the ICT sector of both economies in terms of Value Added (above 90% in the EU and 80% in the US, as observed in Fig. 3). In the next paragraph we analyse this difference further by distinguishing between the two main industries in ICT Services: Telecom services and Computer services (Computer services include software publishing, computer programming, data processing, etc.).

Both ICT Services industries – Telecom services and Computer services – contributed with an equal share to ICT Services Value Added in 2009, in both the EU and US (see Fig. 11). In terms of ICT BERD however, while the EU Telecom services industry contributed in 2009 to about 30% of BERD in ICT Services – and therefore Computer services to about 70% – the US Telecom services industry contributed to only 3% of BERD in ICT Services and therefore Computer services to 97%.

Therefore the difference in ICT BERD intensity between the EU and US can essentially be attributed to the significantly larger investment in R&D in the US of the Computer services industry, which includes for example those companies active in the development of internet worldwide. A possible additional explanation for the disparity in ICT Services Value Added and BERD between the EU and the USA – not independent from the previous one – may be the increasing internationalisation of R&D: it may well be that EU ICT companies perform R&D in the USA to a much greater extent than US ICT companies do in the EU.[21] This observation and possible explanation require further research.

Interestingly, although the Telecom services industry in both economies produced about the same amount of Value Added in 2009, it invested about five times more in BERD in the EU than in the USA. A possible reason could be the fragmented nature of the EU telecom market with separate markets in 28 Member States that could lead to additional R&D activities in the different markets. This point also requires further research.

4.3. Comparing ICT labour productivity in Korea, Taiwan and Japan

In this last section, we compare ICT labour productivity in Korea, Taiwan and Japan. As shown in Fig. 5, ICT labour productivity in Korea and Taiwan is lower than that of the EU, the USA and Japan. In both Korea and Taiwan, ICT labour productivity in 2009 was about €40,000 per employee, while it was €90,000 in Japan, more than twice as much. This strong difference is puzzling given that ICT sectors in these countries are certainly similarly technologically advanced and produce

[16] One can therefore also look at this issue from the opposite side and claim that US ICT Employment may well be underestimated.

[17] See also the case of Nokia N95 in Ali-Yrkkö, Rouvinen, Seppälä, and Ylä-Anttila (2011).

[18] http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/lfs.

[19] The Current Population Survey (CPS), sponsored jointly by the U.S. Census Bureau and the U.S. Bureau of Labor Statistics, is the primary source of labour force statistics for the population of the United States.

[20] http://www.spiegel.de/international/business/europe-versus-america-do-longer-holidays-translate-to-greater-productivity-a-643900.html.

[21] See Nepelski and Stancik (2011) and De Prato et al. (2011b).

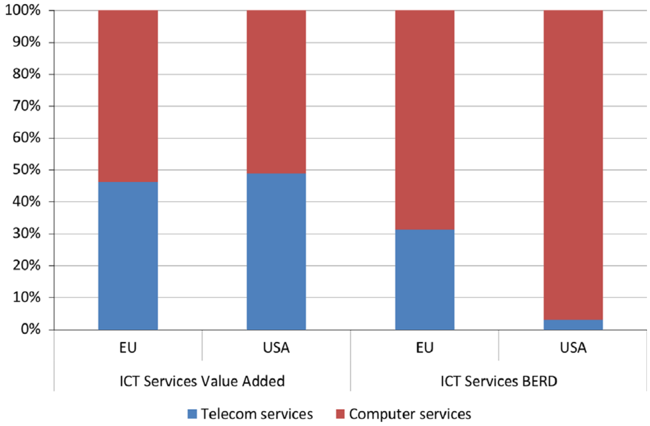

Fig. 11. ICT Services Value Added and BERD breakdown by main ICT service industries in the EU and the USA (2009).

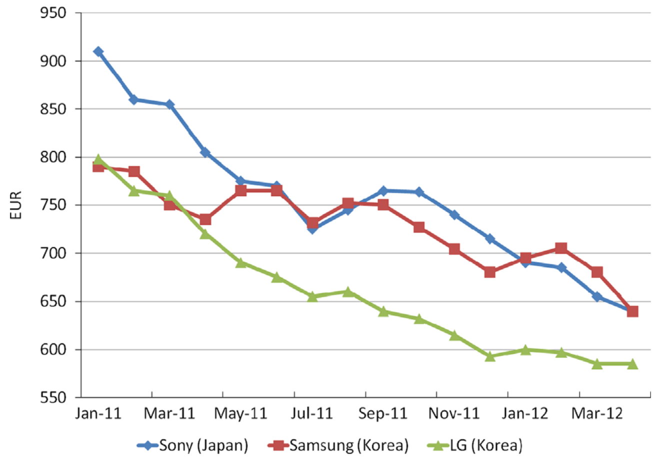

Fig. 12. Average LCD TV pricing of Samsung, LG and Sony (2011–2012).
Source: Meko – a specialist European market research consultancy with expertise in displays. http://www.meko.co.uk/index.php/component/content/article/52-tv/221.

very similar products. Here again we do not provide demonstrated explanations but propose possible factors to be further investigated.

A first likely explanation is the strong specialisation in ICT Manufacturing of the ICT sector of Korea and even more of Taiwan, while the ICT sector of Japan is more specialised in ICT Services.

One of the possible reasons for the lower labour productivity in ICT manufacturing in Korea versus Japan could be comparatively lower Value Added, rather than comparatively higher level of Employment. This lower Value Added may be due to difference in the price that the market was or is ready to pay for a product sold by a Korean company versus a product sold by a Japanese company. It could be the case that for products with similar characteristics put on the market by Korean and Japanese ICT firms, the Korean products have (or had) a lower price than the Japanese ones, resulting in lower Value Added in Korea for similar volumes. For instance, as we can observe in Fig. 12, Sony LCD TV sets were in early 2011 on average about €100 more expensive than Samsung or LG sets. While the Samsung price eventually caught up with Sony in 2011, the price of the average LG set remained by early 2012 about $50 less than of a Sony or Samsung one. Although this price difference could explain only about 10–15% of the difference in ICT labour productivity between these countries, it can also be assumed that the price difference was larger in 2006–2009. Here again, this possible factor and others require further investigation.

A possible explanation for the lower ICT manufacturing labour productivity of Taiwan's ICT sector (versus that of the Japanese one) could also be the lower Value Added of its products. In the case of Taiwan this lower Value Added could be due to the fact that its – strong – ICT manufacturing sector is more focused on a production of intermediate goods and components whose prices are essentially lower than final products. Therefore, lower ICT manufacturing Value Added in Taiwan may be due to its component-oriented production, while in Korea it may be due to a lower market maturity of its products (see Tsai, Lee, and Yu (2008) for further discussion about the ICT sector in Taiwan). Monitoring of this indicator and of the evolution of the markets for Korean and Taiwanese products over time should tell whether these explanations are realistic or not.

5. Conclusions

In this paper, we have characterised and compared, using most recent official macro-economic data, status and evolution of the ICT industry of the six major global economies in terms of their ICT industry: China, the EU, Japan, Korea, Taiwan and the USA. The ICT industry provides key technologies and solutions necessary for the development of the digital economy and society, and makes an important direct and indirect contribution to economic growth. Such an analysis is particularly relevant to policy makers and can guide the development and monitoring of policies aiming at increasing economic performance and competitiveness.

In this concluding section we summarise the main observations of the paper. We end with a final remark on the globalisation of the ICT industry and some tentative policy implications of our analysis for the EU.

These six economies are the main global players in ICT either because of their size (EU, USA and China) or of their specialisation in ICT (Taiwan, Korea and Japan). The EU has the largest economy of the world, but it was in 2009 the least ICT-specialised economy of all six major ICT players. Its levels of ICT Value Added, labour productivity, and ICT BERD were strong in 2009, but second after those of the US, and third after Japan in terms of labour productivity. EU and US Value Added in ICT Services were similar, and by far the largest in comparison with other economies. Specialisation of the EU ICT sector towards Services is the strongest of all six players. The EU is the only economy – of the analysed six economies – in which ICT BERD was higher in Services than in Manufacturing in 2009. The EU ICT sector leads over the US in terms of BERD intensity in Telecom Services, while the US ICT sector leads in Computer Services.

The USA is clearly the top global player in ICT in many respects. In both ICT Manufacturing and ICT Services it has the largest Value Added, BERD, BERD intensity and labour productivity. The US ICT sector was in 2009 twice as labour productive as that of the EU. Like in the EU it is strongly specialised in Services. Strong US ICT sector BERD intensity appears to be for a large part due to the important share of BERD in the computer services industry, an industry which includes for example those companies active in the development of internet worldwide.

China has, by far, the largest number of employees in both ICT Manufacturing and Services. Its ICT sector is more oriented towards ICT Manufacturing in terms of employment but its ICT Value Added is equally distributed in Manufacturing and Services. ICT Manufacturing Value Added was in 2009 equal to that of the US. Its levels of ICT BERD and ICT BERD intensity were low in 2009, compared to the EU, USA and Japan, and also compared to Korea and Taiwan in terms of ICT BERD intensity. This may be due to the strong presence of foreign ICT firms in China essentially performing production activities, while R&D investments may mostly be done elsewhere. China is however a strongly emerging economy, and its ICT BERD intensity, number of ICT patents applications, and ICT Employment have strongly grown from 2006 to 2009.

Japan's ICT sector has a larger weight in the national economy than those of the USA, EU, and China. Japan's ICT sector is also strongly specialised in Services in terms of ICT Value Added and Employment. Japan's total ICT BERD was in 2009 lower than that of the EU, although its ICT Manufacturing BERD was higher. Japan still is the country from which the highest number, by far, of ICT patent applications originated, although this number decreased significantly from 2006 to 2009.

Of all six major global players in ICT, Taiwan's economy is the most ICT-specialised. In 2009, Taiwan's ICT Value Added represented more than 10% of the total for its economy and ICT BERD more than 70% of Taiwan's total BERD. Taiwan's ICT sector is also the most specialised in Manufacturing with above 70% of Value Added, above 80% of ICT Employment and above 90% of ICT BERD in 2009. Its level of ICT labour productivity, particularly in manufacturing, is comparatively low, possibly due to specialisation in components manufacturing rather than final products. Its ICT manufacturing BERD intensity is also comparatively low, although it strongly increased from 2006 to 2009.

Korea is also a strongly ICT-specialised economy, although less than that of Taiwan. Its ICT Value Added is more oriented towards Manufacturing than Services. In 2009 almost 90% of its ICT BERD was in Manufacturing and its level of ICT Manufacturing BERD was higher than that of China. From 2006 to 2009 its level of ICT BERD intensity strongly increased, while its number of ICT patent applications, which was second after that of Japan in 2006, was overpassed by the number of applications from China in 2008.

5.1. Globalisation of the ICT industry

While in this paper we have characterised and compared the evolution of major global players in ICT, it was beyond its scope to consider interactions between them, although this interaction is implicitly referred to in Section 4 of the paper. In today's globalised economy, the evolution of the ICT industry in particular cannot be fully understood without considering also global networking. ICT value chains span the globe; ICT firms select on a global basis the best locations, not only for ICT production, but also for ICT R&D and innovation. Business and R&D and innovation partnerships take place on a global basis. In 2010 the PREDICT project started analysing global collaboration in ICT R&D and innovation by analysing patent data and the location of R&D centres globally. Among the main observations from these studies, there is evidence that international cooperation in ICT R&D is evolving from a previously dominant EU–US link to global networking where the US–Asia relation is taking a growing stake (De Prato, Nepelski, and Paul Simon 2013; De Prato et al., 2011b; Turlea et al., 2010, 2011).

5.2. Policy implications for the EU

Based on the analysis presented in this paper, we venture to propose the following policy implications for the EU.:

The US ICT sector remains the benchmark: The many similarities between the EU and US ICT sectors and the fact that the US is the world leader in this domain – and will most likely remain so in the coming years – clearly indicate that in spite of the rise of Asian economies such as China, the US remains the benchmark for the EU. The EU should continue to compare its performance in the ICT domain with that of the US and aim to improve this performance by looking at good practises from the US.

But watch also the Chinese ICT sector: The fact that BERD intensity in China is strongly rising however indicates that it is also necessary for the EU to monitor and better understand what is happening in China especially in term of R&D in ICT.

And consider the role of global value chains: Although our analysis was focused on individual economies, it is clear that global value chains play an increasingly important role for the ICT industry of these economies. Policy makers need to take into consideration the increasing globalisation of the ICT industry, not only in terms of markets, but also in terms of the global distribution of human resources and knowledge.

A final implication of our analysis is that, as suggested in Section 4, it is often necessary for analysts to "dig deeper" in order to try to identify and understand the root causes of the differences between countries or world regions shown by statistics.

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