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Cloud computing

An overview of economic and policy issues

IN-DEPTH ANALYSIS

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Cloud computing is a new model for providing information technology services over the internet. It promises to reduce costs, increase flexibility in provision and encourage innovation. However, if economic growth and job creation is to be assured, issues of data protection, privacy and security, as well as interoperability and portability of data and applications, may require public policy responses. Cloud computing is an important aspect of the European Union's Digital Single Market Strategy.

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EXECUTIVE SUMMARY

Cloud computing is a model for providing information and communication technology (ICT) services (including servers, systems, storage and applications) over a network such as the internet. By taking advantage of self-service implementation and configuration, and flexible pools of virtual computers based on shared hardware in vast purpose-built data centres managed by third parties, cloud customers can rapidly increase (or decrease) their ICT capacity as needs or demands change, while avoiding capital outlays and paying only for the actual services used.

Cloud computing providers can take advantage of variable demand cycles of different clients and economies of scale to supply computing services at lower cost than would be possible in individual, in-house data centres. More importantly, because cloud customers can ramp up services quickly, they can innovate with new products at low cost or rapidly scale up successful prototype services. Cloud computing is also considered to be more energy efficient than traditional in-house centres, potentially reducing negative effects on the environment. Individual consumers of cloud-based e-mail, file- or media-sharing services get access to their information anywhere, often at little or no cost.

However, because cloud computing uses shared computing environments and relies on the public internet for transmitting information, it raises concerns about security and personal data protection. Also, the lack of interoperability between cloud service products and the absence of standards that would facilitate data portability may make it difficult for customers to switch vendors. Fixed or obscure contract terms that limit liability or service guarantees may also restrict customers' rights.

The European Commission considers cloud computing central to the EU's competitiveness and a key to economic growth and innovation. As part of its Digital Single Market Strategy, the Commission has a European Cloud initiative that will propose certification of cloud services, reduce the risks of vendor lock-in, and provide a research cloud for researchers to share access to research data. The Commission has also promised to propose in 2016 a 'free flow of data initiative' that will tackle restrictions on where data is located.

TABLE OF CONTENTS

List of main acronyms used

CRM:	Customer relationship management
IaaS:	Infrastructure as a Service
ICT:	Information and communication technology
PaaS:	Platform as a Service
SaaS:	Software as a Service

1. Introduction

1.1. What is cloud computing?

Cloud computing is a model for providing or obtaining information and communication technology (ICT) services over a network like the internet.[1] The services provided may include servers, operating systems, networks, software, storage and applications. Cloud services are provided through a scalable and 'elastic' pool of shareable resources based on physical resources (hardware) in purpose-built data centres. Using self-service provisioning, configuration and administration, users can rapidly ramp up (or down) their ICT capacity as demand changes. They also avoid capital costs (i.e. costs incurred in the purchase of assets used in production) and pay only for the actual services used. Because users do not have a direct view of how these virtual computer resources are provided, or even where they are located, and because the resources can be used from anywhere the internet is available, the resources are said to be 'in the cloud'.

Cloud computing is not, strictly speaking, a new technology. Rather, it is a new paradigm for computing that has developed as a result of advances in various technologies, in particular widespread high-bandwidth internet (providing fast response time to remote computing resources from almost anywhere) and virtualisation technology (offering a computing infrastructure that appears to be dedicated to a single customer but in fact shares physical hardware with other cloud customers and applications). A company that specialises in providing cloud services can take advantage of economies of scale and variability in demand across many customers to reduce the cost of the services provided.

1.2. Types of cloud computing

Cloud computing is delivered through one of three basic service models with progressively increasing levels of service offered to end users. **Infrastructure as a Service (IaaS)** provides users with a basic computing infrastructure on which they can install operating systems, security software and applications. In effect, this cloud-based service can substitute for locally installed physical hardware such as server computers and storage drives. In **Platform as a Service (PaaS)** the cloud supplier provides, on top of this physical infrastructure, operating systems, programming libraries and other tools which users can employ to create or deploy their own applications. Finally

[1] The National Institute of Standards and Technology in the US provides a more formal definition of cloud computing as 'a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interactions' (P. Mell and T. Grance, The NIST definition of cloud computing, NIST special publication 800-145, 2011). The International Telecommunications Union's definition is 'a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand where examples of resources include servers, operating systems, networks, software, applications, and storage equipment' (Information technology – Cloud computing – Reference architecture, Recommendation ITU-T Y.3502, 2014). The EU Council of Ministers has recently suggested, in a political agreement on a first reading draft of the Network and information security (NIS) Directive, defining a 'cloud computing service' simply as a 'digital service that enables access to a scalable and elastic pool of shareable computing resources' (Council document 5894/16, 10 February 2016). The OECD defines cloud computing as ICT services used over the Internet as a set of resources to access server, storage and network components, as well software applications.

Software as a Service (SaaS) provides the customer with an end user application (e.g. an email application for an organisation) as well as the underlying computing resources required to run it. It is sometimes referred to as 'software on demand'.

Cloud services can also be deployed in different ways. A **private cloud** is dedicated to the use of a single organisation and can be based on hardware located either on the site of the cloud provider or the organisation. These are used predominantly by large businesses. A **public cloud** is a 'multi-tenanted' environment, in other words, it is intended for shared use by a number of end users (e.g. small and medium-sized businesses, but also public-facing applications for larger corporations) and is located on the premises of the cloud supplier. **Community clouds** provide service to organisations that belong to a community and have similar requirements, for example, companies in a vertical sector such as health care, or different government bodies and agencies. **Hybrid clouds** link private and public cloud instances in order to enable interoperability between public-facing and private applications and data.

While many cloud computing services are aimed at businesses or public sector bodies, it is important to bear in mind that cloud computing is also used directly by individuals for applications like web-based email (Gmail) or for storing or sharing documents, photos, music or video files (e.g. Dropbox, Google Drive). Of course, individuals may also contract directly with a cloud service provider for IaaS or PaaS services, but more common is the situation where consumers use web-based applications whose operations are hosted in a private cloud based in data centres built or leased by the company for its own exclusive use (e.g. Facebook[2]) or applications where the supplier relies exclusively on public cloud infrastructure obtained from a cloud supplier (e.g. Netflix which exclusively uses Amazon's cloud services[3]). As end users of these internet-based services, however, consumers may not be aware that the application uses the cloud, and they may not care.

1.3. The global market for cloud services

Companies offering cloud services originate in a number of different sectors:

- Online consumer services such as Google and Amazon;
- Technology companies such as IBM and Microsoft;
- Application-oriented start-ups such as Salesforce; and
- Telecommunications providers such as Verizon.

Some companies may have cloud offerings that in fact are based on the underlying cloud services of another company. For example, Apple's iCloud end-user service uses some Apple-owned facilities but also lower level cloud services purchased from Google, Amazon and Microsoft.[4]

Overall, the US has been ahead of the EU in terms of cloud computing. For example, a 2014 report found that all but three of the 20 top enterprise cloud computing services in the world were US-based; another analysis of the worldwide IaaS market found that all but two of the 15 vendors analysed were US companies.[5] Economies of scale that

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[2] Data Center Knowledge, The Facebook Data Center FAQ, n.d.

[3] Donnelly, C. Netflix shuts down final datacentre to go all-in on public cloud, ComputerWeekly.com, 2015.

[4] Hook, L, T. Bradshaw. Apple signs up to Google Cloud Services, Financial Times, 17 March 2016.

[5] US Department of Commerce, International Trade Administration, 2015 top markets report: cloud computing, 2015, p. 3.

derive from serving large numbers of organisations mean that a competitive advantage accrues to early entrants into the marketplace. European cloud providers tend to operate in niche markets, although a few European companies such as SAP, a prominent German software firm specialising in business and Enterprise Resource Planning (ERP) software, compete with the largest players.

Table 1 – Selected cloud computing offers

Provider	Type of offering		
	IaaS	PaaS	SaaS
Amazon	EC2	Elastic Beanstalk	AWS
Google		App Engine	Gmail Google Docs
Microsoft		Azure	Office365
Salesforce.com		Force.com	Sales Cloud
Rackspace		Rackspace Cloud	Rackspace Cloud
IBM	Blue Cloud		CloudBurst
EMC	Atmos		
Apple			iCloud
AT&T			Synaptic Hosting
VMware	vCloud Director		

Source: Srinivasan, S. Cloud computing basics, Springer, 2014, p. 10.

Although the technologies underlying cloud computing are not new, cloud computing has increasingly become important both for businesses and individuals, and the global marketplace for the cloud continues to grow rapidly. Consulting firm Gartner has identified the use of different types of clouds to support 'computing everywhere' as one of the top technology trends for a number of years. Gartner estimates that the total market for public cloud services alone was US$ 180 billion in 2015, and expected this to rise to more than US$ 200 billion in 2016.[6] Using a different approach, Forrester Research predicts that worldwide business spending on cloud services will rise from US$ 72 billion in 2014 to about US$ 191 billion in 2020.[7]

Similar rapid growth is seen for networks due to traffic generated by cloud usage. According to equipment supplier Cisco, global cloud traffic will more than quadruple between 2014 and 2019, due in large part to the increasing number of personal mobile devices, the growth in use of public clouds by businesses and increased virtualisation of private clouds.[8] Much of the increase in cloud computing is expected to come from the

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6 Hook, L. 'Sky's the limit for Amazon Web Services', Financial Times, 13 April 2015.

7 US Department of Commerce, International Trade Administration, 2016 top markets report: cloud computing, 2016, p.6.

8 Cisco, Cisco global cloud index, forecast and methodology, 2014-2019 white paper, 2015. Accessible via Cisco global cloud index projects cloud traffic to quadruple by 2019, 2015.

growing importance of SaaS services and from wider adoption of the public cloud.[9] The Internet of Things (IoT)[10] is also expected to contribute to increases in cloud services through storage of the vast amounts of data generated by connected smart objects.

The increasing scale of cloud computing means that cloud computing is beginning to become 'industrialised' and the services treated as a commodity. If these trends continue, computing services may one day approach the status of a utility such as electricity, gas, water and telephone supply. As such, cloud computing could play a critical role in economic and social life, and could increasingly become a focus for public policy.[11]

1.4. The current extent of cloud computing

Measuring the current extent of cloud computing can be problematic in part because of the different types of cloud usage, the difficulty of matching a software service to a generic description, and the fact that many users of cloud computing are not aware that the services they use are part of the cloud. Apart from the usual methodological differences such as differences in sectors covered or survey size, this means figures can vary substantially from one source to another.[12]

According to a Eurostat study in 2014, cloud computing was used by almost one in five enterprises in the EU, although differences in use between Member States, companies of different sizes and different sectors were considerable. Member States with the largest percentage of companies using the cloud were Finland (51%), Italy (40%), Sweden (39%) and Denmark (38%), while in other countries (Romania, Latvia, Poland, Bulgaria, Greece and Hungary) less than 10% used the cloud.

Note, however, that the consulting company IDC, in a study on behalf of the European Commission, found higher rates of cloud utilisation: in 2013, IDC found that more than 63% of businesses in all sectors reported at least one public cloud solution. The difference between these and the Eurostat figures may be due in part to a focus on different aspects of cloud computing, the scope of enterprises surveyed (e.g. Eurostat excludes the financial sector, which IDC found to be the second highest user of cloud computing), geographical scope (IDC study was restricted to five of the large Member States), survey size, respondents' understanding of the concept (particularly packaged offers), and the degree to which survey respondents were prompted about possible cloud services.[13]

Worldwide, in 2014, IDC has found that half of all companies (including all sizes of companies) were using at least one SaaS public cloud service, and a fifth were planning to implement one within the next year. The use of PaaS and IaaS were reportedly lower, at under 40% and just over 30% respectively.[14] Statistics from OECD member

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9 US Department of Commerce, International Trade Administration, op.cit., p. 7.

10 For a general introduction to the Internet of Things, see the EPRS briefing The Internet of Things: opportunities and challenges, Davies, R., European Parliament, 2015, PE 557.012.

11 The proposed network and information security Directive, the subject of a political agreement between Council and Parliament in December 2015, recognises the critical role of cloud suppliers by including them in the category of companies that are obliged to report serious security breaches.

12 See for example, OECD, op.cit., p. 193, Measurability box.

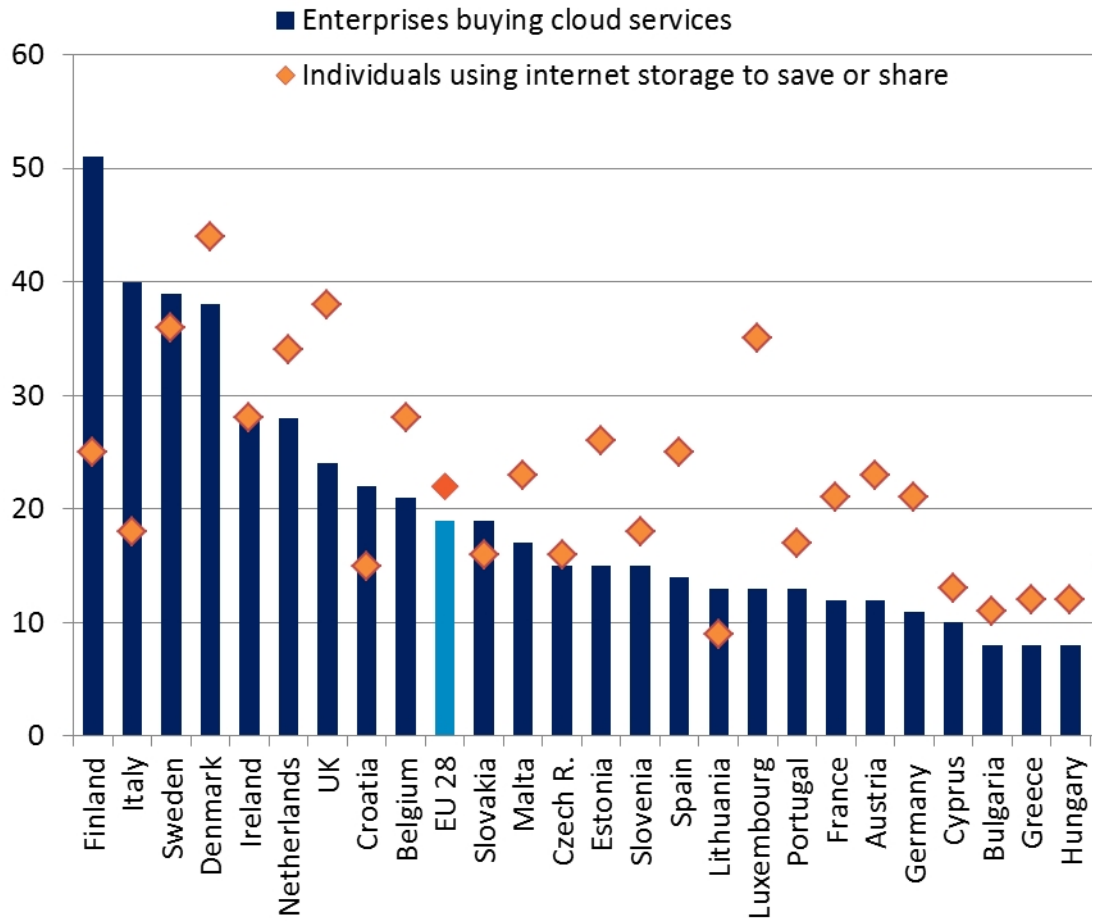
13 IDC states 'cloud usage is often under-reported by user organisations... many respondents fail to realise that web collaboration is a cloud service unless it is pointed out to them.' IDC, Uptake of Cloud in Europe, European Commission, 2014, p. 20.

14 Car, M., Buying into the cloud, IDC market spotlight, 2015.

countries in 2014 showed that cloud computing use varied with company size: among large companies it was higher (almost 40%) than among small (20%) or medium-sized enterprises (27%),[15] although some experts expect that gap to close considerably in the coming years.[16] Perhaps not surprisingly, the ICT sector and finance sectors were reported to have proportionately the most companies using the cloud (45%), followed by the professional, scientific sector and technical sector (27%). IDC also reports that the public sector use of the cloud lags behind the private sector, possibly due to security concerns and long-running contracts for traditional outsourcing, though public sector adoption is increasing.

IDC has also determined that cloud computing now represents a significant proportion of IT budgets when compared to traditional in-house or traditionally outsourced computing services, though it still accounts for less than half of total expenditures (see Figure 2).[17] However IDC expects that the proportion of expenditure on cloud-based services will continue to increase with, for example, external cloud services growing from 42% of IT budgets in 2014 to more than 56% by 2016.[18]

Figure 1 – Enterprises buying cloud services and individuals using internet storage to save or share files in 2014 (% of enterprises or % of individuals)



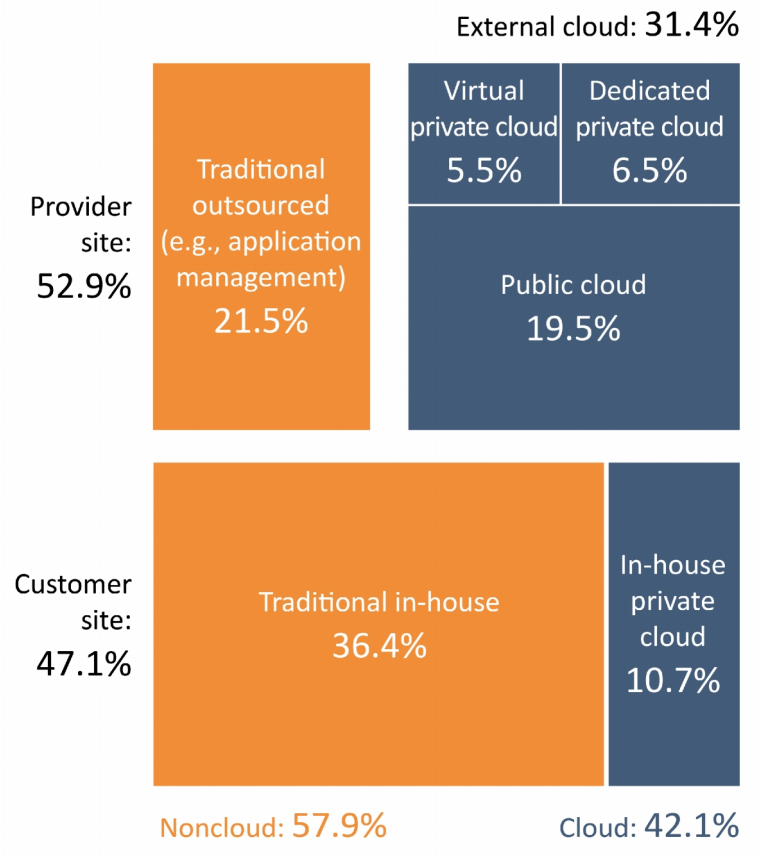
[15] OECD, OECD science, technology and industry scoreboard, 2015: innovation for growth and society, 2015, p. 192.

[16] IDC, Uptake of the cloud in Europe, European Commission, 2014.

[17] Note, however, that elsewhere IDC only predicts that cloud spending in the EU will represent 10.8% of all IT spending by 2020.

[18] Car, M., Buying into the cloud, op.cit.

Figure 2 – Computing approaches as percentage of IT budgets, 2014



Source: M. Car, Buying into the Cloud, IDC market spotlight, 2015.

The most common applications for enterprises using the cloud were email (66% of companies), file storage (53%), database hosting (39%), and office, financial and customer relationship management (CRM) applications (respectively 34%, 31% and 21%); only 17% of enterprises used the cloud for running their own software. However, many organisations are only using the cloud for one or two applications, so there is scope for increasing use of the cloud for other applications within a business: IDC has predicted that the average number of cloud applications per company will have increased from 1.4 to 3.6 between 2013 and 2015.

Cloud computing is not just for businesses, however. It can also be used directly by individuals for applications like email or for storing or sharing documents, photos, music or video files that can be accessed from anywhere at any time. Many of these services are particularly attractive in that they are largely offered for free, i.e. only a small percentage of users pay for them. Measuring individuals' use of cloud services can be difficult, however, in that there is not always in users' minds a clear distinction between cloud computing and other online services that may use on-premises data centres or that may themselves use the cloud, such as Facebook or Netflix;[19] over a quarter of internet users are not aware of cloud services.[20] Nevertheless, in 2015, the OECD reported a considerable rise in the number of internet users using cloud computing services for storing and sharing files.[21] As with companies, the uptake of

[19] OECD, op.cit., p. 219.

[20] European Commission, A Digital Single Market strategy for Europe: analysis and evidence, 2015. Staff working document SWD(2015) 100 final, p. 60.

[21] OECD, op.cit., p. 218.

cloud computing among internet users in 2014 also shows considerable variation between EU Member States, ranging from 46% in Denmark to 13% in Romania (see Figure 1). Perhaps not surprisingly, in 2014 younger Europeans (aged 16-24) were much more likely to use the internet for storing or sharing files (35% and 25% respectively) than either 25-54 year olds (25% and 18%) or older people (10% and 6%).[22]

What is a data centre?

Data centres are facilities that centralise ICT operations and equipment used to store, process and disseminate data.[23] By bringing together critical equipment and systems in one space, ICT staff can better ensure the security and reliability of information, and provide better infrastructure, including power supply and cooling. The evolution of data centres has been characterised in part by the deployment of large numbers of rack-mounted computers, and virtualisation techniques that create a level of abstraction between processing and the underlying physical hardware in order to allow separate computing environments to run on the same equipment. Enterprise data centres are owned and operated to serve one company, and are often located on company premises; public cloud computing suppliers own and run their own data centres in various locations for the use of a wide range of users. In between these two extremes, there are various intermediate options, including enterprise data centres for which the management is outsourced to a specialised ICT company, and a private cloud managed by a cloud supplier for a single enterprise and located on the premises of either the enterprise or the provider.

2. Benefits of cloud computing

2.1. Specific benefits of cloud computing

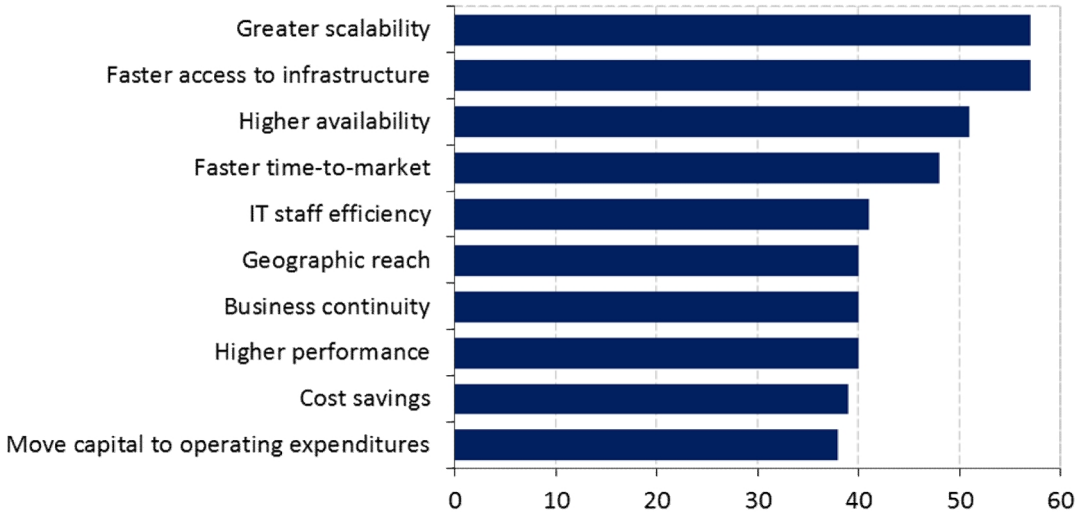
Cloud computing can bring important benefits to both organisations and individuals. Perhaps the most obvious benefit is **cost reduction**. On-site ICT facilities are generally over-provisioned to allow for future growth or spikes in demand. In a data centre run by a cloud supplier, different clients will need computing resources at different times and provision does not need to be made for individual demand peaks: instead, cloud providers can quickly re-allocate resources away from those who currently need less towards those who need more. Server utilisation rates are therefore much higher and the resulting lower costs can be passed on to cloud customers. Due to this aggregation of demand, cloud suppliers also benefit from economies of scale, saving on purchasing and operating costs, including the cost of maintaining and upgrading hardware and software. The result is that four out of every five companies adopting cloud computing were able to reduce costs by 10% to 20%.[24]

[22] Eurostat, Internet and cloud services: statistics on the use by individuals, Statistics in focus, 2014.

[23] Source: Paloalto Networks, What is a data center? n.d.; Bullock, M., Data center definition and solutions, CIO, 2009.

[24] European Commission, Unleashing the potential of cloud computing in Europe, Staff working document SWD(2012) 271 final.

Figure 3 – Benefits of the cloud, 2015
% of survey respondents reporting these benefits



Data source: RightScale, 2015 state of the cloud report, 2015. The survey is based on responses from 930 technical professionals representing a broad cross-section of organisations.

However, cost is not the only, or even the most important, driver for adoption of cloud services: in a 2014 Gartner survey of chief information officers, cost savings only represented 14% of the reasons for use of the public cloud.[25] Rather, it is the **rapidity** with which cloud resources can be obtained, and the **elasticity** in cloud suppliers' ability to meet that demand, that means that companies do not have to plan to invest large sums in ICT hardware and software. The cloud allows enterprises to scale up applications rapidly, and to pay for computing services only when demand arises rather than in advance. In other words, they can purchase computing resources 'just in time' rather than 'just in case' which means that they are able to treat ICT expenditures as operating rather than capital expenditures. Because the need for capital is reduced, the barriers to entry into a market are lower for start-ups or firms wishing to innovate.

Figure 4 –Expected benefits of cloud computing, 2013
% of survey respondents reporting these as 'high' or 'very high'

Data source: ETSI, Cloud computing user needs, 2015. The web-based survey targeted European SMEs in the private sector, but accepted input from larger entities. 376 responses were received.

[25] Gartner, The top 10 cloud myths, 2015. Also perhaps surprisingly, the high cost of cloud services was mentioned by 31% of enterprises that did not currently use the cloud.

In the words of one expert, 'the major beneficiaries of cloud computing are **small and medium-sized businesses** as this new concept provides them an opportunity to try out high-end services with no up-front costs, allowing them to use the pay-as-you-go model.'[26] An informal 2015 survey on cloud computing users' needs (see Figure 4) that concentrated principally on small and medium-sized enterprises (SMEs) found that the users' expectations for cloud computing were highest in terms of improved business agility (76% of respondents had 'high' or 'very high' expectations), faster time-to-market (71%), and reduction of capital expenditures (61%); these were considerably above other expectations such as increased focus on core mission (51%) and reduction of operational costs (50%).[27]

Because cloud resources are accessed over the internet, businesses or individuals can also use data and applications from locations **almost anywhere** in the world, even on mobile devices. This benefit can be particularly important in the research community, where large data sets (often expensive to collect or maintain) can be used or shared by researchers at different institutions or in different countries.

Cloud computing also has the potential to boost **energy efficiency** and reduce **environmental effects**. Cloud services are provided through large data centres with very large numbers of servers. Energy costs represent about 30% of the total cost of data centres.[28] Given these costs, cloud suppliers make efforts to endure that their data centres are as efficient as possible, typically locating them in places where electricity supply is cheap and abundant, water supply is reliable and temperatures are low (cooling represents the largest energy need).[29] Calculation of the energy requirements of the cloud is complex due to the variable factors of network transmission,[30] application use and server utilisation rates; however, globally, total energy use of data centres (including both cloud and on-premises centres) is expected to increase from 95 billion kilowatt-hours to more than 140 billion between 2015 and 2020.[31] An American model showed that if businesses moved common applications to the cloud, they could shrink their computing energy footprints by 87%.[32] And although the real environmental effects depend on the source of the electricity consumed in data centres[33] (e.g. 'dirty' fossil fuels versus 'clean' renewable sources), it has been estimated that small and medium-sized organisations that move from on-premises servers to a private cloud would see an average improvement in carbon emissions of almost 80%.[34] A 2012 study funded by the Global e-Sustainability Initiative (GeSI) and Microsoft confirmed that if 80% of enterprises in 11 countries studied[35] closed down on-site servers and instead adopted cloud-based email, CRM and groupware

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[26] Srinivasan, S. Cloud computing basics, Springer, 2014, p. 6.

[27] European Telecommunications Standards Institute, Cloud computing users needs (Phase 2), 2015.

[28] Shead, S. Energy costs mean tough decisions for datacentre owners, ZDnet, 2013.

[29] Bery, R and M. Reisman, Policy challenges of cross-border cloud computing, Journal of international commerce and economics, Web version, May 2012.

[30] Zyga, L., 'How energy-efficient is cloud computing?' PhysOrg.com, 8 October 2010.

[31] Ascierto, R. et al., 2016 trends in datacenter technologies, 451 Research, 2015. For comparison purposes, the final electrical energy consumption of Poland in 2014 was 126 billion kilowatt-hours. Source: Eurostat, nrg_105a, 2016.

[32] Irfan, U, 'Cloud computing saves energy', Scientific American 12 June, 2013.

[33] Greenpeace, How clean is your cloud?, 2012.

[34] Natural Resources Defense Council, 'Is cloud computing always greener?' Issue brief, October 2012.

[35] Brazil, Canada, China, Czech Republic, France, Germany, Indonesia, Poland, Portugal, Sweden, the UK.

applications, they would reduce greenhouse gas emissions by 4.5 megatonnes (Mt) of CO2 (equivalent to the emissions of 1.7 million cars) and would pocket more than US$ 2.2 billion in energy savings.[36]

For **individuals**, low cost is also one factor in the use of cloud services: only 11% of Europeans using the cloud in 2014 actually paid for internet storage space,[37] although cloud service suppliers can benefit from using user data, e.g. in targeted advertising. Similarly, cloud computing provides individuals with flexibility and ease of access to applications and stored content which can be accessed irrespective of time and place. Europeans cite the ability to use files from several devices or locations (59% of cloud users), the ability to share files with others (59%), protection against data loss (55%), access to a larger memory space (44%), and access to large libraries of content such as music, films or TV programmes (22%) as reasons for using cloud services.[38]

2.2. General economic impact

The reductions in ICT costs, increased business competitiveness and the greater investment in business development that cloud computing can bring about are expected to have a beneficial effect on the overall economy of the EU. According to a study by IDC for the European Commission, based on the most likely scenario for future economic trends over the period 2015-2020, the value of cloud services is expected to be between €24.4 billion and €59.6 billion in 2020 (IDC). The use of cloud computing in the EU would create an additional 1 million jobs, give rise to more than 300 000 new companies, and cumulatively contribute almost €450 billion to the EU's gross domestic product (including more than €100 billion of new GDP in 2020, which represents about 0.71% of GDP).[39] These figures exclude the impact of cloud computing on the public sector, e.g. in eGovernment services.[40]

Nevertheless, some analysts feel that projections for economic growth due to cloud computing are overestimated, since moving to the cloud often involves just a shift from one form of expenditure to another, and may in fact be deflationary.[41] For example, the IDC study found that every euro spent on SaaS replaces €2.30 of expenditure needed to achieve the same result through a traditional ICT solution; replacement figures for PaaS and IaaS were slightly lower at €1.80.[42] This reduced spending could have a negative effect on GDP unless it results in increased competitivity, greater investment in new or improved products or services, increased sales and more jobs.

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[36] Thomond, P. The enabling technologies of a low-carbon economy: a focus on cloud computing, Enabling technology 2020, 2013. Note, however, that cooling systems of data centres in populous areas may also cause noise pollution. See 'Un data center trop bruyant dans le quartier du Sentier à Paris', L'usine nouvelle, 2016.

[37] Eurostat, 'Internet usage by individuals in 2014', 2014. Newsrelease 196/2014.

[38] Eurostat, Internet and cloud services - statistics on the use by individuals, Statistics explained, 2015.

[39] IDC, The uptake of cloud in Europe, 2014.

[40] For more information on eGovernment, see Davies, R. eGovernment: using technology to improve public services and democratic participation, European Parliamentary Research Service, 2015.

[41] 'EU looks to the cloud for economic relief', Information management, Jan/Feb 2013, p. 11.

[42] IDC, op.cit.

3. Barriers to adoption of cloud computing

Despite these touted advantages, not all analysts are enthusiastic about cloud computing. In Gartner's 2015 technology hype cycle, cloud computing is considered to be moving towards the so-called 'trough of disillusionment' after the surrounding hype has peaked and before the technology is widely accepted and implemented effectively.[43] A number of problems regarding cloud implementation have been raised by businesses and other organisations in different contexts including IDC studies for the European Commission, a European Parliament study,[44] and a public data consultation; each has led to slightly different formulations of issues and concerns.

Arguably the most discussed issue related to cloud computing is **personal data protection and privacy**. The issue is complex because different countries have taken different approaches to the legal frameworks so that, as one ICT executive put it, 'data flows are global, yet privacy laws remain local.'[45] The revelation in 2013 by Edward Snowden of mass surveillance of personal communications has led many to consider more carefully who is storing and transmitting their confidential data and where that information is being stored. In some cases, to counter the 'location independence' inherent in cloud computing, national legislation (e.g. in Russia[46]) has required the storage of personal data in a specific geographic location to ensure that it falls under national legislation. However, this requirement may dampen efficiencies and increase costs, fall foul of trade or competition commitments, and raise concerns about surveillance from national security agencies. Also, in many consumer-oriented cloud services, users are provided with free services while cloud providers use collected personal data (e.g. for targeted advertising) to help pay for them. The recently adopted General Data Protection Regulation[47] will have far-reaching consequences for both cloud suppliers and consumers. The issues related to cloud computing and personal data protection will be discussed in greater depth in a separate, forthcoming EPRS publication.

Closely related to the question of data protection is the question of **jurisdiction** In cloud computing, users may be located in one country, suppliers may have their headquarters in another one and have sites in various others. Applications and data are stored in any one of those various sites or even move between them. Cloud suppliers and customers alike may suffer from uncertainty about the applicable regulations concerning intellectual property, data retention and deletion, court orders for disclosure, contract and consumer protection as well as data protection.

Another related problem is **computer security**, which involves the protection of data, communications and applications from unauthorised use or access (including denial of service) as well as any compromise to the integrity of data and applications. Companies moving to the cloud lose direct control over their computing resources and have to rely on a third party to act as their agent; they may suffer if that agent does not perform reliably. Organisations or individuals may justifiably be concerned when they trust other parties with their sensitive data or critical applications. Their data may be less

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43 Gartner Group, Gartner's hype cycles for 2015: 5 megatrends shift the computing landscape, 2015.

44 Policy Department A, European Parliament. Cloud computing, 2012. PE475.104.

45 'Too important to fail - advancing digital values', Microsoft EU policy blog, 28 January 2016.

46 Bauer, M. L. Hosuk, E. Van der Marel, Data localisation in Russia: a self-imposed sanction, European Centre for International Political Economy, 2015.

47 The General Data Protection Regulation (GDPR), Regulation 2016/679, was adopted on 27 April 2016.

secure if it shares a physical infrastructure with other users (in theory, each customer has a separate virtual computing space, but hackers may be able to exploit vulnerabilities.) A significant, though small, percentage of individuals using cloud storage or file sharing claimed they had privacy issues, either in terms of security problems (1%), unauthorised use of information by the service provider (3%) or unauthorised use by third parties (5%).[48]

On the other hand, while security is perceived as a public cloud problem, Gartner points out that most data breaches involve on-premises data; only a small percentage of enterprise-level security incidents have exploited vulnerabilities on the side of cloud providers.[49] Many SMEs lack the resources or expertise needed to provide a high level of security; cloud providers may be better placed to recruit specialised security staff, to install security patches and software updates and to preserve continuity through load balancing and redundant capacity, and hence provide better security than the SMEs are capable of providing on their own. A recent Cloud Security Alliance survey found that 69% of executives and IT managers around the world considered SaaS cloud services to be more secure, or as secure, as on-premises software.[50] Also, the forthcoming EU Directive on network and information security (NIS) that was agreed between Parliament and Council in December 2015, and expected to be adopted by Parliament at second reading later in 2016, requires cloud providers, as well as other digital service providers, to take appropriate security measures and to report cybersecurity breaches to the appropriate authority.

Reliability is another issue when business-critical services are provided by an external supplier. Observers point out the risk of data centres going down, leaving cloud users stranded.[51] However one commentator asserts that the specialists employed by large cloud suppliers are better able to respond to problems than the staff of a soap company or car maker: a victim of one large supplier outage in 2011 is quoted as saying 'Amazon employs some of the best infrastructure engineers in the world. If they can't make it work, then probably no one can'.[52]

Terms and conditions of cloud computing contracts frequently put onerous conditions on usage. For example, a comparison of four consumer cloud service contracts[53] showed that providers avoided liability for availability or functionality, and were indemnified against any harm caused to consumers. The providers could exercise broad discretion in terms of user content or conduct, could change terms and conditions without explicit notification, and could terminate or suspend services without notice. Some standardisation or regulation of service provision could help customers, inspire confidence in cloud services, and encourage uptake. Also, terms and conditions were not always clear: 15% of individuals using cloud services to save or share files reported difficulties understanding the contract.[54]

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[48] Eurostat, Problems experienced when using cloud services, isoc_cicci_pb, 2014.

[49] Gartner, Top strategic predictions for 2016 and beyond: the future is a digital thing, 2015.

[50] Cloud Security Alliance, CSA survey: 69% of IT trusts the cloud as much or more than on-premises solutions, 2015.

[51] Gillis, T., Criticism abounds but cloud computing is here to stay, Forbes, 24 May 2011.

[52] *Ibid.*

[53] Lipinski, T. 'Click here to cloud! End user issues in cloud computing terms of service agreements' In: Gathegi, J. et al. Challenges of information management beyond the cloud, Springer, 2014, pp. 92-111.

[54] Eurostat, Problems experienced when using cloud services, isoc_cicci_pb, 2014.

Since data can be stored or applications used widely, and without regard to physical location, complex questions for cloud suppliers and customers can arise in terms of **export controls and trade commitments**. One observer gives the example of a US-based cloud supplier with an EU customer that has a local office in a country, such as Iran, which is under US trade sanctions[55]. Furthermore, proving copyright infringement may be more difficult when the infringing service is using various cloud suppliers in different jurisdictions to supply its service.

In order for customers to realise the full benefits of cloud computing, **standards** will need to be defined that increase interoperability and the transfer of data and applications between different cloud providers. Otherwise users may find themselves constrained in terms of what they can do, or locked in to a particular vendor's offer. Richard Stallman of the Free Software Foundation has characterised cloud computing as a trap aimed at forcing people to buy into locked, proprietary systems that would cost them more than open software over time.[56] In a Eurostat survey, 5% of individuals using the cloud complained of incompatibilities in devices or file formats, while 2% complained of difficulties in moving data between suppliers; both are issues that could perhaps be alleviated by standards.[57]

In its Digital Single Market Strategy, the European Commission indicated that industry standards activity is increasingly taking place outside of Europe, and that the European bodies responsible need to move quickly to define missing standards essential for digitisation, including cloud computing. Respondents to the ETSI survey found that in terms of the organisational concerns, standards on security (61% of respondents said the impact would be 'high'), privacy and integrity (53%), interoperability across vendor solutions (49%), portability across vendor solutions (49%) and vendor/data lock-in (48%), would have the most impact.[58] The Commission's Rolling Plan for ICT standardisation[59] highlighted the importance to stakeholders of coordination between various different standards bodies, groups and platforms (of which it listed more than 17) including the International Organisation for Standardisation (ISO), where various vocabulary, reference architecture and security standards have been issued and work is ongoing in terms of service level agreements, interoperability and portability.

Other analysts point out **accessibility** concerns in moving to cloud computing. Higher speed broadband connections, which are not available in all areas in the EU, may be required for accessing cloud applications, hence reinforcing a digital divide. Other observers voice concerns about the exclusion of those who do not have or cannot afford cheap, 24 hour internet connections,[60] or argue that EU cloud initiatives have not sufficiently addressed the issue of accessibility for people with disabilities.[61]

Of course, moving computer systems to the cloud, like any ICT project, comes with **risks** for companies: Gartner Research underlines reasons why many cloud computing

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55 Silverman, J., US trade controls and cloud computing, IP litigator, 18(5), pp. 24-30, 2012.

56 Johnson, B. 'Cloud computing is a trap, warns GNU founder Richard Stallman', The Guardian, 29 April 2008.

57 Eurostat, *op.cit.*

58 European Telecommunications Standards Institute, Identification of cloud computing users' needs, Cloud standards coordination phase 2, 2016.

59 European Commission, Rolling plan for ICT standardisation, 2016.

60 Smith, Z., Criticisms of cloud computing, ZSmith.co., n.d.

61 Mitrano, T., How accessibility in the cloud could redefine European citizenship. Euractiv, 2015.

projects may fail, including not engaging with users, putting too much too quickly in the cloud, not changing the operational or funding models or choosing the wrong technology.[62] For some observers, these kinds of risks are too important to justify what they feel may be a relatively small reduction in costs.[63]

eGovernment and the cloud[64]

The benefits and challenges for public sector bodies considering the use of the cloud are similar to those for private businesses and industries. Governments can reduce costs while increasing the speed of deployment of new and innovative public services, but they must take care to ensure effective management of cloud resources and guarantee the security and privacy of the information they hold, particularly that on private citizens. Nevetheless, government initiatives may differ from the private sector in several important respects. On the positive side, they may be able to share cloud services with other government bodies and agencies in a community cloud managed by a shared-services agency, so as to benefit from the security and manageability features developed or tested by others. However, they may have more complicated interoperability requirements, as information or functionality needs to be shared with other bodies, particularly in the light of the principle that data should be registered once only and that the 'whole of government' should work together to meet a particular citizen's need. Also, public sector bodies may have more rigid and longer-range budgeting and funding cycles, which can complicate the shift from capital to operating expenses that cloud computing implies.

4. EU support for research in cloud computing

The EU has long supported research in cloud computing and related issues. For example, the 7th Framework Programme (2007-2013) provided support to projects in areas as diverse as public sector use of the cloud, open source in cloud computing, analysis and mitigation of security risks, and evaluation of different cloud services.

The successor Horizon 2020 research programme (2014-2020) contained, as part of its first work programme (2014-2015), a call for Advanced Cloud Infrastructures and Services, under which some 23 different projects were selected to receive more than €70 million in EU funding. The projects deal with a wide range of cloud-related topics, including access to power efficient resources, software-defined storage platforms, the management of virtual computers, federated private clouds for public sector bodies, security techniques and standardisation of service level agreements. In parallel, a 2015 call dealt with boosting public sector productivity and innovation through cloud computing services.[65]

The second Horizon 2020 work programme (2016-2017) also targets research and innovation projects related to cloud architectures, management and deployment of clouds as well as security and privacy needs. Funding under the Leadership in Enabling and Industrial Technologies (LEIT) heading includes €45 million in support for cloud computing. Support is also planned or on-going for a European cloud to aid scientific research (see Section 7, 'Next steps'), and for cooperation in cloud computing with

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[62] Bittman, T., Six reasons why private clouds fail, and how to succeed, Gartner, 2014.

[63] Stogdill, J., Public vs. private cloud: price isn't enough. Radar (O'Reilly), 2015.

[64] Source: Nichols, K., K. Sprague, 'Getting ahead in the cloud', McKinsey on government, 2011, pp. 50-57. See also Davies, R., eGovernment, European Parliamentary Research Service, 2015, PE 565.890.

[65] European Commission, Horizon 2020 - Information and communication technologies (web page), 2015. See Work programmes for 2014-2015 and 2016-2017.

researchers in Japan, Brazil and South Korea. An EU-Brazil Cloud Connect project has already deployed a joint platform to federate European and Brazilian scientific cloud resources which is benefitting from research in areas such as epidemiology, heart simulation, and biodiversity.[66]

5. EU policy and positions

5.1. European Commission

In September 2012, the European Commission issued a **Communication on cloud computing**[67] that aimed at speeding up adoption of cloud computing in order to reduce ICT costs and increase productivity, growth and jobs. The Communication proposed key actions in order to encourage the development of standards, technical specifications and certification schemes; to work towards safe and fair contract terms and conditions, including terms of sale and data protection; and to promote public sector adoption of the cloud.

In this latter regard, a **European Cloud Partnership**[68] was formed to identify common requirements with public authorities in Member States and to develop specifications for public sector procurement so as to ensure interoperable commercial offerings throughout the EU. The Steering Board of this Partnership called for the consensus-building and the development of a common framework of best practices, (including legal and operational guidelines as well as technical standards) that cloud providers could use to show compliance with the needs of different groups of users. In the opinion of this Steering Board, such a framework would eliminate national regulatory barriers for cloud providers (such as procurement rules and data location restrictions) and foster confidence in cloud users that legal norms and international standards (including those regarding security and privacy) were being respected.[69]

The importance of cloud computing was reaffirmed in the Commission's 2015 **Digital Single Market (DSM) Strategy**.[70] The Commission considers that the DSM has to be built on reliable networks and services that will make use of advanced digital technologies such as cloud computing in order to maximise the potential growth of the economy. Along with big data and the Internet of Things, cloud services are considered central to Europe's competitiveness, and a fragmented market does not provide sufficient scale for cloud computing to reach its full potential. Restrictions as to where data are located may limit customers' choice of cloud providers and force providers to build expensive infrastructures in each of the Member States; the lack of interoperability and data portability can serve as a barrier to the flow of data and new services. The Commission has promised to propose in 2016 an initiative on the free flow of data, covering data flows between cloud providers, with the aim of removing restrictions on where data is located or accessed. In February 2016, the Commission awarded the first contracts for public and private cloud services (IaaS as well as PaaS)

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66 European Commission, Building an intercontinental EU-Brazil cloud for scientific advancement, 2016.

67 European Commission, Unleashing the potential of cloud computing in Europe, 2012. COM(2012) 529 final.

68 European Commission, European Cloud Partnership, [web site], last updated 21/03/2016.

69 Steering Board of the European Cloud Partnership, Establishing a Trusted Cloud Europe, 2014.

70 European Commission, A Digital Single Market strategy for Europe, 2015. COM(2015) 192 final.

that it will use for its own public administration, retaining the services of American firms as well as European suppliers.[71]

The Commission ran a public consultation from September 2015 to January 2016 on some regulatory aspects of the Digital Single Market including online platforms and data and cloud computing. Preliminary results indicate that individuals and small businesses in particular were concerned about security and protection of data. While many recognise the economic benefits of interoperability and data portability between cloud providers, contract terms and conditions are often fixed by the provider and non-negotiable.[72]

5.2. Council and European Council

In October 2013, the European Council emphasised the role of the cloud as an enabler of productivity and better services, and called for the EU to provide the right framework conditions in the single market for big data and cloud computing.[73] In May 2015, the Competitiveness Council reiterated an earlier conclusion that full and efficient use of tools and services like cloud computing can improve productivity and should be facilitated through market solutions, research, skill-building and standardisation. The Council welcomed, in particular, the European Open Science Cloud for researchers.[74]

5.3. European Parliament

In its reaction to the Commission's 2012 Communication, the European Parliament recognised that the main benefits of cloud computing were lower costs, ubiquitous access, convenience, reliability, scalability and security. It underlined the role of widespread broadband in the use of cloud services, and the importance of the application of European data protection standards. It emphasised the importance of consumer information and freedom to choose the cloud provider they prefer and consumer rights in cases where a contract is cancelled. It called for greater emphasis on the risks to fundamental rights and data protection, and for further consideration of issues raised by the storage of copyright works in the cloud.[75]

More recently, in its response to the DSM strategy,[76] Parliament again emphasised the opportunity that cloud computing provides for economic growth, and expressed concern that cloud infrastructures for researchers were fragmented, calling for an action plan for a European Open Science Cloud by the end of 2016.

The 2014 assessment of cloud computing carried out in the context of the European Parliament's STOA project, 'Potential and Impacts of Cloud Computing Services and Social Network Websites', put forward various options for European policy-makers including the support of highly secure solutions, a modernised data protection regime,

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71 European Commission, European Commission awards its first Cloud contracts, Informatics newsroom, [5 February 2016].

72 European Commission, First brief results of the public consultation on the regulatory environment for platforms, online intermediaries, data and cloud computing and the collaborative economy, 26 January 2016.

73 European Council, Conclusions, 24/25 October 2013. EUCO 169/13.

74 Council of Ministers, Council conclusions on open, data-intensive and networked research as a driver for faster and wider innovation, 29 May 2015.9360/15.

75 European Parliament, Unleashing the potential of cloud computing in Europe, 2013/2063(INI).

76 European Parliament, Towards a digital single market act, 2015/2147(INI).

increasing legal certainty, and support for innovative and fast-growing companies through standardisation, human skills development and broadband infrastructure.[77]

A Europe-only cloud?[78]

Partly as a result of the 2013 Snowden revelations of mass surveillance and data collection by US security agencies, calls arose to create a 'Europe-only' cloud that would ensure that sensitive data gathered by the public and private sector was stored and processed in data centres located in Europe and not routed to third countries. (This notion is largely distinct from that of a European cloud for researchers, described below, which focuses on building storage and high performance processing capacity rather than on data protection.) This would have the objective of promoting European suppliers, as well as reassuring cloud users that appropriate data protection measures would be applied. However observers see considerable difficulties in envisaging how a 'Europe only' cloud would work, citing the largely US-based services favoured by Europeans, jurisdictional conflicts over cloud suppliers, the imposition of location restrictions on internet-routed data, and the compatibility of measures with competition rules and trade agreements.

The Europe-only cloud concept has elements in common with a 2015 German federal decision concerning consolidation of government IT infrastructure that will require cloud providers to store sensitive information on servers located within Germany, and to guarantee that the data will not be disclosed to foreign jurisdictions. However, for some cloud services, identifying and separating sensitive and non-sensitive data may not always be simple. While cloud suppliers are already building data centres in Europe (and Microsoft has launched a German-only cloud with Deutsche Telekom), this so-called 'Bundescloud' decision has been criticised as increasing security risks by concentrating data in a small number of locations, artificially limiting competition, increasing costs and preventing innovative business models. It is also not clear how this decision will fit in with the European Commission's future 'free flow of data' initiative. A spokesperson says the Commission supports initiatives that aim to build trust in cloud computing, but 'common solutions at European level are necessary to avoid the fragmentation of the market and to create jobs and growth for the digital economy in Europe'.

6. Stakeholders' views

6.1. Business and consumer associations

BusinessEurope's approach to cloud computing emphasizes the crucial ability of businesses to transfer data across borders and opposes any forced data localisation requirements; they support harmonisation of licensing, taxation and other legal issues, voluntary standards for interoperability and cloud certification, and a balanced approach to determining legal responsibilities.[79] **BEUC**, the European consumer

[77] STOA - Science and Technology Options Assessment, Potential impacts of cloud computing services and social network websites, European Parliament, 2014. PE 513.546

[78] Sources: Hon, W. K. et al., Policy legal and regulatory implications of a Europe-only cloud, Queen Mary University of London, Legal studies research paper 191, 2015; Kuschewsky, M. Data localization requirements through the backdoor? Germany's 'Federal Cloud' and new criteria for the use of cloud services by German federal administration, Inside privacy, 15 September 2015; DW, 'Microsoft launches German-only data cloud', 11 November 2015; Bauer, M. The Bundes Cloud: Germany on the edge to discriminate against foreign suppliers of digital services, ECIPE Bulletin, no. 5, 2015. Stupp, C. 'Germany to set up Bundescloud', Euractiv, 2015.

[79] BusinessEurope, Response to the public consultation on regulatory environment for platforms, online intermediaries, data and cloud computing and the collaborative economy, 2016. See also BusinessEurope, Letter to Commission Vice-President Kroes re the Commission Communication 'Unleashing the potential for cloud computing in Europe', 11 December 2012.

organisation, is concerned about unfair cloud computing contracts with consumers resulting from (among other factors) lack of transparency, implied consent to the processing of personal data, limitations on consumer rights, and issues of liability and consumer ownership of content.[80] **Anec**, representing the European consumer in standardisation, underlines that hundreds of thousands of apps are used by consumers with no direct contractual relationship with the providers, so that commercial, technical and privacy standards must be applied.[81]

6.2. ICT-related associations

The European Telecommunication Network Operators (**ETNO**) believe that enabling switching mechanisms between cloud suppliers is important to avoid lock-in effects, but is concerned that European cloud suppliers do not have the scale to fully engage in policy processes.[82] The European Competitive Telecommunications Association (**ECTA**) has called for harmonised data protection, market-driven and global standards, and free movement of data to ensure the scalability, flexibility and efficiency of cloud services.[83]

DigitalEurope, an association representing the digital technology industry in Europe, believes that data location restrictions should be applied sparingly and with caution since they disrupt the free flow of data and could prevent the emergence of a Digital Single Market. It calls for the EU to use international standards and for any local or regional standards to be aligned with these global ones to ensure that European cloud providers are ready to provide services around the world. It further believes that there is no regulatory mandate for cloud-related data portability or interoperability regulations, but that, given the rapid innovation in this area, reliance should instead be placed on standards that are voluntary, industry-led, global and open.[84] The European Committee for Interoperable Systems (**ECIS**), a non-profit association of hardware and software providers, emphasises that restrictions on data flows or regionalised standards can hurt Europe's competitiveness; new regulation should be approached cautiously lest it restrict innovation.[85] On the other hand, **Openforum Europe** (OFE), a not-for-profit industry organisation that seeks to promote openness in computing, supports full interoperability and portability to avoid lock-in through vendors' commercial practices or proprietary interfaces.[86]

7. Next steps

In April 2016, the European Commission presented a package of initiatives relating to the Digital Single Market with the intention of helping European industry to make the

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[80] BEUC, Unfair contract terms in cloud computing service contracts: discussion paper, 2014.

[81] ANEC, Domestic privacy and the privacy of digitally connected devices, 2015.

[82] European Telecommunication Network Operators, Regulatory environment for platforms, online intermediaries, data and cloud computing and the collaborative economy, 2015.

[83] European Competitive Telecommunication Association, Response to the European Commission public consultation on cloud computing, 2011.

[84] DIgitalEurope, DigitalEurope's response to the public consultation on the regulatory environment for platforms, online intermediaries, data and cloud computing and the collaborative economy, 18 December 2015.

[85] ECIS, Ensuring a thriving cloud market: why interoperability matters for business and government, n.d.

[86] Openforum Europe, Open cloud [web page], n.d.

most of new digital technologies, and of boosting innovation in growth-related areas including cloud computing. In introducing the package, Commission Vice-President Andrus Ansip stated that cloud computing was set to expand massively over the next few years due to the vast amounts of data created by digitisation of industry and the Internet of Things. However, the capacity in the EU to process this data is not increasing at the same pace.[87]

Two communications in the package relate particularly to cloud computing. In one, the Commission sets out[88] **a European Cloud Initiative** which proposes two principal actions. A **European Open Science Cloud** will create a new data infrastructure for research and innovation by linking together existing scientific data infrastructures across disciplines and Member States, thereby increasing computing and storage capacity for research scientists and engineers. In conjunction with open science data (including data made openly available through EU-funded research projects), specifications for data-sharing and interoperability, and the development of new cloud-based services, scientists and researchers should be able to benefit from data-driven science. The Commission anticipates subsequently opening this Open Science Cloud to government and business users.

The second main cloud-related development outlined in the Communication, is the **European Data Infrastructure** which will underpin the Open Science Cloud. This initiative aims to build, by 2020, a European high performance computing (HPC) capacity based in large measure on European technology. Data and network infrastructure will be developed along with supercomputing facilities that could potentially use EU-supported quantum technologies. Here too, the intention is to progressively open the European Data Infrastructure to the public sector and businesses to provide them with cost-effective access to cloud-based storage and advanced processing for massive amounts of 'big data'.

The details of the expected €6.7 billion financing for this European Cloud Initiative have not yet been finalised by the Commission, but will need to be determined in cooperation with Member States and stakeholders. At the EU level, it is expected that this will involve a blend of funds from the Horizon 2020 Framework Programme, the Connecting Europe Facility, the European Structural and Investment Funds (ESIF) and the European Fund for Strategic Investments (EFSI, often referred to as the Juncker Plan). A combination of EU and national funding will be used to leverage private research funds. Existing Horizon 2020 funds will support the European Open Science Cloud and kick-start the data infrastructure development. An additional €4.7 billion of combined public and private financing will be needed over the next five years, of which €3.5 billion will be for data infrastructure; the rest will go towards EU-wide quantum computing development (€1 billion) and actions for extending access and building trust (€0.2 billion).

Standards are also a highly strategic area, and the proposed measures in the second Communication dealing with a new **Strategy for Standardisation**[89] include actions to accelerate standardisation work in cloud computing, as well as in four other ICT areas.

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87 Ansip, A., Helping European industry to turn digital [speech], 5 April 2016.

88 European Commission, European Cloud Initiative – Building a competitive data and knowledge economy in Europe, 2016. COM(2016) 187 final.

89 European Commission, ICT standardisation priorities for the Digital Single Market, 2016. COM(2016) 176 final.

Better standards and interoperability will allow cloud-based systems to communicate with each other and to be shared more easily. In addition, the DSM package supports mechanisms for certification of cloud services to build up trust in cloud computing and to encourage take-up of the cloud by European businesses and governments.

The initial reaction to the DSM package from stakeholders appeared to be mostly positive. BusinessEurope believes that the Commission's priorities are right, and that it is justified in trying to reduce fragmentation within the EU.[90] For ETNO, European researchers need access to world-class supercomputing, data storage and analysis capacity to succeed in today's data-driven world.[91] Openforum Europe stated that the emphasis on international and global standards, rather than divergent European ones, would help to drive innovation and competitiveness in the EU.[92] However, one source reported that the possible opening of an EU research cloud to the EU public and private sectors was worrying to American businesses, which saw it as unfair competition to their commercial cloud services by a publicly sponsored project.[93]

[90] BusinessEurope, EU industrial digitisation strategy just in time - Act now, 19 April 2016. Available on the BusinessEurope site.

[91] ETNO, Digital industrial leadership: telcos welcome new strategic approach, 19 April 2016.

[92] Openforum Europe, Open standards: a key to success in the delivery of the DSM, 19 April 2016.

[93] L'Usine digitale. Plan industrie du futur: Bruxelles veut à tout prix éviter une guerre des normes, 10 April 2016.

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Cloud computing is a model for providing information and communication technology (ICT) services over the internet. Businesses, public bodies and individuals can all benefit through lower costs, global access to data and applications, flexibility in provision, and the ability to innovate without large capital costs. Cloud computing may also have beneficial effects on energy consumption and carbon emissions.

However, cloud computing raises concerns about personal data protection and privacy, security and interoperability and portability of data and applications, as well as contract terms that may be overly restrictive of customers' rights.

The European Commission considers cloud computing central to the EU's competitiveness and a key to economic growth and innovation. The EU has provided support to research in cloud computing. Determining the appropriate responses to the challenges of cloud computing is part of the European Commission's Digital Single Market strategy. The Commission has announced its intention to propose a 'free flow of data initiative', tackling restrictions on where data is located, and a European Cloud initiative that will cover certification of cloud services, reduce the risks of vendor lock-in, and provide a research cloud for researchers to share access to data.

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