

# The Economic Consequences of the Diffusion of Cloud Computing

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Cloud computing is an emerging general purpose technology (GPT) that could provide a fundamental contribution to efficiency in the private and public sectors, as well as promote growth, competition, and business creation. It is an Internet-based technology through which information is stored in servers and provided as a service and on-demand to clients. The impact of cloud computing on both households and companies will be substantial. On one side, consumers will be able to access all of their documents and data from any device (the home or work PC, the mobile phone, or an Internet Point, among others), as they already can for email services or social networks. On the other side, firms will be able to rent computing power (both hardware and software in their latest versions) and storage from a service provider and pay on demand, as they already do for other inputs such as energy and electricity.<sup>1</sup> The former application will affect our lifestyles, but the latter will have a profound impact on the cost structure of all the industries using hardware and software,<sup>2</sup> and therefore it will have an indirect but crucial impact on business creation and on the macroeconomic performance of countries.

Cloud computing can exert a number of effects on the economy. For instance, it can enable huge cost savings and more efficiency in large areas of the public sector, including hospitals and healthcare (especially for providing information and technology to remote or poorer locations), education (especially for e-learning), and the activity of government agencies that experience periodic spikes in usage. Moreover, substantial positive externalities are expected because of energy savings: the improvement of energy efficiency may contribute to the reduction of total carbon emissions in a substantial way—information and communication technologies (ICT) is responsible for 2 percent of carbon emissions in Europe, of which 1.75 percent is due to the use of ICT products and services, and 0.25 percent to their production. The introduction of cloud computing can provide cost savings in the private sector as well: it can create multilateral network effects among businesses and increased productivity within businesses, and it can promote entry and innovation in all the sectors where ICT costs are relevant and are drastically reduced by the adoption of cloud computing. This last effect can be quite large in terms of consequences for the aggregate economy, and is the focus of the evaluation of the economic impact of cloud computing on the economy conducted in this chapter (for this reason, our estimates should be regarded as conservative estimates).

In a recent study, we estimated the economic impact of the diffusion of cloud computing in Europe through the incentives to promote business creation.<sup>3</sup> Starting from conservative assumptions about the cost-reduction process associated with the diffusion of cloud computing over five years, we obtained results showing that the diffusion of cloud computing could provide a

positive and substantial contribution to the annual growth rate (up to a few decimal points), helping to create about a million new jobs through the development of a few hundred thousand new small- and medium-sized enterprises (SMEs) in the whole European Union (EU27). The driving mechanism behind the positive contribution works through the incentives to create new firms, in particular SMEs. One of the main obstacles to entry in new markets is represented by the high up-front costs of entry, often associated with physical and ICT capital spending. Cloud computing allows potential entrants to save on the fixed costs associated with hardware/software adoption and with general ICT investment, and turns part of this capital expenditure into operative expenditure that is in variable costs. This reduces the constraints on entry and promotes business creation. The importance of such a mechanism is well known at the policy level, especially in Europe, where SMEs play a crucial role in the production structure.<sup>4</sup>

The next section will describe the development of cloud computing in greater detail and comment on the consequences of its diffusion for the economy. The following section will provide the results of our economic investigation on EU countries, and the last section will draw some policy implications and conclusions.

## 2

### **What is cloud computing and what will be its impact?**

Cloud computing is an Internet-based technology through which information is stored in servers and provided as a service and on-demand to clients, possibly jointly with the traditional form of access. It is probably going to develop along different concepts, focused on the provision of Infrastructure as a Service (IaaS, or renting virtual machines), Platform as a Service (PaaS, on which software applications can run) or Software as a Service (SaaS: renting the full service, as for email). In preparation for its introduction, many hardware and software companies are investing to create new platforms able to attract customers “on the clouds.” Cloud platforms provide services that facilitate the creation of applications in competition with, or in alternative to, on-premises platforms—the traditional platforms based on an operating system, a group of infrastructure services, and a set of packaged and custom applications. The crucial difference between the two platforms is that, while on-premises platforms are designed to support consumer-scale or enterprise-scale applications, cloud platforms can potentially support multiple users at a wider scale, namely at Internet scale.<sup>5</sup>

The introduction of cloud computing is going to be gradual. Currently we are only in a phase of preparation, with a few pioneers offering services that can be regarded as belonging to cloud computing. These services are often derived from internal solutions (turning private clouds into public ones). Meanwhile, many large high-tech companies are building huge data centers

loaded with hundreds of thousands of servers to be made available for customer needs in the near future. The first mover in the field has been Amazon, which has provided access to half a million developers by way of Amazon Web Services (initially developed for internal purposes). Through this cloud computing service, any small firm can start a Web-based business on its computer system, add extra virtual machines when needed, and shut them down when there is no demand. For this reason the utility is called Elastic Cloud Computing (Amazon EC2). Google is also investing huge amounts of funds in data centers. Already nowadays Google provides word processing and spreadsheet applications online, while software and data are stored on the servers. Google App engine allows software developers to write applications that can be run for free on Google’s servers. Even the search engine of Google or its mapping service can offer cloud application services: for instance, when Google Maps was launched, programmers easily found out how to use the maps with other information to provide new services. Microsoft started later but has made high investments in the creation of new data centers. In January 2010, the leading software company launched a cloud platform called Windows Azure (introduced in a beta version in 2008) that is able to provide a number of new technologies: a Windows-based environment in the cloud to store data in Microsoft data centers and to run applications; an infrastructure for both on-premises and cloud applications (through .NET Services); a cloud-based database (through SQL Data Services, which can be used from different users and different locations); and an application tool to access Live Services, which allows for the synchronization and constant updating of data across systems that are into a “mesh” (for all the personal devices). Moreover, Windows Azure provides a browser-accessible portal for customers, who can create a hosting account to run applications or a storage account to store data in the cloud. They can be charged through subscriptions, per-use fees, or other methods. Another important player is Salesforce.com with its Force.com products. Also Oracle has introduced a cloud-based version of its database program and is merging with Sun Microsystems to prepare further expansion in the field. Yahoo! is developing server farms as well.

The battle for the clouds among these companies is going to reshape the ICT market structure, just as PC distribution did in the 1980s. However, the need for creating network effects in the development of a cloud platform will keep the margins low for a while and will maximize the speed of diffusion of cloud computing between firms at the global level. Therefore, in the long run, we expect a rather competitive situation on the supply side of cloud computing.

It is crucial to understand the economic impact of the introduction of this GPT.<sup>6</sup> The diffusion of cloud computing will certainly have a solid and pervasive impact on the global economy. The first and most

relevant benefit of cloud computing is associated with a generalized reduction of the fixed costs of entry and production by shifting fixed capital expenditure in ICT into operative costs; the size of the shift will depend on the size of demand and production. This generalized reduction of fixed costs contributes to reducing the barriers to entry, especially for SMEs—because infrastructure is owned by the provider, it does not need to be purchased for one-time or infrequent intensive computing tasks; this reduction also generates quick scalability and growth. The consequences to the endogenous structure of the markets with largest cost savings will be wide and will include the entry of new SMEs, a reduction of mark ups, and an increase in average and total production.<sup>7</sup>

In spite of the fact that the relative size of IT cloud services will probably remain limited for the next few years, they are destined to increase and to have a significant macroeconomic impact, especially in terms of the creation of new SMEs and of employment. In times of global crisis, this could be an important contribution to promoting recovery and fostering growth. Cloud platforms and new data centers are creating a new level of infrastructure that global developers—especially SMEs that are so common in Europe—can exploit. This new infrastructure will open new investment and business opportunities currently blocked by the need for massive up-front investment. The new platforms will enable different business models, including pay-as-you-go subscriptions for computing, storage, and/or IT management functions; these models will in turn allow small firms to scale up or down to meet their demand needs.<sup>8</sup>

The economic impact of the diffusion of this new GPT may be quite large, as was the case for the diffusion of telecommunications infrastructures in the 1970s and 1980s or the introduction of the Internet in the 1990s.<sup>9</sup> To evaluate the impact of cloud computing, we adopt a macroeconomic approach that emphasizes the effects of this innovation on the cost structure of the firms investing in ICT and consequently on their incentives to create and expand new business; on the market structure; on the level of competition in their sectors; and ultimately on the induced effects for aggregate production, employment, and other macroeconomic variables.<sup>10</sup> The methodology is based on a dynamic stochastic general equilibrium-calibrated model augmented with endogenous market structures and is in line with recent developments in the macroeconomic literature.<sup>11</sup> This model is perturbed with a realistic structural change to the cost structure in order to study the short- and long-term reactions of the economy.

Our experiment is focused on Europe taking as a given the rest of the world (which is an additional conservative hypothesis).<sup>12</sup> Therefore, all our data derive from official EU statistics (Eurostat): these data are mainly the number of firms, which is basically equivalent to the number of SMEs; employment; and gross domestic

product (GDP). We used data for most of the EU member countries and Norway, for which we had complete data. Moreover, we focused on a few aggregate sectors for which we have detailed and comparable EU statistics: manufacturing, wholesale and retail trade, hotels and restaurants, transport storage and communication, and real estate renting and business activities. These aggregate sectors cover the majority of firms in terms of number (more than 17 million firms) and provide much of the employment for the European countries (more than 113 million workers). They also include all the sectors where the effects emphasized in our analysis are relevant—namely, the manufacturing and service sectors—where the use of ICT capital and the role of entry costs and competition effects are more relevant. We ignored other aggregate private sectors (such as electricity, gas, and water supply) and the public sector, where we believe that our mechanisms are either weaker or absent, and sectors where comparable data were not available (such as part of the financial sector). Country-specific heterogeneity and sectoral differences were considered on the basis of statistics on the labor market and the entry/competitive conditions at the level of EU countries and their aggregate sectors.

A key factor for determining the impact of cloud computing is the size of fixed-cost savings. The business literature emphasizes large savings. Dubey and Wagle conjecture large reductions in the cost of ownership for typical business services, suggesting that this cost could be as much as 30 percent lower in the case of customer relationship management delivered through software as a service.<sup>13</sup> International Data Corporation (IDC) estimates a reduction of about 50 percent.<sup>14</sup> On the other hand, Carr suggests that about half of the capital expenditure of modern firms is ICT related, and therefore a large part of it may be eliminated and (partially) turned into operative expenditures.<sup>15</sup> Although this may be true in a number of sectors and for advanced companies, we prefer to adopt a more conservative assumption for our macroeconomic investigation.

One of the best reviews of the state of ICT in Europe is provided by the e-Business W@tch of the European Commission. The 2006 *e-Business Report* provides a comprehensive survey of ICT adoption and spending, showing that, of the total cost, 5 percent is spent on ICT. Since only part of the total cost corresponds to fixed costs of production, the average ICT budget must be more than 5 percent of the total fixed costs of production. Of course, only part of ICT spending represents fixed costs, and only a part of it will be cut even after the adoption of cloud computing in alternative to a fully internal solution. For this reason, we decided to adopt a conservative assumption and consider a range of fixed-cost reduction of between 1 percent and 5 percent in the long run. Even the limited technological change resulting from cloud computing delivers substantial

effects at the macroeconomic level. Needless to say, larger shocks will be associated with wider effects.

### The results for EU countries

In this section we report the results of our simulation of the introduction and diffusion of cloud computing in the European economy. We focus on the impact on GDP, business creation, and employment in the short term (after one year) and in the medium term (after five years). Two scenarios are considered: slow adoption corresponds to a sluggish 1 percent reduction in the fixed costs of entry and rapid adoption to a speedy 5 percent reduction in the fixed costs.<sup>16</sup>

The contribution of cloud computing to GDP growth can be hardly differentiated among countries and sectors, so we simply summarize our average estimates for the European countries. The estimate averages range between 0.05 percent growth in the short run under slow adoption and 0.3 percent in the medium run under fast adoption. Given the conservative assumptions on the size of the shock, these are remarkable contributions to GDP growth, and have a direct counterpart in the effects on employment.

One should take the estimates on the impact on employment with care. Even if we consider country-specific factors related to labor market conditions, our basic simulations emphasize the impact in terms of hours worked. In terms of new jobs, the impact depends on a number of institutional and structural features of the labor markets and their country-specific regulation. Keeping this in mind, we found that the introduction of cloud computing could create, on average, about a million additional jobs in Europe. About two-thirds of this job creation is expected to occur in the six largest countries (the United Kingdom, Germany, France, Poland, Italy, and Spain), but each country could enjoy a temporary increase in its workforce. Of course, this increase will vanish over time because the structural features of the economy lead employment toward its natural level, which is affected in only a small measure by the reduction of the fixed costs. However, the short-run impact can be quite strong and, in a period of crisis such as the one forecasted for the forthcoming years, it can contribute to limiting the increase of the unemployment rate in a substantial way. Our estimates of the reduction of the unemployment rate in European countries from the introduction of cloud computing are around 0.5 to 0.6 percent in the short run and 0.2 to 3 percent in the medium run.

Before adding further details, it is worthwhile sketching the mechanism emphasized in our model. The gradual introduction of cloud computing reduces the fixed costs and increases incentives for entry into each sector. This increases current and future competition in each market and tends to reduce mark ups, thus increasing demand and therefore increasing production. The

associated increase in labor demand induces an upward pressure on wages that, in turn, induces workers to work more (or new agents to enter the labor force). The current and expected increase in output affects consumption/savings behavior. In the short run, the demand for new business creation requires an increase in savings, which may result in a temporary negative impact on consumption. However, in the medium and long runs, the positive impact of cloud computing on output leads to an increase in consumption toward a higher steady-state level. Of course, a faster adoption exerts a large impact on business creation and therefore on output and employment as well.

Given this overview of the results in terms of GDP and employment, we now present our results in terms of estimated new business creation. The largest impact is expected, in the medium run under fast adoption, to occur in the aggregate sectors of wholesale and retail trade (156,000 new firms) and of real estate and other business activities (with 144,000 new SMEs). Our empirical exercise shows a strong impact on the creation of new SMEs, of the magnitude of a few hundred thousand in the whole European Union (again, this is in addition to new SMEs created in a normal situation, without the introduction of cloud computing). The effect is permanent and tends to increase over time: the creation of new SMEs will not vanish, but will remain over time, making a permanent impact on the structure of the economy. Moreover, the effect is deeper in countries where the diffusion of SMEs is particularly strong or where ICT adoption has been generally rapid. In absolute terms, cloud computing is estimated to have the largest impact in Italy in terms of new business (with 81,000 new SMEs in the medium run under fast adoption), followed by Spain (plus 55,000), France (48,000), Germany (39,000), the United Kingdom (35,000), and Poland (32,000).

We have also examined the impact of cloud computing on employment in each country, distinguishing among aggregate sectors. In absolute terms, the largest impact is expected for the manufacturing sector and also for the sector under the label “hotels and restaurants.”<sup>17</sup> According to our estimates, the United Kingdom will exhibit the greatest impact in terms of new workers (with 240,000 new workers in the short run under fast adoption), followed by Germany (160,000), France (100,000), Poland (94,000), Italy (76,000), and Spain (69,000). Overall, the results country by country are affected by differences in labor market conditions that tend to influence the ability of the economy to react to a positive change through job creation, and also by differences in the regulatory framework and in the competitive conditions of the goods markets that create the conditions for rapid business creation.

## Conclusions

Part of the positive effects of cloud computing will be positively related to the speed of adoption of the new technology. There are a number of factors that may slow down this adoption, such as a lack of understanding of the cloud by firms, systemic risk, security, privacy and interoperability issues, reliability, jurisdictional complexity, data governance, loss of IT control, and general status quo inertia. For this reason, our investigation suggests that policymakers should promote as rapid an adoption of cloud computing as possible. Concrete interventions include:

- international agreements in favor of unrestricted flow of data across borders (since data centers are located in different countries with different privacy laws, data portability remains a key issue for the diffusion of cloud computing);
- agreements between EU authorities and industry leaders on a minimum set of technological standards and process standards to be respected in the provision of cloud computing services—these agreements would guarantee data security and privacy and promote a healthy diffusion of the new technology;
- expansion of broadband capacity; and
- introduction of fiscal incentives for the adoption of cloud computing and a specific promotion in particular dynamic sectors (for instance, governments could finance, up to a specified limit, the variable costs of computing for all the domestic and foreign firms that decide to adopt a cloud computing solution).

These policies may be studied in such a way to optimize the process of adoption of the new technology and to strengthen the propagation of its benefits within the country. The benefits of cloud computing are many, and countries now have the opportunity to jump-start their economies by making policies that will enhance its adoption.

## Notes

- 1 See Dubey and Wagle 2007 and Armbrust et al. 2009 for early reviews of the topic.
- 2 The positive association between ICT innovations and competition is well known, and policymakers recognize that it may work in both directions: on one side competitive sectors adopt ICT innovations earlier and become more productive; on the other side ICT adoption enhances competition. For instance, the *e-Business Watch* of the European Commission (2008) notices that “while it seems obvious that increasing levels of competition can push companies to adopt and use ICT, the opposite might well also be the case. In fact, ICT and the usage of the internet have drastically impacted on certain sectors such as banking and reshaped the competitive scenario” (p. 42).

- 3 Etro 2009a.
- 4 Again, the *e-Business Watch* of the European Commission (2008) emphasizes this aspect clearly: “SMEs form significant industry segments in the EU and account for the majority share in EU employment. Thus, they require specific policy attention. While their strength lies in the flexibility with which they can adjust to changing market conditions, their small size makes them less able to face high up-front costs” (p. 53).
- 5 In the business literature, cloud computing has been seen as a step in the commoditization of IT investments (Carr 2003); as the outcome of an evolution toward a utility business model in which computing capabilities are provided as a service (Rappa 2004); as the core element of the era of Web 2.0, in which Internet is used as a software platform (O’Reilly 2005); or simply as an application of the generativity power of the Internet (Zittrain 2007). See also IDC (2008).
- 6 For an introduction to innovation and growth theory, see Acemoglu 2009 and Aghion and Howitt 2009.
- 7 Moreover, cloud computing is going to introduce the possibility of (1) sharing resources (and costs) among a large pool of users, (2) allowing for centralization of infrastructures in areas with lower costs, and (3) allowing for peak-load capacity increases (generating efficiency improvements for systems that are often only 10–20 percent utilized). These features will lead to additional savings in energy and to greater environmental sustainability, whose measure, however, is subject to large uncertainty.
- 8 This mechanism is going to be crucial in Europe because of the large presence of SMEs and of the higher risk aversion of European entrepreneurs compared with their American counterparts (largely because of differences in the capital and credit markets and in the venture capital market). Reduction of the fixed costs may reduce the risk of failure and promote entry even more.
- 9 On the diffusion of telecommunications infrastructures, see Röller and Waverman 2001; on the introduction of the Internet, see Varian et al. 2002. These were econometric studies done after the introduction of these technologies took place. We rely on simulations because our analysis occurs before the introduction of the technology; of course, this makes our calculations subject to greater uncertainty.
- 10 Etro 2009a.
- 11 See Ghironi and Melitz 2005; Bilbie et al. 2007, 2008a, b; Etro 2007; Etro and Colciago 2010; and Colciago and Etro 2008. See Etro 2009b for a survey.
- 12 Taking into consideration the gains in the competitiveness of firms in other continents may increase the benefits of this technology and also increase the costs of a slower diffusion in Europe.
- 13 Dubey and Wagle 2007.
- 14 IDC 2008.
- 15 Carr 2003.
- 16 Further details can be found in Etro 2009a.
- 17 Overall, the impact of cloud computing on employment is more limited than its impact on business creation for a simple reason. One of the main advantages of cloud computing is an induced change in the market structure of many sectors, with the creation of more firms and an increase in the level of competitiveness; this increase in competitiveness is also associated with a reduction in prices. This change in the market structure, associated with larger efficiency, induces a re-allocation of jobs that does not greatly increase the number of workers. In this case we are talking about a few hundred additional workers (or a corresponding lower number of unemployed agents) at the European level. Our simulation emphasizes a slow reduction of the net impact on employment in the medium run compared with its impact in the short run. This is normal because the absolute impact on the labor force tends to vanish in the long run.

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