ICTNET Assessment Paper 2

ICT-enabled Innovation

September 2011

Introduction

Business innovation is regarded as a key determinant of both the success of businesses and the economic growth of countries. At the micro level, the commercialisation of business innovation has the potential to increase consumer demand through the introduction of new goods and services, the improvement of existing ones, and a decrease in production costs and product prices. More importantly, strong business innovation increases multifactor productivity at a macro level thus lifting international competitiveness, economic growth and per capital income. Therefore, it is of great interest to businesses and policy makers alike, to identify those factors which stimulate innovation and to understand how these factors interact.

ICTs appear as a major enabler of innovation. They have the potential to increase innovation by speeding up the diffusion of information, favouring networking among firms, enabling closer links between businesses and customers, reducing geographic limitations, and increasing efficiency in communication.

Previous analysis confirms that ICTs play an important role in enabling business innovation (e.g. Brynjolfsson and Hitt, 2000; Crespi *et al.*, 2007; Gago and Rubalcaba, 2007; Eurostat, 2008; Van Leeuwen, 2008; Polder *et al.*, 2009, 2010, and 2011; Bertschek *et al.*, 2011; Hagen, 2011; Todhunter and Abello, 2011; Spiezia, 2011). These studies, however, differ as regards methodology and country coverage and they do not focus on the link between ICT use and innovation.

ICT as enabler of firm innovation

ICTs are a valuable source of business innovation because they provide substantial efficiency gains. As Koellinger (2005) puts it "ICT makes it possible to reduce transaction costs, improve business processes, facilitate coordination with suppliers, fragment processes along the value chain (both horizontally and vertically) and across different geographical locations, and increase diversification."

Each of these efficiency gains provides an opportunity for innovation. For example, IT automated system links lead to more streamlined businesses processes and allow staff to be more responsive to emerging customer needs. Similarly, technologies which allow staff to effectively communicate and collaborate across wider geographic areas will encourage strategies for less centralized management, and more flexible external relations, all of which involve different types of innovative activity.

Gretton *et al.* (2004) suggested two reasons why business use of ICT encourages innovative activity. Firstly, ICT is a 'general purpose technology' which provides an 'indispensable platform' upon which further productivity-enhancing changes, such as product and process

innovations, can be based. For example, a business which establishes a web presence sets the groundwork from which process innovations, such as electronic ordering and delivery, can be easily developed. ICT-based methods for design, test and simulation enable greater precision and reduce costs (Sudarsan *et al.*, 2005; Thomke, 2006; Kleis *et al.*, 2011). In this way, adopting general purpose ICT makes it relatively easier and cheaper for businesses to develop innovations.

Secondly, the spillover effects from ICT usage, such as network economies, can be sources of productivity gains. For example, staff in businesses which have adopted broadband Internet are able to collaborate with wider networks of academics and international researchers more closely on the development of innovations and keep abreast of current consumer trends. These are spillover benefits because the R&D efforts of other researchers in the collaborative group can be appropriated by all.

Econometric analysis confirms that ICTs play an important role in enabling business innovation. Gago and Rubalcaba (2007) find that businesses which invest in ICT, particularly those which regard their investment as very important, or strategically important, are significantly more likely to engage in services innovation.

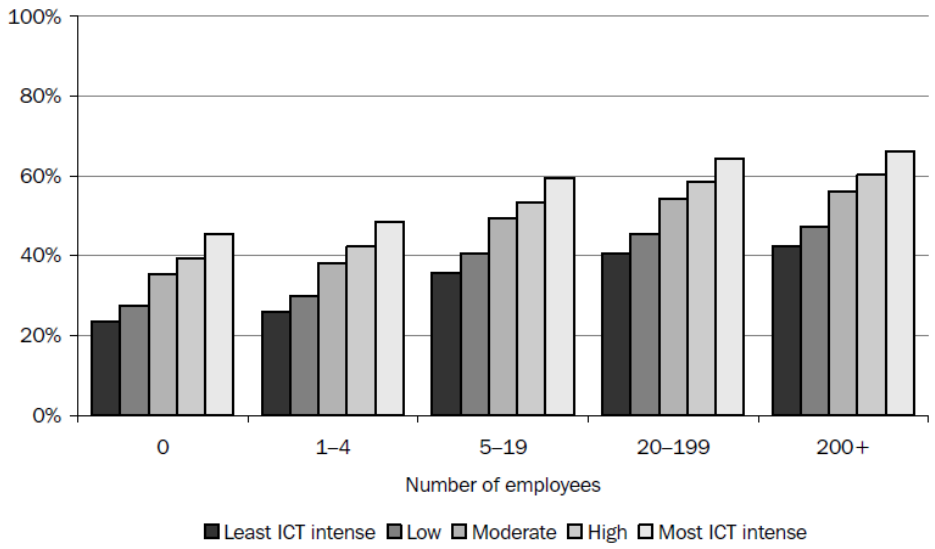
Just the fact of having a broadband connection seems to enable the innovative activity of firms. According to Grimes *et al.*(2011) broadband-enabled firms are more likely to have a webpage than firms without this type of connection, which in turn provides a simple platform to introduce innovations related to the use of the Internet for commercial transactions. In this sense, the results of Bertschek *et al.* (2011) confirm that high-speed Internet connections have a significant and positive effect on a firm's probability to introduce new products or processes.

Todhunter and Abello (2011) estimate that firms with a broadband connection are about four percentage points more likely to engage in innovation than enterprises with no connection. Moreover, the importance of ICT for innovation increases with the intensity of its use as shown in Figure 1. Among Australian firms, those enterprises with both broadband and web presence are eight to nine percentage points more likely to engage in innovation than those which have a high-speed connection only. Ten more percentage points are added if the firm makes a "high-extensive" use of IT for business activities.

A number of studies have shown that linking firm level datasets provides a valuable insight into the relationships between innovation and ICT.

Abello and Prichard (2008) link the Innovation Survey and the Business Use of Information Technology Survey in Australia and find that different ICT technologies are associated to different types of innovations. For example, connection to the Internet via cable modem is significantly associated with innovation in products, while wireless connection is more significant for organisational/managerial operations.

Figure 1. Estimated probability of engaging in innovative activity in 2006-07 among Australian firms



Source: Todhunter and Abello (2011).
Note: The variable ICT intensity considers 5 categories: *basic*, no broadband connection; *low*, only broadband; *moderate*, broadband and web presence; *high*, broadband, web presence, e-selling and "high-extensive" use of IT in less than 5 activities; *very high*, broadband, web presence, e-selling and "high-extensive" use of IT in at least 5 activities.

The Eurostat ICT impacts project (Eurostat, 2008) shows that, on average, ICT usage is positively related to firm performance. The strength of these results varies over countries, however, and it also appears that the benefits of different types of ICT usage are industry specific. By linking Eurostat firm-level data on ICT use with firm-level estimates of ICT investment, Van Leeuwen (2008) shows that e-sales and broadband use affect productivity through their effect on innovation output. Broadband use, however, only has a direct effect on productivity if R&D is not considered as an input to innovation.

Hagén and Lagerquist (2011) address the latter issue and find that, among Swedish firms, the availability of broadband in 2004 was positively associated with ICT use in 2005, which, in turn, had a positive effect on firms' productivity in 2006.

This approach has been further developed in several works by Polder *et al.* (2009, 2010, and 2011). They consistently find that ICT investment is important for all types of innovation in services, while it plays a limited role in manufacturing, being only marginally significant for organisational innovation.

The findings by Spiezia (2011) support the hypothesis that ICTs act an enabler of innovation, in particular for product and marketing innovation. Unlike the findings by other studies, these effects appear large both in manufacturing and services. No evidence is found, however, that ICT use increases the capability of a firm to cooperate with other firms/institutions, to develop innovation in-house or to introduce more "innovative" (new-to-the-market) products. These results suggest that ICTs enable firms to adopt innovations developed elsewhere but they

do not increase their "inventive" capabilities, i.e. the capability to develop new products and processes.

Another line of literature, based on case studies, confirms the importance of ICT for organisational innovation (see Brynjolfsson and Hitt, 2000 for a survey). The introduction of information technology is combined with a transformation of the firm, investment in intangible assets, and of the relation with suppliers and customers. Electronic procurement, for instance, increases the control of inventories and decreases the costs of coordinating with suppliers, and ICTs offer the possibility for flexible production: just-in-time inventory management, integration of sales with production planning, etc. Underinvestment in intangible assets is seen as a possible candidate for explaining the differences in productivity growth that are observed between Europe and the US.

The available econometric evidence at firm level shows that a combination of investment in ICTs and changes in organisational and working practices contributes to firm productivity growth. Crespi, Criscuolo and Haskel (2007) use CIS data for the UK and find a positive effect on firm performance of the interaction between ICT and organisational innovation.

ICT, Knowledge Flows and Innovation Networks

Information and communication technologies can also be seen as a source of innovation because they enable closer links between businesses and their suppliers, customers, competitors and collaborative partners. These agents are all understood to be important sources of ideas for innovation. By enabling closer communication and collaboration, ICTs assist businesses to be more responsive to innovation opportunities and provide significant efficiency gains. For example, broadband Internet, a web presence and automated system linkages help businesses to keep up with changes in customers' preferences, to monitor competitors' behaviours and to get rapid feedbacks from users. In this way, ICTs help firms to exploit opportunities for all types of innovations.

In recent years, the idea has emerged that the diffusion of ICTs, particularly the Internet, has significantly reduced the geographic barriers to knowledge flows and innovation networks (Friedman, 2005). In the words of Friedman's bestseller, "the word is flat": information travels around the globe at rapid speed so that ideas generated in California spread to Calcutta or Coventry through the Internet, conferences, telephone and other communication devices at an unprecedented rate, and geography plays little role. The diffusion and adoption of ICTs, therefore, would have increased the opportunities to innovate anywhere. Firms, therefore, would not need to be physically close to other firms to innovate (Forman *et al.*, 2008).

There are, however, several counter-arguments that suggest that "the world is spiky" (Florida, 2005) and geographical proximity continues to exert a strong influence over knowledge flows and innovation networks.

First, some recent studies have showed that the propensity to cite prior art and scientific knowledge is correlated significantly with spatial proximity of inventors (Criscuolo and Verspagen, 2008; Guellec and Thoma, 2008; Usai, 2008).

Second, there is little evidence that distance has become any less important for trade flows (Leamer, 2007; Disdier and Head, 2008), and some evidence that its importance may have actually increased (Evans and Harrigan, 2005). The deployment of these ICT networks can go with a reinforced need to face-to-face contact and increase complementarity between new means of communication and face-to-face contact (Gaspar and Gleaser, 1998). Face-to-face interactions remain important even in high-tech sectors, because knowledge is tacit and hard to codify.

Overall, the importance of distance might depend on the type of ICT applications used by firms. The more enhanced ICT use, the more the firm will benefit from being close to other enterprises. In contrast, when ICT is mainly employed for basic communication (e.g.: e-mail, web browsing, document sharing, etc.), distance looses relevance (Forman *et al.*, 2005).

The discussion of the channels of knowledge flows cannot be dissociated from the conditions underlying the ability of firms to benefit from these flows. Absorption capacities based on internal resources, human capital, diversity of competencies and the technological gap between transmitters and receivers of knowledge may all play a role in describing observed differences in knowledge diffusion efficiency (Autant-Bernard and Massard, 2009). In particular, the positive effects of ICTs on innovation appear to be based on both the technological applications and high-skilled workforce (Todhunter and Abello, 2011).

Understanding the role of ICTs in knowledge diffusion and innovation networks is key to better implement a number of innovation policies, namely the intellectual property rights regimes, the system of R&D subsidies, and the broader regulatory framework. Four main lines of research try to disentangle the role of ICTs in knowledge diffusion and innovation networks.

A first line tries to identify the indirect transfer of technology based on the assumption that the faster productivity growth in countries or industries lagging behind is due to the transfer of ideas. A recent development of this approach explores the role of knowledge flows and TFP growth by using direct survey data on knowledge flows linked to firm-level TFP growth data (Crespi *et al*., 2007).

A second approach uses an augmented production function framework, with the inclusion of R&D performed in foreign countries as an additional variable. This approach has the advantage of using a direct measure of technology (Bernstein and Mohnen, 1998; Griffith *et al.* 2006). Papers belonging to this approach tend to find that the foreign R&D is valuable but usually less than domestic R&D

A third line of research uses patent citation as a direct measure of the transfer of knowledge. The citation of one patent by another application suggests that the first patent contained useful knowledge which helped the second innovation. This approach appears promising to investigate the role of ICTs. On the one hand, it permits to examine whether knowledge spread more quickly in technological fields that are ICT intensive, eg: computer, communication, biotechnology, etc. (Spiezia, 2008). On the other hand, one can test if the observed differences in the speed of knowledge diffusion through time and across industries can be ascribed to the diffusion of ICTs (Griffith *et al.*, 2007). Using firm-level data, Kleis *et al.* (2011) find that IT capital is significant and positively associated with citation-weighted firm patent output. This issue is further explored by Forman and Van Zeebroeck (2010) who find that

the use of the Internet significantly contributes to the research productivity of distant collaborators.

Finally, the fourth and most recent line of research analyses knowledge flows in the framework of network analysis. These papers usually focus on patent-citations in order to capture the links between researchers (Breschi and Lissioni, 2005; Breschi and Catalini, 2010; Hanaki et al., 2010). De Prato and Nepelski (2011) follow this approach and apply it to the analysis of the internationalisation of R&D activities. In this context, network analysis proves a useful tool to assess the links between R&D centres and the knowledge flows among them, their intensity and direction, that is, who is generating knowledge and who is receiving it. These authors identify US and Germany as the countries which are receiving more R&D from other nations. These two countries together with China are also the most important sources of R&D. Nonetheless, some emerging economies (such as Brazil, Poland, Russia, and the Czech Republic) occupy a relevant position in the R&D generation network.

Issues for discussion

Despite a rich economic literature, there are still several unresolved questions on the relationship between ICTs and innovation. For example, it remains unclear whether ICTs stimulate cooperative efforts in innovation.

Spiezia (2011) addresses this issue and finds little evidence for the association between ICT intensity and cooperation in innovation. Out of the nine countries analysed, he finds a significant and positive association only for manufacturing firms in the United Kingdom and service firms in the Netherlands. Todhunter and Abello (2011) find significant and positive evidence among Australian firms. However, this result does not discriminate innovations developed in co-operation with other firms and innovations developed internally. Forman and Van Zeebroeck (2010) find that ICTs make a significant contribution to cooperation in innovation when researchers are distant, but not when they are at the same location.

The link between ICTs and innovation novelty also requires further research. To the extent that ICTs increase the invention capabilities of a firm, a positive association can be expected between the intensity of ICT use and the degree of innovation novelty. The available empirical evidence is little and mixed. Spiezia (2011) finds that a high level of ICT use does not lead to an increase in the probability to develop a product new-to-the-market (as opposed to new-to-the-firm). The only exception is for manufacturing firms in Switzerland but such result presents a weak statistical significance (10%). In contrast, the findings of Todhunter and Abello (2011) indicate that, among innovative firms, those using ICT more intensively exhibit a higher propensity to develop more novel innovations than those with lower levels of ICT use. Specifically, these firms are more likely to produce innovations which are new to Australia or to the world as opposed to innovations which are only new to the business.

More research is also needed in order to untangle the effects of certain ICT applications on innovation. Table 1 shows some results regarding the use of e-commerce and the type of innovation. The associations between these variables are far from clear. Polder *et al.* (2010) find a significant association between e-purchases and process innovation in manufacturing. Nonetheless, in a most recent paper, their preliminary results show for the same sector that e-

purchases are only relevant for non-technical innovations, like organisational and marketing (Polder *et al.*, 2011).

Table 1. Significant associations between e-commerce variables and the types of innovation

	Polder et al. (2010)			Polder et al. (2011)			
	Process	Product	Organi-sational	Process	Product	Organi-sational	Marke-ting
Manufacturing							
e-sales	X			X			
e-purchases	X					X	X
Services							
e-sales		X					
e-purchases	X	X	X		X	X	X

Note: significant associations were marked with "X".

Little is known also about ICT innovation networks. Which are the determinants of the creation of R&D linkages between countries? How much is the intensity of these relationships? Are these innovation networks creating knowledge spillovers?

A possible shortcoming of all these studies is that ICTs themselves can be regarded as an innovation, as indicated by Todhunter and Abello (2011). Grimes *et al.* (2011) find that firms doing R&D and those in high-knowlegde-intensity sectors are more likely to use broadband compared to those which do not. These findings bring the causality between ICT and innovation to the forefront of the discussion: do ICTs lead to more innovation or do innovative firms use ICTs more? Such concerns were also raised by participants at the OECD High Level Meeting on the Internet Economy that took place at the end of June in Paris (http://www.oecd.org/internet/innovation).

Above all, the question on the channels through which ICTs affect innovation and productivity is still unanswered. Bertschek *et al.* (2011) find a direct impact of broadband on innovation but not on productivity. The preliminary results of Polder *et al.* (2011) cannot detect any significant effect of IT capital on firm performance. Nonetheless, ICT could affect productivity indirectly through innovation (Van Leeuwen, 2008; Polder *et al.*, 2010). However, there is no evidence on whether ICT-enabled innovation has a different impact on productivity compared to other types of innovation.

A final issue refers to the scarce cross-country evidence, the exceptions being Hagén and Lagerquist (2011) and Spiezia (2011). In this context, it is difficult to infer whether some of the results are specific to some countries or whether they could be generalised to others nations. Only a wider access to internationally comparable data sources would permit policy-makers to learn from the experience of other countries.

Bibliography

Abello R. and G. Prichard (2008), Exploring Business Use of IT and Innovation using Linked Firm-Level Data, Australian Bureau of Statistics, *Working Party of National Experts on Science and Technology Indicators*, 16-19 June 2008.

Autant-Bernard C. and N. Massard (2009), Underlying Mechanisms of Knowledge Diffusion, *IAREG Working Paper No. 4.7*.

Bernstein, J. and P. Mohnen (1998), International R&D Spillovers between US and Japanese R&D Intensive Sectors, *Journal of International Economics*, 44, pp. 315-38

Bertschek, I., D. Cerquera and G.J. Klein (2011), More Bits - more Bucks? Measuring the Impact of Broadband Internet on Firm Performance, *ZEW Discussion Paper No. 11-032*.

Breschi, S. and F. Lissoni (2005), Cross-Firm Inventors and Social Networks: Localised Knowledge Spillovers Revisited, *Annales d'Economie et de Statistique*, 79-80, pp. 1-29.

Breschi, S. and C. Catalini (2010), Tracing the Links between Science and Technology: An Exploratory Analysis of Scientists' and Inventors' Networks, *Research Policy*, 39(1), pp. 14-26.

Brynjolfsson, E. and L.M. Hitt (2000), Beyond Computation: Information Technology, Organizational Transformation and Business Performance, *Journal of Economic Perspectives* 14(4), pp. 23-48.

Crespi, G., C. Criscuolo and J. Haskel (2007), Information Technology, Organizational Change and Productivity Growth: Evidence from UK Firms, *CEP Discussion Paper No. 783*.

Crespi, G., C. Criscuolo, J. Haskel and M. Slaughter (2007), Productivity Growth, Knowledge Flows and Spillovers, *CEP Discussion Paper No. 785*.

Criscuolo. P. and B.Verspagen (2008), Does it Matter Where Patent Citations Come From? Inventor vs. Examiner Citations in European Patents, *Research Policy* 37, pp. 1892–1908.

De Prato, G. and D. Nepelski (2011), The global ICT R&D network, *ICTNET 2nd Workshop on ICT, Intangibles and Innovation*, London, April 11-12.

Disdier, A. and K. Head (2008), The Puzzling Persistence of the Distance Effect on Bilateral Trade *Review of Economics and Statistics*, 90(1), pp. 37-48.

Eurostat (2008), *Information Society: ICT Impact Assessment by Linking Data from Different Sources (Final Report)*, Brussels: Eurostat.

Evans, C. and J. Harrigan (2005), Distance, Time and Specialization: Lean Retailing in General Equilibrium, *American Economic Review*, 95, pp. 292-313.

Florida, R. (2005), The World is Spiky, *The Atlantic Monthly*, October 2005.

Forman, C., A. Goldfarb and S. Greenstein (2005), How Did Location Affect Adoption of the Commercial Internet: Global Village vs. Urban Leadership, *Journal of Urban Economics*, 58(3), pp. 389-420.

Forman, C., A. Goldfarb and S. Greenstein (2008), Understanding the Inputs into Innovation: Do Cities Substitute for Internal Firm Resources?, *Journal of Economics and Management Strategy*, 17(2), pp.295-316.

Friedman, T. (2005), *The World is Flat*, New York: Farrar, Strauss and Giroux.

Gago, D. and L. Rubalcaba (2007), Innovation and ICT in Service Firms: Towards a Multidimensional Approach for Impact Assessment, *Journal of Evolutionary Economics*, 17, pp. 25-44.

Gaspar, J. and E.L. Glaeser (1998), Information Technology and the Future of Cities, *Journal of Urban Economics*, 43(1), pp.136-156.

Gretton, P., J. Gali and D. Parham (2004), The Effects of ICTs and Complementary Innovations on Australian Productivity Growth, in: OECD (2004), *The Economic Impact of ICT: Measurement, Evidence and Implications*, OECD, pp. 105-130.

Griffith R., S. Lee and J. Van Reenen (2007), *Is Distance Dying at last?*, CentrePiece, Winter 2007/08.

Griffth, R., R. Harrison and J. Van Reenen (2006), How Special is the Special Relationship? Using the Impact of US R&D Spillovers on UK Firms as a Test of Technology Sourcing, *American Economic Review*, 76(5), pp. 1859-1875.

Grimes, A., C. Ren and P. Stevens (2011), *The Need for Speed: Impacts of Internet Connectivity on Firm Productivity*, Ministry of Economic Development, Government of New Zealand.

Guellec, D. and Thoma G. (2008), *University Inventions and Entrepreneurship: A Regional Perspective*, mimeo.

Hagén, H.O. and M. Lagerquist (2011), ICT-Use, Organization, Innovation and Productivity, *ICTNET 2nd Workshop on ICT, Intangibles and Innovation*, London, April 11-12.

Hanaki, H., R. Nakajima and Y. Ogura (2010), The Dynamics of R&D Network in the IT Industry, *Research Policy*, 39 (3), pp. 386-399,

Kleis, L., P. Chwelos, R.V. Ramirez, I. Cockburn (2011), Information Technology and Intangible Output: The Impact of IT Investment on Innovation Productivity, *Information Systems Research*, (published online before print April 8, 2011).

Koellinger, P. (2005), Why IT matters- An Empirical Study of E-business Usage, Innovation and Firm Performance, *German Institute for Economic Research Discussion Paper No. 495*.

Leamer, E. (2007), A Flat World, a Level Playing Field, a Small World or None of the Above? *Journal of Economic Literature*, XLV(1), pp. 83-126.

Leeuwen, van G. and S. Farooqui (2008), ICT, Innovation and Productivity, in: Eurostat (2008), *Information Society: ICT Impact Assessment by Linking Data from Different Sources*, Eurostat, pp. 222-239.

M. Polder, F. Zand, G. van Leeuwen and C. van Beers (2011), Complementarities between Information Technologies and Innovation Modes in the Adoption and Outcome Stage: A Micro-Econometric Analysis for the Netherlands (preliminary draft), *ICTNET 2nd Workshop on ICT, Intangibles and Innovation,* London, April 11-12.

M. Polder, G. van Leeuwen, P. Mohnen and W. Raymond (2010), Product, Process and Organizational Innovation: Drivers, Complementarity and Productivity Effects, *UNU-MERIT Working Paper No. 2010-035*.

OECD (2005), *Oslo Manual (3rd Ed) Guidelines for collecting and Interpreting Innovation Data*, OECD, Paris.

Polder, M., G. van Leeuwen, P. Mohnen and W. Raymond (2009), Productivity Effects of Innovation Modes, *MPRA Paper No. 18893*.

Spiezia, V. (2008), The Speed of Knowledge Flows across OECD Regions: New Evidence from Patent Citations, *55th North American Meetings of the Regional Science Association International*, New York.

Spiezia, V. (2011), Are ICT Users More Innovative? An Analysis of ICT-Enabled Innovation in OECD Firms, *OECD Journal: Economic Studies* (*forthcoming*).

Todhunter, J. and R. Abello (2011), Business Innovation and the Use of Information and Communications Technology, *Australian Bureau of Statistics Research Paper No. 1351.0.55.033*.

Usai S. (2008), The Geography of Innovation Activity in OECD Regions, *STI-OECD Working Paper 2008/3*.