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ICT Investments and Labour Demand in OECD Countries

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2.1 Introduction

Major technological innovations in economic history have always been accompanied by major transformations in the labour market. By increasing labour productivity, innovation enables producing a given amount of goods and services with less employment, thus leading to the possibility of *technological unemployment*. At the same time, innovation triggers a number of *compensation mechanisms* with potential positive effects on employment.

Information and communication technologies (ICTs) are no exception to this historical pattern. Information technologies replace workers that perform routine tasks with computer-directed production processes (*automation*). Furthermore, communication technologies allow coordination of complex production activities across space and delocalisation of labour-intensive productions activities to low-wage countries (*offshoring*). At the same time, ICTs create new employment opportunities in the ICT sector and in the whole economy.

The overall effect of these different factors is predicted to be positive under the conditions postulated by economic theory in the long run. As economies may deviate from these conditions in the short run, the net employment effect of ICTs is likely to depend on institutions and policies.

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This chapter provides new estimates of the effects of ICT investments on total labour demand in 19 Organization for Economic Cooperation and Development (OECD) countries over the early 1990s–2012. By looking at the total economy, these estimates enable measurement of both the positive and negative employment effects of ICTs, which recent studies at the firm or industry level cannot account for.

The chapter is organised as follows. Section 2.2 summarises the main predictions of the economic theory on the effects of innovation on employment while Sect. 2.3 reviews recent empirical studies on the topic. Sections 2.4 and 2.5 introduce the model and the data for the analysis. The main findings are discussed in Sect. 2.6 while Sect. 2.7 concludes.

2.2 ICTs and Employment: What Does Economic Theory Say?

The analysis of the effects of innovation on employment goes through the history of modern economics, e.g. Say, Ricardo, Marx, Hicks, Marshall and Keynes, among others. The results of this analysis are known in the economic literature as "compensation theory." At the core of compensation theory is the prediction that, while innovation may reduce labour demand and lead to unemployment, it also triggers a number of automatic mechanisms that are expected to compensate for the direct decrease in labour demand. The compensation theory provides useful insights on the effects of ICTs on employment (OECD 1994; Spiezia and Vivarelli 2002).

Figure 2.1 provides an illustration of the opposing forces at play. Changes in employment (L) are the results of growth in output (Y) and the changes

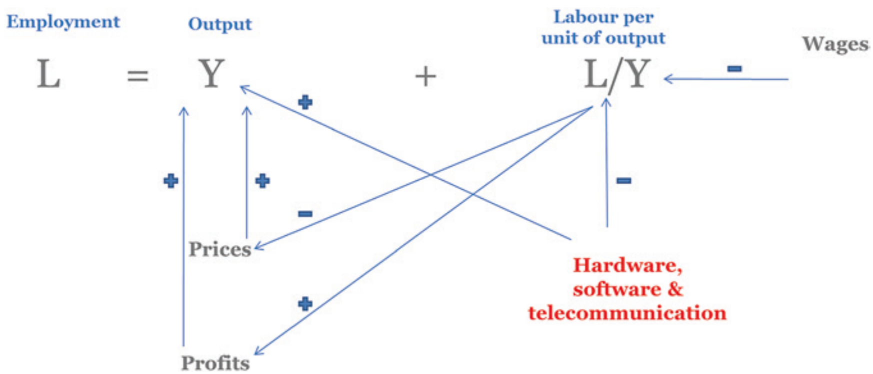

Fig. 2.1 Effects of ICTs on employment

in the quantity of labour required to produce one unit of output (L/Y). As shown in the figure, ICTs have an impact both on labour requirements and on output.

To start with, it is useful to distinguish between process innovations and product innovations. A process innovation increases productivity and reduces unit costs whereas a product innovation results in the commercialisation of new goods and services. Interestingly, ICTs comprise both process innovations, e.g. computer-controlled machineries, automated inventory flows and product innovations, e.g. smartphones, e-books, etc.

By increasing total productivity, ICT process innovations enable firms to produce a given amount of goods and services with less employment, thus leading to the possibility of technological unemployment. This effect is stronger the larger the *labour-saving bias*[1] of the new technology, i.e. the more ICTs reduce the demand of labour relative to that of capital, at constant input prices. The labour-saving bias may be different depending on the type of labour, e.g. ICTs tend to be biased against low-skill workers and towards high-skill labour.

At the same time, ICT process innovations lead to lower unit costs of production. In a competitive market, this decrease is translated into lower prices, which stimulate higher demand for products. In turn, higher demand generates additional production and employment (compensation "via decrease in prices"). The strength of this effect depends positively on two factors: first, the degree of competition in the product markets; and, second, the price elasticity of final demand.

In less competitive product markets, the decrease in unit costs induced by ICTs is not fully translated into prices and generates extra-profits for the innovative firms. Part of these extra-profits is directly reinvested and increase production and employment in the capital good sector (compensation "via increase in machineries"). The other part provides additional income for share-holders (as dividends) and workers (through wage bargaining), who may spend it on higher consumption or save it. Higher consumption directly increases aggregate demand while savings are lent through the financial system to finance investment by firms and consumption by households. Through these different channels, the increase in income generated by ICTs raises aggregate demand, production and employment (compensation "via increase in income"). The strength of these effects would be larger the higher the firms' propensity to invest, the higher the households' propensity to consume and the higher the efficiency of the financial system to reallocate savings.

The direct effect of ICT process innovation on employment may be further compensated by a decrease in real wages, which leads to an increase in the labour intensity of production and/or to a decrease in unit production costs (compensation "via decrease in wages"). The strength of the former effect depends on, first, the degree of substitutability between labour and the other production inputs and, second, the degree of wage flexibility in the labour market. The latter effect leads to the compensation "via decrease in prices" discussed above.

Finally, the commercialisation of new ICT goods and services increases consumption and production and raises the demand for labour (compensation "via new products"). This effect would be larger the lower the substitutability of new products with existing ones and the higher the labour intensity of the production of the new products. In respect to the latter factor, one may expect the labour intensity of ICT products to decrease faster than in other industries, as ICT producing industries are the most intensive users of ICT process innovations.

This brief recollection of the predictions of the compensation theory suggests three main considerations. First, the impact of ICTs on employment is the result of opposing forces, which operate through a variety of channels, agents and industries. Looking only at some of these forces is likely to provide a biased assessment of the employment impact of ICTs.

Second, the mechanisms that are expected to compensate for the direct, negative effect of ICT process innovations on employment depend on several conditions that may not apply in reality, e.g. additional income generated by ICT process innovations may not be fully spent or invested, or that may take time to become effective, e.g. lower unit costs are not immediately translated into lower prices.

Finally, the compensation for the decrease in labour demand that may result from ICTs occurs through the mobility of resources—financial capital, knowledge assets and labour—across firms and sectors. By its very nature, this process of structural change takes time and may be hampered by institutional barriers and market imperfections. More fundamentally, entrepreneurial skills, intangible assets and workers' skills tend to be industry-specific and may not be fit to the business environment, the work organisation and the tasks composition of the activities where they would have to move. This is likely to be the case especially for new markets that did not exist before, like those created by new ICT goods and services.

2.3 Innovation and Employment: Findings from Recent Studies

Several empirical studies have analysed the relationship between innovation and employment. While only few of them focus on ICTs, their findings shade light on the effectiveness of the compensation mechanisms discussed in the previous section.

In the 1980s and 1990s, macroeconomic analysis dominated the research on the employment effects of innovation (e.g. Layard et al. 1994; Freeman and Soete 1994; Machin and Van Reenen 1998) whereas more recent analyses on this topic have been carried at the sectoral or firm level. Given the scope of the chapter, this section reviews the latest studies only (see Sabadash 2013 for a review of earlier studies).

In general, sectoral studies show that structural change is the driving force behind employment growth, with opportunities for both innovation and for jobs being sector-specific. Industry-level evidence for the 1990s and early 2000s in Europe suggests that the decrease in manufacturing employment was due to a combination of weak final demand, increasing wage and the prevalence of labour-saving process innovations over product innovations (Bogliacino and Pianta 2010; Bogliacino and Vivarelli 2011). Job losses occurred mostly in large firms, among low-skilled workers, in ICT and capital-intensive industries and in the financial sector. Job creation was concentrated in industries with high demand growth and those where product innovation dominated process innovation, as well as in open economies specialised in innovative and fast growing activities.

While the positive employment effects of product innovation are confirmed by firm-level studies, the effects of process innovations range from negative to positive according to the specification and the dataset.

A series of studies on European Community Innovation Survey (CIS) data based on a common micro-funded model (Peters 2004; Harrison et al. 2014) find out that employment losses are largely concentrated in non-innovating firms while employment growth is mainly driven by the introduction of new products. Process innovation was found to have negative employment effects only in German manufacturing industry.

Hall et al. (2008) run a similar model on a panel of Italian manufacturing firms over the period 1995–2003 and find positive employment effects for product innovation but no significant effect for process innovation.

Lachenmaier and Rottmann (2011) estimate a dynamic employment equation on a dataset of German manufacturing firms over the period

1982–2002. They find positive employment effects for different innovation measures, including process innovation.

Coad and Rao (2011) find out a positive correlation between employment and a composite innovativeness index (including both R&D and patents) in US high-tech manufacturing firms over the period 1963–2002.

Bogliacino et al. (2011) analyse a longitudinal database covering 677 European manufacturing and service firms over the period 1990–2008 and find a positive impact of R&D expenditures on employment in services and high-tech manufacturing but not in traditional manufacturing.

Finally, Evangelista and Vezzani (2012) find out that all types of innovation—including organisational innovation—affect employment indirectly by improving performances, leading to higher sales and more jobs. However, the classical distinction between product and process innovation is not able to capture these differentiated effects. Innovation strategies characterised by a combination of product, process and organisational innovations show the strongest positive impact on employment, whereas the negative direct effects of process innovations are found only in the manufacturing firms when process innovations are combined with organisational changes.

Different measures of innovation and ICTs are likely to explain to a large extent the different findings of these studies. In a study on Germany, Severgnini (2009) provides an interesting comparison among three different measures of ICTs: (1) a time trend, (2) the ratio of ICT investment to output, and (3) the contribution of ICTs to total factor productivity. These measures give opposite results. When ICTs are measured by a time trend, their employment effects tend to be negative in the short run and positive in the long run. However, long-run effects become statistically not significant when labour and product market regulations are controlled for. The second measure—the ratio of ICT investment to output—has mixed effects on employment while the third measure—the contribution of ICTs to total factor productivity—has negative effects in both the short and the long run.

While firm-level analyses permit a richer characterisation of innovation strategies and avoid the confounding effects from averaging different behaviours at the sectoral or macro-level, they miss out the employment effects that ICTs may have on other firms or industries.

First, firm-level databases are, in general, not representative of all firms and tend to be biased towards large manufacturing ones.

Second, micro-level studies do not distinguish whether employment growth in innovative firms results in net job creation—through "market expansion"—or it occurs at the expense of their rivals—through "business stealing." For instance, Greenan and Guellec (2000) show that the positive employment effects of process innovation found in French firms disappear at industry level.

Finally, when the business stealing effect is accounted for, firm-level analysis does not measure to what extent the same innovation that destroys jobs in one industry may result in job creation in a different industry via the compensation mechanisms discussed in Sect. 2.2.

Recent estimates of ICT employment multiplier based on input-output analysis suggest that these indirect effects are sizable. Such multipliers measure the overall increase in employment generated by 1 additional job in the ICT industry.

Katz (2012) reviews the broadband employment multiplier estimated by different studies: their value vary between 1.92 in Germany and 3.6 in the United States. Mandel and Scherer (2012) estimate that each new job in the mobile application industry generates another 0.5 jobs in the rest of the economy.

In their study of the employment impact of Facebook app development in the United States, Hann et al. (2011) use multipliers of 2.4 for the broadband industry, 2.5 for the communication sector and 3.4 for the whole economy.

Moretti (2012) argues that the high-tech job multiplier is as high as 5: for each job created in the software, technology and life-sciences industries in the United States, five new jobs are indirectly created in the local economy, 2 in high-skill occupations (e.g. doctors and lawyers) and 3 in low-skill occupations (e.g. waiters, barbers and store clerks).

Mazzolari and Ragusa (2013) find evidence of a strong positive relationship in the United States between the change in a city top-wage-bill share and the growth in local employment in jobs that substitute for home production. Consumption spillovers may account for one third of the growth of employment in home production substitutes experienced in the 1990s by non-college workers in the United States.

2.4 Modelling the Effects of ICT on Employment

This chapter analyses the effects of ICTs on employment within the standard labour demand theory (Hamermesh 1986). This framework has the advantage of modelling the employment effects of ICTs as a result of firms' decisions and market mechanisms rather than as a technology-driven outcome.

Fast technological progress in ICTs has led to a rapid decrease in the price of ICT equipment and software and to large investments in ICTs. Such investment have resulted into changes in the production mix of labour, ICT capital and other types of capital, on the one hand, and into a decrease in production costs and an increase in final demand, via lower prices and/or higher income, on the other.

The net impact of technological progress embodied in ICT capital on labour demand depends, therefore, on: (i) the extent to which ICT capital substitutes for labour (*partial elasticity of substitution*) and (ii) the extent to which lower unit costs generate higher demand and production via a decrease in prices (*price elasticity*) and/or an increase in income (*income elasticity*).

For the total economy, the economic theory predicts that both the price elasticity and the income elasticity of final demand are equal to one. Indeed, any decrease in the output price raises real income, thus leading to a proportional increase in real consumption and/or savings. Similarly, any increase in extra-profits raise nominal income, consumption and/or savings by the same proportion. By accounting identity, savings equals investments plus net exports. Therefore, any decrease in the output price and any increase in income would translate into an equal increase in final demand (consumption, investments and net exports).

It follows that ICT investments increase or decrease labour demand depending on whether the elasticity of substitution between labour and ICT capital is smaller or bigger than 1. The main aim of this study is, therefore, to estimate the value of the partial elasticity of substitution between labour and ICT capital. Spiezia (2018) provides a formal description of the model and its econometric specification.

This approach accounts for the employment effects of technological progress embodied in ICT capital goods but it does not consider disembodied technical change. The latter has effects both on the substitution between labour and ICT capital, on the one hand, and on the decrease in output price, on the other.

First, as discussed in the Sect. 2.2, disembodied technical change reduces the demand for labour per unit of output if it is labour-saving. Therefore, estimates based on embodied technical progress only may underrate the negative impact of ICT on employment. Second, disembodied technical progress raises multifactor productivity (MFP) thus reducing unit cost and output prices. Not accounting for disembodied technical change may, therefore, underestimate the positive effects of ICTs on final demand and employment.

While it is hard to quantify disembodied technical progress due to ICTs, two considerations suggest that the above measurement errors may not be large. First, there is growing evidence that: (i) a significant part of MFP is associated with investment in intangible assets (OECD 2013) and (ii) for ICT capital to raise productivity, it requires complementary investments in intangible assets (Corrado et al. 2014). Therefore, ICT investments are strongly correlated to intangible assets and are likely to capture a significant proportion of disembodied technical progress due to ICTs.

Second, firms' expectations about the future value of ICT capital services would also reflect productivity increases due to disembodied technical progress stemming from ICTs. As discussed in the following section, such expectations are reflected in ICT capital user costs and in the investment decisions by firms. Therefore, to the extent firms anticipated the productivity effects of disembodied technical progress, these effects would be also be captured by the estimates provided in this chapter.

2.5 The Dataset

The data for the analysis are drawn from the OECD Productivity Database (PDB), http://www.oecd.org/std/productivity-stats/. The PDB combines a consistent set of data on GDP, labour input, capital services, hourly wage and capital user costs for 19 countries over 1985–2012. The default source for the dataset is generally the OECD's Annual National Accounts, although other sources have been used when national accounts data were not available.

Labour input is defined as total hours worked of all persons engaged in production.

Capital inputs are measured as capital services: for any given type of asset, there is a flow of productive services from the cumulative stock of past investments. Capital service flows in the PDB relate to non-residential fixed capital only and can be broken down by seven types of assets: Hardware and office machinery; Communication equipment; Other machinery and equipment; Transport equipment; Non-residential construction; Software and Other products.

Estimates of capital services in the OECD PDB are based on the perpetual inventory method (PIM). The PIM calculations are carried out by the OECD, using an assumption of common service lives for given assets for all countries, and by correcting for differences in the national deflators used for hardware, communications equipment and software assets (Schreyer 2002;

Schreyer et al. 2003). The “harmonised” deflators assume that the ratios between ICT and non-ICT asset prices evolve in a similar manner across countries, using the United States as the benchmark.

The price of ICT capital services is the most important information for the purpose of this chapter. In general, the price of capital services is measured as their rental price. If there were complete markets for capital services, rental prices could be directly observed. This is, however, not the case for many capital goods that are owned and for which rental prices have to be imputed. The implicit rent that capital good owners “pay” themselves is defined as user costs of capital.

It is worth noticing that, unlike in other databases, e.g. EUKLEMS, the user cost of capital is not estimated by imposing the equality between capital remuneration and gross operating surplus (value added minus total wages) but it is based on firms’ expectations about future capital productivity. Furthermore, this approach does not require perfect competition in the product market nor constant returns, e.g. to scale in production (Schreyer 2010).

Keeping aside more technical issues, two theoretical assumptions are crucial to the estimation of user costs. First, in a fully functioning asset market, the purchase price of an asset will equal the discounted flow of the value of services that the asset is expected to generate in the future (Jorgenson 1963). Second, a rational, cost-minimising producer will choose a vintage composition such that the relative productivity of different vintages is just equal to the relative user costs of the two vintages (Hulten 1990).

Changes in ICT user costs do not simply reflect improvements in technology but they also depend on firms’ expectations about the future value of ICT capital services. Therefore, for a given ICT technological trend, country differences in the factors that affect these expectations, e.g. competition, regulation, cost of borrowing, consumer preferences, market size, etc. may affect the expected value of ICT capital services and the evolution of user costs.

Figure 2.2 shows the dynamics of the user cost of ICT capital over early 1990s–2012 for the three periods early 1990s–2001, 2001–2007 and 2008–2012. These periods correspond to three phases of the business cycle: before the dot.com bubble, after the subprime crisis and between the two crises.

Figure 2.2 shows two main trends. First, in all countries the decrease in ICT user costs has been faster in the second period (2001–2007) than in the first one (before 2001). The 2001–2007 decrease was the largest in Denmark, the Netherlands and Japan (about 10% a year). Second, in most countries, the decrease in ICT user costs has continued after the crisis but

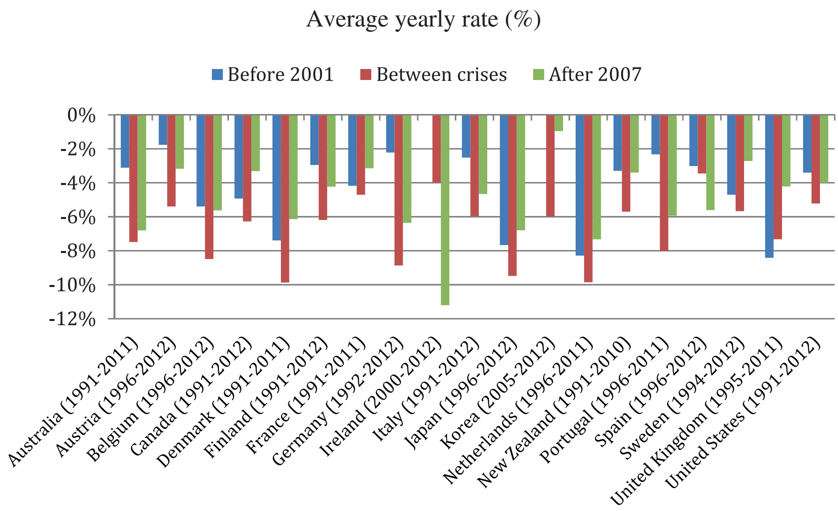

Fig. 2.2 Change in the user cost of ICT capital, 1990–2012 (*Source* Own calculations based on the OECD Productivity Database, 19 November 2015, http://www.oecd.org/std/productivity-stats/)

at a significantly slower rate. This slowdown is likely to reflect lower firms' expectations about future growth due to the crisis. Ireland and Spain are the only exceptions to this trend, as ICT user costs decreased at a faster rate than before.

2.6 Results

The partial elasticity of substitution between labour and ICT capital was estimated through system GMM (Blundell and Bond 1998) and detailed regression outputs are discussed in Spiezia (2018). The estimates provide two main results:

- In the long run, the estimated coefficient on ICT unit user cost is not statistically different from zero and the partial elasticity of substitution between labour and ICT capital is equal to one. Therefore, a permanent decrease in the user cost of ICT capital reduces labour demand per unit of output but it increases output by the same proportion. In other words, the substitution effect and the scale effect compensate each other completely. As a result, based on these estimates, investments in ICTs do not have any effect on labour demand in the long run.

- In the short run, however, firms cannot change production inputs immediately because of staggered contracts, regulations and other adjustment costs. In addition, ICT investments are likely to trigger a process of reallocation of production inputs across industries and this process takes time. As a consequence, a permanent decrease in the user cost of ICT capital does have an impact on labour demand in the short run. The adjustment path of employment can be described as follows.

In the first period, production techniques are fixed because it takes time for firms to change inputs. A decrease in the user costs of ICT capital leads to lower costs and prices and higher demand. As a result, firms hire more and employment increases. In the next period, firms can change their production technique. At a lower user of cost of ICT capital, they invest more in ICTs and reduce labour. As the hiring started in the first period is still producing its effects due to staggered contracts and adjustment costs, firms reduce employment below its long-run level. In the following periods, therefore, firms progressively increase employment as to bring it back to equilibrium.

The adjustment path following a permanent decrease in ICT user costs is illustrated in Fig. 2.3. The changes in employment are larger the larger the decrease in ICT user costs and the smaller the labour share in total costs. The return of employment to its long-run level is also slower the smaller the labour share. For the values of the labour share in OECD countries—between 0.65 and 0.88—the employment effects disappear after about 20 years.

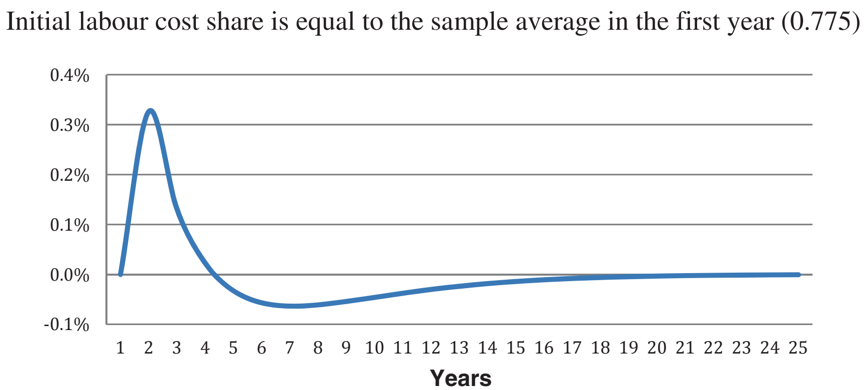

Fig. 2.3 Change (%) in labour demand following a permanent 5% decrease in the user cost of ICT capital (*Source* Own estimates based on regression output)

This dynamics is compounded by the fact that the permanent decrease in the user cost of ICT capital is not a "one-off" but it has been a continuous trend over more than two decades. Therefore, its employment effects have accumulated over time and become more persistent. In general, the employment effect of ICT remains positive for as long as the decrease in ICT user cost occurs at an increasing rate. When the decrease in ICT user cost slows down, the negative short-run effects of past capital accumulation prevail and result in a decrease in labour demand.

Figure 2.4 shows the change in employment driven by the accumulation of ICT capital over early 1990s–2012 for the three periods before 2001, 2001–2007 and 2008–2012, as discussed in Sect. 2.5.

The estimates suggest that ICT investments raised labour demand in all countries in both the period before 2001 and the subsequent period 2001–2007. In some countries, the cumulated contribution of ICT investments to employment growth over the two periods was significant: 7% in Denmark, Japan and the Netherlands; 6% in Germany; 5% in Australia, Belgium, Portugal and the United Kingdom; 4% in Canada, Finland, France, Italy, New Zealand, Sweden and the United States.

After 2007, ICTs have resulted in a decrease in labour demand in almost all countries. This seems due to the accumulation of short-run negative effects from past ICT investments and the slowdown in the decrease in ICT user costs and current ICT investments. The yearly decrease in labour demand after 2007, however, was much smaller than the yearly increase over

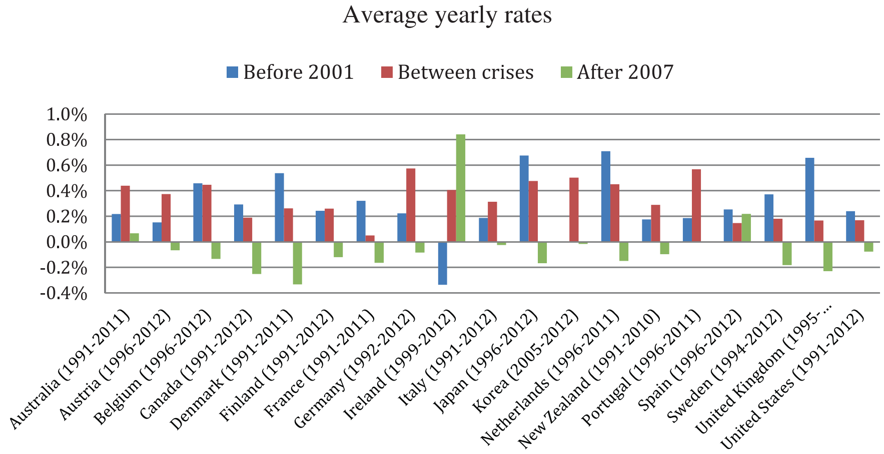

Fig. 2.4 Changes in labour demand due to growth in ICT capital (*Source* Own estimates based on regression output and the OECD Productivity Database, 19 November 2015, http://www.oecd.org/std/productivity-stats/)

the period early 1990s–2007. Therefore, the overall effect of ICT investment on labour demand over the whole period remains positive. Ireland, and to a lesser degree, Spain and Australia were the only countries where ICT investment led to an increase in labour demand after 2007.

As the post-2007 decrease in labour demand appears to be related to a slowdown in ICT investments, policies to foster such investments would be beneficial to employment. Also, the cost of temporary job losses due to the accumulation of past ICT investments could be relieved through labour market activation policies and temporary income support.

2.7 Conclusions

This study provides new estimates of the effect of ICT investments on labour demand in 19 OECD countries over the period early 1990s–2012. Its approach has been to measure ICT technical progress as the decline in the user cost of ICT capital and to estimate the effects of such decline on the demand for labour.

The findings suggest that ICT investments have no effects on labour demand in the long run. A permanent decrease in the user cost of ICT capital reduces labour demand per unit of output but it increases output by the same proportion. In other words, the substitution effect and the scale effect compensate each other completely.

In the short run, however, due to sluggish adjustments in production inputs, a one-off permanent decrease in ICT user cost results in a temporary increase in labour demand followed by a temporary decrease. Our estimates suggest that these temporary effects tend to disappear in about 20 years in most OECD countries.

This dynamics is compounded by the fact that the permanent decrease in the user cost of ICT capital is not a "one-off" but it has been a continuous trend over more than two decades. Therefore, its labour effects have accumulated over time and become more persistent. In general, the employment effect of ICT remains positive for as long as the decrease in ICT user cost occurs at an increasing rate. When the decrease in ICT user cost slows down, the negative short-run effects of past capital accumulation prevail and result in a decrease in labour demand.

Our estimates suggest that ICT investments raised labour demand in all countries in the early 1990s–2007 but reduced it afterwards. The decrease in labour demand after 2007, however, was smaller than the increase before

2007, thus leading to a positive effect of ICT investment on labour demand over the whole period.

While the negative employment effects of ICTs are estimated to fade away eventually, their persistence seem enough to justify appropriate policy measures, such as incentives to ICT investments, labour market activation policies and temporary income support.

This study has looked at the impact of ICT investments on the level of employment but not on its composition. Depending on data availability, the present framework could be extended to estimate labour demand for different types of skills or educational attainments.

Note

1. According to Hick's classification of technological progress.

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