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# INNOVATION AND JOB QUALITY.
# AN INITIAL EXPLORATION.

## QUINNE WORKING PAPER
## WP5-1-2016

VERSION 2

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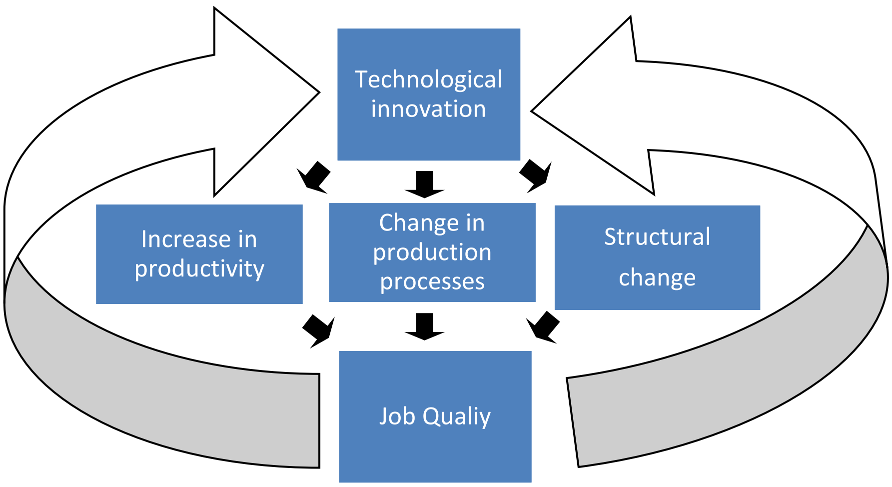
*Executive summary*

The aim of this paper is twofold. First, it is intended as a reflection about the interactions between innovation and job quality. Secondly, we will test some of the potential interactions analyzed in the first part of the paper using the 2010 European Working Conditions Survey that for the first (and so far the last) time includes information about innovation in the firm. As shown in Figure 1, the paper argues that there are several different channels of transmission going from innovation to job quality and vice versa.

Figure 1: Relations between technological innovation and job quality



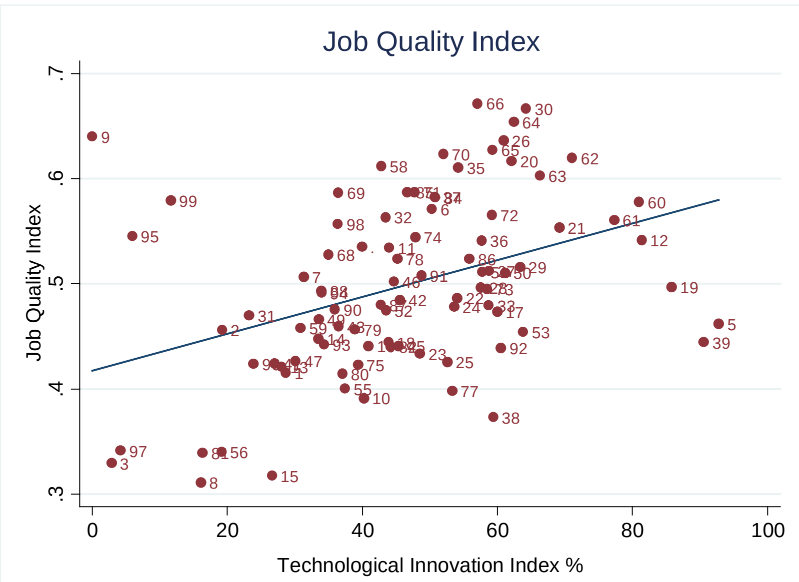

In the first place, technological (and organizational) change produces increases in productivity, what we could call a "productivity dividend" that can, and has be used, among other things to increase job quality mostly by increasing wages and reducing working time. In the second place, technological innovation (TI) changes the nature of jobs, also affecting job quality by improving working conditions. In the third place, technological innovation alters the structure of the economy through structural change, also affecting overall job quality as job quality differs among the different industries of the economy. Last, job quality might itself be a driver of innovation. There are two different mechanisms that could explain the existence of a positive relation between job quality and innovation. The first builds on the role played by job quality in incentivising productivity through an increase in employee identification with the firm. The second, a completely different perspective, argues that good working conditions translate into higher unit labour cost (*i.e.* not all the increase in labour cost is compensated by increase in productivity), putting pressure on firms to increase productivity through innovation.

The second part of the paper explores the interactions between job quality and innovation using the European Working Conditions Survey 2010 with information about job quality and innovation. In order to do so we construct a multidimensional and objective indicator of job quality following the work of Muñoz de Bustillo *et al.* (2011), that allows for adding the different dimensions of job quality: (1) pay, (2) intrinsic quality of work, (3) employment quality, (4) health and safety, (5) work-life balance, into a single aggregate indicator: the *Job Quality Index*. This analysis is performed on the EU-15 at different levels: at the country level, at the industry level, and at the level of the worker.

The analysis performed at the country level confirms the existence of a positive and statistically relevant relation between job quality and innovation ($R^2 = 0.366$). This positive relation is present in all five dimensions of the JQI, although with different intensity: very high for intrinsic quality of work and employment quality and lower for health and safety and work-life balance. The low relation between wage and innovation is explained by the major role played by the differences in GDP per capita among European countries in explaining wage differences.

The analysis performed at the level of the EU industries (two digits) also confirms the existence of a positive relation between job quality and innovation (Figure 2). At the level of the dimensions of the JQI the exception to such positive relation is work-life balance, where the relation is negative, although very weak.

Figure 2. Job Quality Index and Technological Innovation Index at industry level (EU-15)




Source: Authors' elaboration from *European Working Conditions Survey* (2010) microdata

Last, the analysis performed at the level of the individual, which is more revealing from a methodological perspective as it allows us to disentangle the role of innovation on job quality controlling for a whole array of variables (country, activity, age, gender, etc. that can have an impact on the JQI) also confirms the positive role played by technological innovation on job quality. The regression results confirm the existence of a significant and strong correlation between the quality of employment and technological innovation (both the direct variable of TI and the indirect variables of working with computers and using Internet), now at an individual level for the EU-15. However, while technological innovation is positively correlated with the JQI in the three statistical models developed, organizational innovation has no significant effect on the quality of jobs when we control for industry or occupation. Overall, model 3 accounts for nearly 40% of variations of job quality among jobs ($R2 = 0.394$).

The effect of other variables should also be highlighted: (1) Controlling for other factors, being female implies less job quality; (2) Age and educational level increases job quality; (3) Regarding firm size we observed that large companies have a higher quality of work, but that is also true for the self-employed compared to medium-sized companies (10-49 employees); (4) In relation to the sector of activity, workers in public administration and defense, in education and, especially, in financial services show higher job quality that industrial workers; (5) In terms of the effect of occupation, managers and other professional occupations show higher job quality.

# INNOVATION AND JOB QUALITY. AN INITIAL EXPLORATION

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## 1. Introduction[1].

The purpose of this paper is to present a first round of results regarding the relation between job quality and innovation. With that aim, after a brief review of the concept of job quality used in the paper and its operationalization, in section 2 we briefly review the different mechanisms through which innovation may affect job quality. In section 3 we present some descriptive statistics exploring the relation between job quality and innovation at the EU and national level, using individual data from the European Working Conditions Survey. In section 4 we explore in more detail the role played by different variables, including technological and organizational innovations, in the determination of job quality from a multivariate perspective. Finally, in section 5, as customary, we review the major conclusions of the paper.

The measure of job quality presented in this paper draws on the model of job quality developed by Muñoz de Bustillo *et al.* (2011) and Fernández-Macias *et al.* (2016). The proposed Job Quality Index (JQI) is composed of five different dimensions: (1) pay, (2) intrinsic quality of work, (3) employment quality, (4) health and safety, (5) work-life balance. In the baseline formulation of the JQI, each dimension receives the same weight (20%) and the aggregation is carried out using a weighted geometric average. The sensitivity of this weighting scheme is assessed in Muñoz de Bustillo *et al.* (2011), finding that the rank correlation of country results obtained using alternative systems of weights is remarkably high, with very few changes in the ordering of the countries when the weights are adjusted using different formulas. This assessment provides evidence of the robustness of the JQI for international comparisons. The score of each of the five dimensions is computed using an arithmetic average of the values of its

[1] The authors want to thanks Martina Bisello for her assistance in the conversion of the US Standard Occupational Classification (SOC) into the European ISCO system, as well as in the processing of Frey and Osborne (2014) probabilities of computerization estimates.

lower-level components, weighted according to the values shown in Table 1, while the aggregate index is obtained using the geometric mean of the five dimensions, as previously mentioned. Formally, for a certain individual *i*, the JQI responds to the following formula:

$$(1) \qquad JQI_i = \prod_{j=1}^{5} X_{ij}^{1/5}$$

where $X_{ij}$ denotes the score received by dimension *j* for the individual *i*. Each dimension takes a value between 0 and 100.[2]

From our perspective, the JQI exhibits two advantages worth highlighting. In the first place, its tree-like design allows having an aggregate final single job quality indicator without jeopardizing the possibility of studying the role played by the different dimensions, components and sub-components of the index in its overall value. Secondly, the JQI is constructed at the level of the individual worker, which allows evaluating the complementarily or substitution of attributes in the same job and computing the JQI for any group of specific workers (women, youth, etc.) or, in general, measures of dispersion (inequality) of job quality. Other key features of the JQI (see Muñoz de Bustillo et al 2011 for more details) are the emphasis on results (rather than procedures), the grounding of the model in a detailed discussion of the specialized literature in the traditions of the social and health sciences and the focus on objective (rather than subjective) elements. In relation to the last item, although there is a large literature exploring job quality from the subjective perspective of the worker, or work satisfaction, the JQI focuses (whenever possible) on the objective elements of the job in order to be able to have a single metric of job quality independent of workers' preferences and characteristics.[3]

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[2] The standardization of the original variables to a 0-100 scale was carried out according to a normative logic, as explained in Muñoz de Bustillo et al. (2011), pp. 153-154. The wage dimension has been subject to further procedures for normalization. First, the values were adjusted for purchasing power parities, relative to the EU-15 average. Second, all the values were adjusted for the real increase in purchasing power over time (indexed to the EU-15 value for 2000). Third, in each wave, the values were rescaled to 0-100 with 0 corresponding to the lower decile in the lowest paid country and 100 to the highest. It is important to note that the pay variable has suffered very significant changes in the three waves used in this paper (in 2000, it used *ad-hoc* intervals; in 2005, intervals linked to wage deciles in each country; in 2010, it was measured as a continuous variable).

[3] For a critical appraisal of the use of job satisfaction as an indicator of job quality see, among others, Muñoz de Bustillo and Fernandez-Macías (2005).

Table 1 presents a summary of the dimensions considered in the job quality index, JQI, used in the rest of the paper to measure job quality, as well as the questions in the EWCS used to construct the different dimensions[4].

Table 1. Index of Job Quality.

| Dimension | Variables and questions |
|---|---|
| 1. Pay | -Gross monthly wage in Power Purchasing Parity (20%) |
| 2. Intrinsic quality of work (20%) | - Skills (6.6%) [ ISCO, q49d, q49e, q49f ]<br>- Autonomy (6.6%) [q25a, q50b, q50c, q49b]<br>- Social support (6.6%) q51a] |
| 3. Employment quality (20%) | - Contractual stability (10%) [q6 q7 q12]<br>- Development opportunities (10%) [q61a, q77c] |
| 4. Workplace risks (20%) | - Physical risks (20%); [q23a-g, 24a, q24c, q24e] |
| 5. Working time and work-life balance (20%) | - Duration (6.6%); [q18]<br>- Scheduling (6.6%); [q32, q33, q34, q35]<br>- Intensity (6.6%); [q45a, q45b] |

Note: The weights of the items and the question number of the EWCS dealing with the item are shown between brackets.
Source: Authors' elaboration from EWCS.

## 2. Technological innovation and job quality: transmission mechanisms

A priori, there are four major transmission mechanisms relating innovation and job quality (Figure 1):[5]

(1) The first one is related to the leading role played by innovation in the determination of productivity, which is in turn one of the key determinants of job quality.

[4] The index used in this paper follows closely the proposal of Muñoz de Bustillo *et al*. (2011), with the updates and adaptations presented in Antón *et al*. (2016).

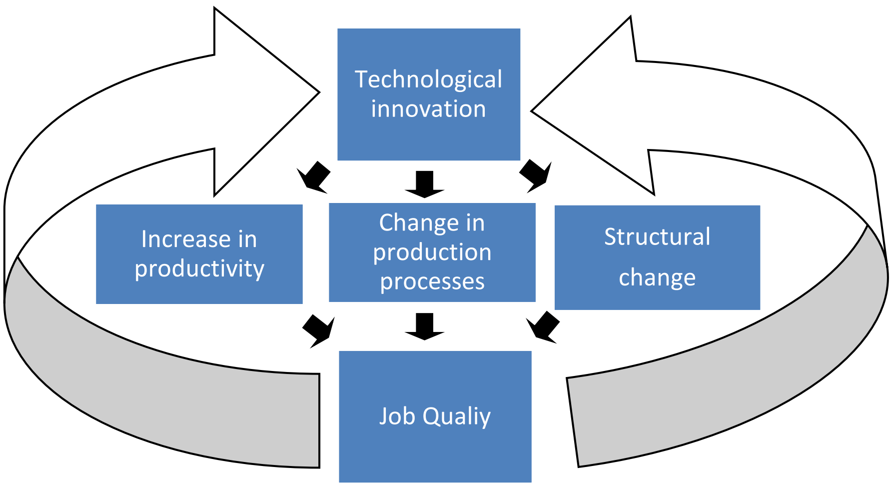
[5] As stated in the title, in this section we will follow a narrow definition of innovation, mostly centered in technological innovation. This focus omits analysis of the other types of innovation considered in the Oslo Manual (OECD 2005) and which include non-technological innovation related to organizational and marketing innovations. Two reasons lie behind this choice. First, there is an issue of data availability – the more robust data collected by the EU focuses on technological innovation. Second, despite the rhetoric otherwise, most policy focus within the EU - nationally and at EC level – also centres on technological innovation (Mako et al. 2016). Notwithstanding this point, we will briefly address the issue of organizational innovation in our analysis of High Performance Work Systems in section 2.4 and in the empirical section.

(2) The second mechanism is associated with the impact that innovation has on the structure of production and employment, and the implications of such changes on job quality.

(3) The third mechanism refers to the direct impact of different technological and organizational innovations on the working environment and the conditions of work, and the subsequent implications for job quality.

(4) If the three previous mechanisms refer to the effect that productivity may have on job quality, the fourth looks at the other way round: job quality can also act as driver of innovation.

Figure 1: Relations between technological innovation and job quality




It is important to highlight, from the very beginning, that the above mechanisms cannot be considered in isolation. The relationship between technological innovation and job quality is mediated by a myriad of factors operating at different levels, from trade unions to labour market institutions. The adoption of particular technologies in production and the associated organizational changes are themselves affected by power relations in the workplace and by the wider socio-economic context.[6] However,

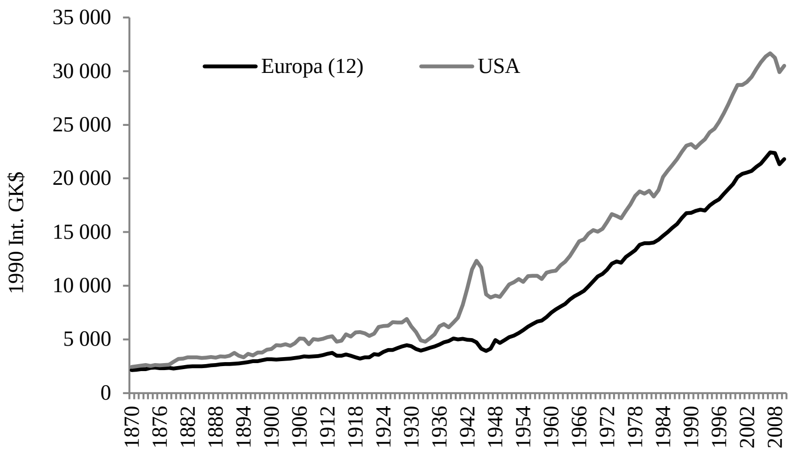
[6] For an analysis of how social relations affect innovations (and investment in specific technologies) see the mesmerizing account of the history of industrial automation of Noble (2011)

such effects are beyond the scope of this paper, and we acknowledge their importance.

*2.1. Technological change, productivity and job quality.*

The increase in productivity is the driving force of the tremendous economic growth experienced by modern developed economies in the last two centuries. From 1870 to 2010 GDP per capita increased tenfold in 12 European countries and twelvefold in the USA (Figure 2). Even in a context of intensive capital accumulation such an increase in GDP would have not been possible without the corresponding increase in labour productivity.

Figure 2. GDP per capita in Europe (EU-12) and USA, 1870-2010.




Source: Author´s analysis from Bolt and van Zanden (2013).

As it is well known, GDP per capita can be expressed as:

$$(2)\ GDP\ pc = \frac{GDP}{population} = \frac{GDP}{hours}\ x\ \frac{hours}{employment}\ x\ \frac{employment}{population}$$

$$(3)\ GDP\ pc = \pi_j .\ j\ .\ e$$

Where $\pi_j$ is hourly productivity, *j* is annual working hours and *e* is the employment rate (defined here as employment by population). We know that working hours have decreased since the 1800s across all developed countries. If we take the United States as example, according to Whaples (1990), in 1870 the US average laborer worked approximately 63 hours per week, compared to 36.5 hours in 2010 (OECD labour statistics). The employment rate has followed a different path. In 1987 total employment amounted to roughly 1/3 of the population, while by 2010 it added up to 45.5%. In any case, the 40% increase of the employment rate has not been strong enough to compensate for the decrease in working hours, leaving a compound negative impact on GDP pc of -20%. As result, we can say that the increase in GDP per capita in the period is fully explained by the rise in hourly productivity.

Although there are many elements behind the rise in productivity (investment in fixed and human capital and the corresponding increase in the capital/labour ratio, economies of scale, etc.), in the long run most of the increase in productivity is explained by technological change. This causal relation is buttressed by both the historical literature and by the more specific literature on Growth Accounting. Starting with the former, we can quote, among many others, Joel Mokryl (1990), for whom technological change is the "lever of riches", or Kranzberg and Pursell (1967) who in their epilogue to the *History of Technology* argued that "by the end of the 19th century technology had shown its capacity to transform human condition and, in many cases, to contribute to its improvement" (p. 825). In fact, according to a widely cited paper by Robert Gordon (2012):

> "A useful organizing principle to understand the pace of growth since 1750 is the sequence of three industrial revolutions. The first (IR #1) with its main inventions between 1750 and 1830 created steam engines, cotton spinning, and railroads. The second (IR #2) was the most important, with its three central inventions of electricity, the internal combustion engine, and running water with indoor plumbing, in the relatively short interval of 1870 to 1900 (...) The computer and Internet revolution (IR #3) began around 1960 and reached its climax in the dot.com era of the late 1990s" (pp. 1-2).

From a different perspective, the methodology of Growth Accounting[7], concludes that for most countries and periods, Total Factor Productivity explains a substantial part – as much as half (if not more) – of total growth (Easterly and Levine, 2001)[8].

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[7] Growth Accounting theory aims to ascribe economic growth to changes in labor and changes in capital input, following a Cobb Douglas production function, considering that the residual, i.e. the part not

Once one acknowledges the role of technological innovation in the growth of nations, its relation with job quality is fairly obvious. One of the effects of technical change, through productivity growth, was to make compatible a reduction in working time with an increase in labour income. As working time and wages are two major components of job quality, the improvement of job quality in these realms is directly related with the productivity dividend of technological innovation. It is far from our intention to argue that such relation was automatic and painless. It is well known that the struggle for the 8-hour work-week was long and painful (Roediger and Foner, 1998). But in any case, without an underlying increase in productivity it would have been much more difficult to reach the 8-hour work-week, as it would have required a direct and drastic redistribution from profits to wages. From equation (3) and the definition of factor distribution of income (the share of wages, t, and profits, b, from total output) we can say that the rate of change of the participation of profits in GDP is equal to:

$$(4)\ \dot{b} = \dot{j} + \dot{\pi} - \dot{w}$$

where the dot above the variables indicates rate of change. From equation (4) we can see how a sufficiently high rate of productivity growth would allow for the squaring of the circle: a reduction of working hours and an increase in wages, without altering the factor distribution of income (that is, with a fixed share of profits from total income). Figure 3 shows the tight correlation between growth in productivity and wages[9].

Summing up, technological change, by increasing productivity, is the major source behind two of the major improvements in job quality in the past: the decrease in working time and the increase in wages[10]. From this (partial) perspective, technological

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explained by such changes -Total Factor Productivity, TFP, in the terminology used – or in Abramowitz (1956) words the "measure of our ignorance"(p.11) – is the result of technical change.

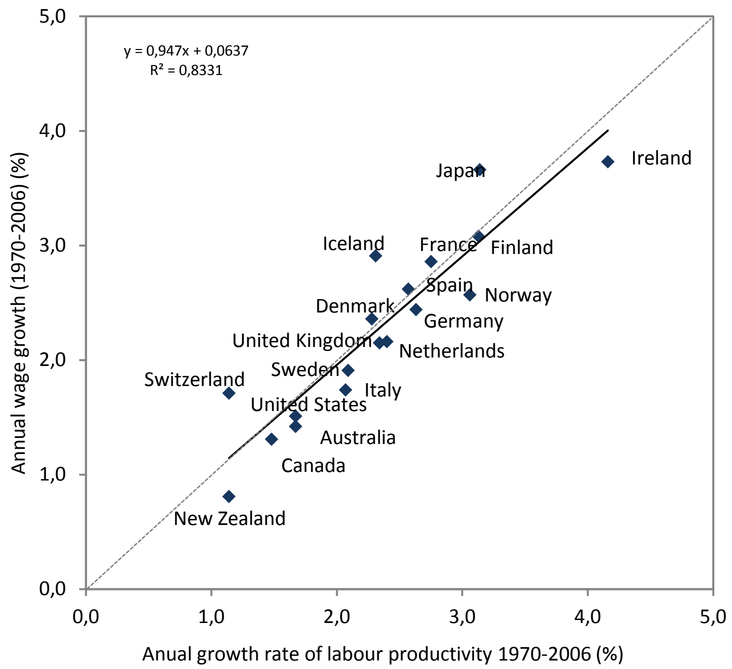
[8] For an updated account of the methodology of growth accounting from a theoretical perspective, with its pros and cons, see Hulten (2009), or Bosworth and Collins (2008), with application to India and China. An account of the allocation of growth to labour and capital inputs and productivity-technical change for the EU an USA since 1980 can be found at the GGDC Total Economy Growth Accounting Database (Timmer, Ypma and Bart van Ark, 2003).

[9] Wages are defined as labour compensation per hour worked, deflated with an output price deflator, or product wages in the denomination used by Sharp et al. (2008)

[10] To the extent that technological change (among many other important supply and demand variables) might have an impact on female labour force participation rates, technical change would have another indirect impact on job quality: the development of a new dimension of job quality related to work-life balance issues.

change has to be considered as a progressive force in terms of the improvement of job quality.

Figure 3. Wages and productivity growth. OECD countries, 1970-2006.



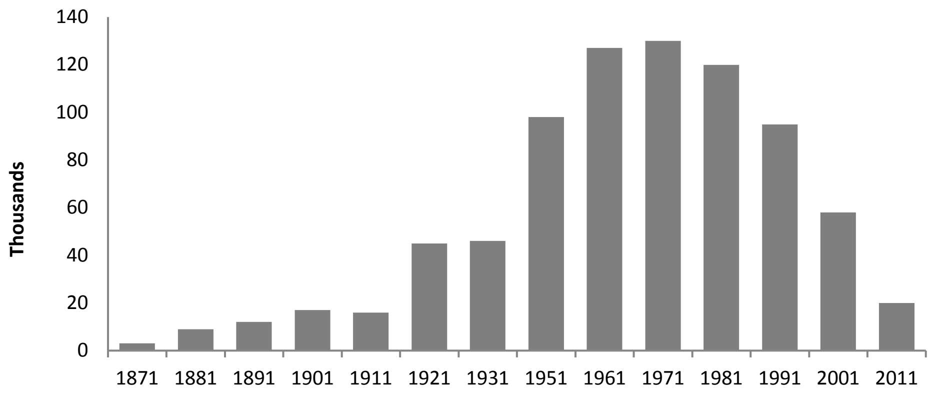

Source: Based on Sharpe et al. (2008): p.49.

*2.2. Technology, structural change and the structure of employment.*

One of the features of economic growth, known as structural change, is the changing importance of the different economic activities in terms of their contribution to GDP as countries transit from low to high income economies. Low income countries are characterized by having a large primary sector, absorbing more than 2/3 of employment, while on the other end, high income economies are basically service economies with nearly 80% of employment employed in tertiary activities. This ongoing process of structural change is explained first by the introduction of new technologies in agriculture and the corresponding emigration of rural workers to the urban industrial and service sectors, and second, by the introduction of labour saving technologies in manufacturing and the off-shoring of many industrial activities (a process itself facilitated by innovation in the transportation and communication industries).

The debate about the impact of these changes on job quality can profit from the distinction between technological changes leading to product innovation and those leading to process innovation[11]. When the first type of technological drive is in place, the development of new products might lead to the disappearance of whole industries producing highly substitutive goods (and the jobs and skills related to them). The candle industry first crowded out by the development of kerosene and gas lamps and later by the introduction of electricity and the light bulb is an example of this type of change. Computers and the development of Internet and digital switchboards are another interesting and much more recent example of technological change that implies the practical disappearance of different occupations in the recent past (Figure 3).

Figure 3. Telephone and telegraph operators in England and Wales




Source: Stewart et al (2015), p. 7

In the second case, the development of new ways to produce old products, usually associated with the increase in capital/labour ratios,  will lead to a restructuring of employment, both within the sector where the process innovation is taking place, and in the capital goods sector that produce the new technologies. A good example of this type of process is the automatization of warehouses[12], or the use of robots in industrial processes of welding and painting, now common in the automobile industry.

The impact of technologically driven structural change on job quality in the case of product innovation depends on the job quality of the jobs in the falling and rising

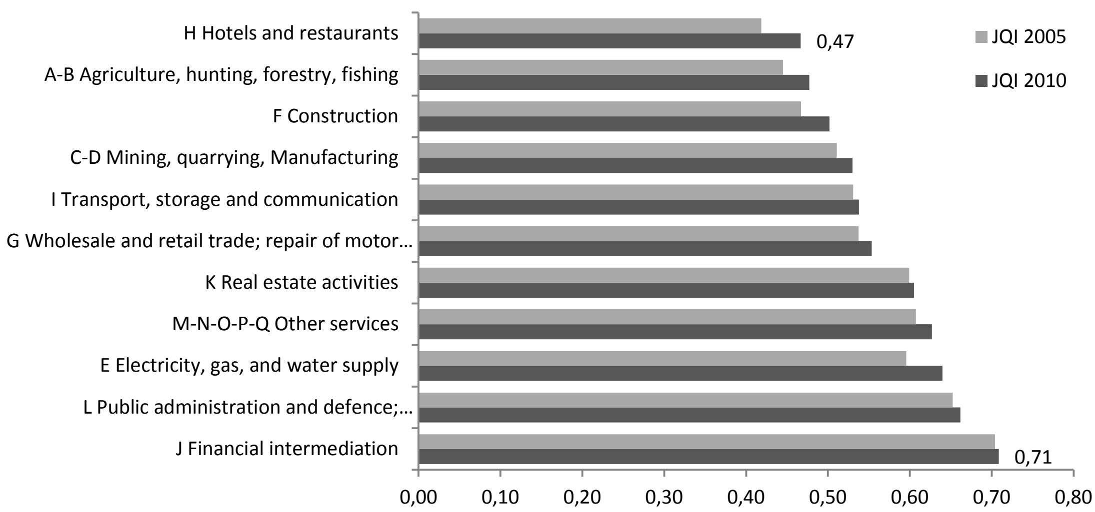
[11] Although following the Oslo manual we are fully aware of the existence of other types of innovation (marketing and organizational innovation), due to the nature and restrictions of the data bases used in this paper we focus mainly on technological innovation.

[12] A. Chang (2014) “Army of Amazon robots ready to help fulfill orders on Cyber Monday” *Los Angeles Times. Technology Now*. (http://www.latimes.com/business/technology/la-fi-tn-amazon-warehouse-cyber-monday-20141130-story.html)

industries. While the impact of the second type of change, process innovation, will depend on the type of jobs subject to substitution by machines and the characteristics of the jobs in the capital goods industry producing the new technologies.

Regarding the first issue, Figure 4 reproduces the JQI developed by Muñoz de Bustillo et al. (2011) by broad category of economic activity for the EU-15 in 2010. As can be seen, there is a sizeable difference in job quality by sectors, with JQI going from 0.47 in HORECA to 0.71 in Financial Intermediation. This means that any technologically driven reshuffling of sectors in terms of their relative importance in the economy will have implications in terms of overall job quality.

Figure 4: Job quality by major sectors of economic activity. JQI 2005 and 2010, EU-15.




Source: Authors analysis from EWCS 2010 microdata

The second question, the impact of technological change leading to the automatization and robotization of production on job quality, has been the center of an important debate about the present and future changes in the structure of employment. Depending on the type of jobs substituted by machines, of their position in the distribution of jobs according to their quality, technological change (process innovation) might have different implications in terms of job quality. There are two major (and consecutive) hypotheses that dominate the debate regarding this issue. The first one, known as Skilled Biased Technical Change, SBTC, related to the original work of Levy and Murnane (1992), argues that recent changes in the technology of production favors skilled workers over unskilled workers, leading to the increase in demand of the former type of workers and to an increase in wage inequality (Violante, 2008). The second hypothesis, known by the abbreviation RBTC, Routine Biased Technical Change, argues that the last wave of technical change (more specifically, the application in the 1990s of innovations derived from the IT Revolution of the late 1970s and 1980s) is having a strong polarizing impact on the employment structures of most advanced capitalist economies (see Autor, Katz and Karney, 2006; Goos and Manning 2007; Goos, Manning and Salomons 2009; Acemoglu and Autor 2010). In a nutshell, these papers argue that the application of these new information technologies to production (especially valuable in the substitution of routine tasks) tends to substitute labour in the middle of the skills/wage structure, while simultaneously expanding demand for labour at the top and bottom (high and low skilled non-routine activities). From this largely empirical literature, the evolution of the employment structure across all high income countries would show a hollowing out of the jobs in the middle of the wage distribution, and the corresponding polarization of labour markets in terms of wages (an important component of job quality).

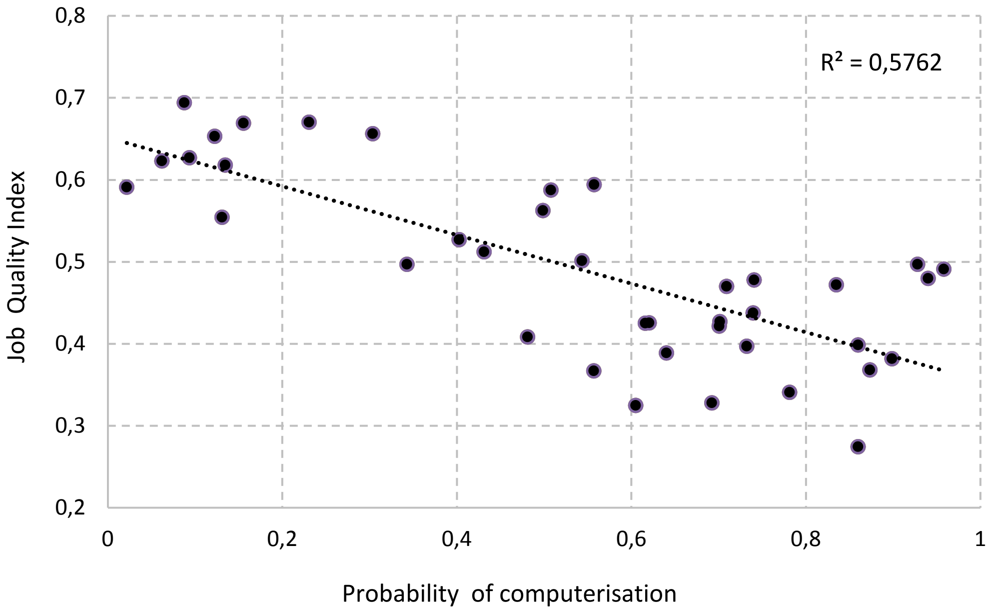
The thesis of worldwide polarization in developed countries has been empirically contested by work done under the umbrella of the European Foundation for the Improvement of Living and Working Conditions (Fernández-Macías, 2010, 2012; Fernández-Macías and Hurley, 2008; Fernández-Macías, Hurley and Storrie, 2012). This strand of work defends the existence of diverse patterns of change in the structure of employment, arguing that such plurality can be better understood by a more open approximation to structural employment change, in which not only technology, but also institutions shape the pattern of employment and how it changes over time.

It is beyond the scope of this paper to explore in detail the subtleties of this debate. Our intention is just to use it as an example of the potential impact of technological change on job quality. When the assumptions behind the SBTC apply and there are no other factors in play compensating for the impact of technology on labour demand, the result would be, as defended by Goos, Manning, and Salomon (2009), a process of labour polarization. Germany in the first decade of the 21st century is a good example of such kind of process. In other cases, such as Sweden in the same period, the results are different, pointing to a general process of upgrading. In both cases, the change in the structure of employment is explained by the combination of technical change within sectors, and structural change. But such changes do not operate in a vacuum, the results are affected also by institutional and supply side factors that can make a difference in terms of the final impact of technological change on employment structure.

The combination of the recent work by Frey and Osborne (2013) estimating the probability of computerisation for 702 detailed occupations and our JQI for Europe can give us a glimpse about the direct impact of such changes on job quality in the future by identifying whether the occupations with higher probability of computerisation are characterized now by high or low job quality according to our JQI.[13] Figure 5, that reproduces the JQI and the probability of computerization of 39 sectors of activity, shows a clear inverse relation between the computarisation rate and job quality, according to which those jobs with lower quality face a higher probability of being substituted in the future by machines. In this respect, at least in a partial equilibrium context, if Frey and Osborne (2013) are right regarding the different probabilities of computerisation of the occupation reviewed in their research, the new technological innovation wave would result in an increase in the average job quality by reducing the number of low quality jobs through the substitution of labour by capital. A different question is whether the workers no longer demanded in those jobs increasingly computerisated will find employment in other sectors of the economy, and what the quality of the new jobs performed by them will be.

[13] To do this analysis, the 702 occupations analyzed by Frey and Osborne (2013), according to the US SOC classification, were converted into 39 ISCO occupations.

Figure 5. Probability of computerisation and JQI in 39 sectors of economic activity




(*) See Annex 2 for the data of the specific sectors
Source: Author´s analysis from Frey and Osborne (2013) and EWCS microdata.

*2.3 The microeconomic impact: technological change and job quality at the job level.*

The previous two mechanisms of transmission going from technological change to job quality can be considered largely as mechanisms working at the aggregate or macro level: (a) The increase in productivity and how it is distributed between labour (reduction in working time and increase in wages) and capital (increase in profits); (b) the impact of technological change on the structural composition of output and on the labour mix (skilled, semi-skilled, unskilled) used in the production process. In both cases the changes in aggregate job quality are explained by changes occurring at the higher end of the economy. In the first place, job quality is affected by the surplus of time or output made possible by the increase in productivity. In the second place, job quality is affected by changes in the composition of employment between sectors and firms and within firms. In contrast, this subsection focuses on how changes in technology affect the process of work itself, the things workers do and the environment in which they do them. The question now is to investigate how technological change, while improving some areas of work, might generate new risks, deteriorating other areas of job quality.

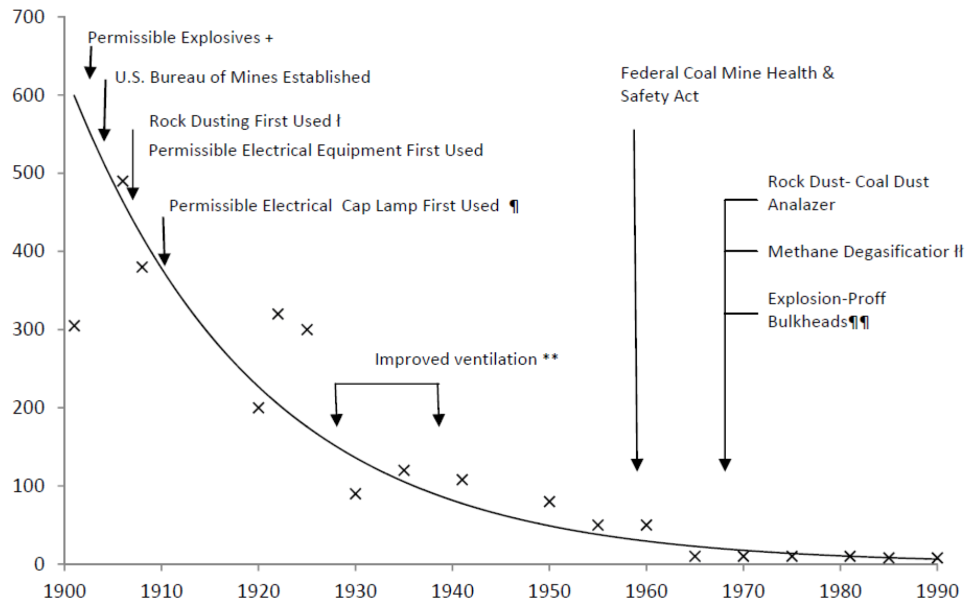
A first illustrative way to approach the issue of the impact of technological change on working conditions at the job level is by looking at what is doubtlessly the most fundamental working condition: the security of one's own life while at work. Taking the US as example, according to official statistics (AFL-CIO, 2013), in the last four decades (1970-2011), the national fatality rate (work related deaths per 100.000 workers) decreased by 80%, from 18 to 3.5[14]. Obviously, the reduction of the fatality rate is the result of a combination of many interrelated factors, not solely related with micro-level technical change. Among them we could mention structural change: agriculture and mining have fatality rates more than six times higher than the average, and construction more than twice as high, while the fatality rate in education is less than 20% of the average. The development of stricter health and safety regulations is another major factor affecting the reduction in fatality rates. But these considerations should not lead us to think that technical change played a marginal role in the reduction of fatality rates. A good example of the role of technological innovation in the reduction of fatality rates is the mining industry in the US. Although the introduction of new machinery also introduced some new hazards (MMWR, 1999), the result of technological change in terms of lower casualties in the sector reproduced in Figure 6 is telling.

But technological innovation can also deteriorate working conditions, creating new risks. One of the first (if not the first) economist to draw attention to the negative impact of technological change on job quality was Adam Smith (1776), and he did it with powerful words:

> In the progress of the division of labour, the employment of the far greater part of those who live by labour, that is, of the great body of the people, comes to be confined to a few very simple operations, frequently to one or two. But the understandings of the greater part of men are necessarily formed by their ordinary employments. The man whose whole life is spent in performing a few simple operations, of which the effects are perhaps always the same, or very nearly the same, has no occasion to exert his understanding or to exercise his invention in finding out expedients for removing difficulties which never occur. He naturally loses, therefore, the habit of such exertion, and generally becomes as stupid and ignorant as it is possible for a human creature to become. (1776, Book 1, Chapter 5).

[14] The figure for 2011 is calculated in terms of total hours. AFL-CIO (2013), pp. 41-42

Figure 6: Five year averages of annual number of deaths related to coal mine explosions in the United States, 1901-1995*




* Each X represents the 5 years average of the number deaths related to coal mine explosions; the line is a smoothed regression line through the 5 years average
+ Explosives and equipment that can be used in an explosive methane-rich environment without causing a methane explosion.
ɫ The process of applying a layer of rock dust over the coal dust, which creates an inert mixture and inhibits a coal dust explosion
¶ Lamp worn on miners' caps
** Ventilation improvements, including the use of reversible fans, reduce the concentration of methane and remove the explosion gas from the mine
++ A hand-held monitor that provides instantaneous readings of the rock-to-coal dust mixture to ensure that it is inert
ɫɫ Techniques to remove methane from the coal before mining the coal
¶¶ Explosion proof walls used to seal abandoned (mined-out) areas to protect workers in active parts of the mine

Source: MMWR, 1999.

### *2.4. Job quality as a driver of innovation.*

In previous sections, job quality was considered (at least partly) as the output of technological change. Working through different channels (the nature of the job performed, the types of sectors developed or the kind of work substituted or complemented by new technologies), technical innovation affects the type and nature of employment and work and job quality. In this section we will change radically the perspective, exploring whether job quality might be one among the many variables affecting innovation itself. Do good (or bad) jobs lead to faster technological change? Is job quality among the multiple factors affecting the pace of innovation?
There are two different mechanisms that could explain the existence of a positive relation between job quality and innovation from this perspective. The first one builds on the role played by job quality in incentivising productivity. The theory of efficiency wages (Akerloff and Yellen, 1986) is probably one of the best known approaches relating job quality (specifically the wage dimension of it) to improvements in output.

As it is known, the theory of efficiency wages argues that higher wages lead to higher productivities through different mechanisms that go from the higher identification of the workers with the firm and the intensification of their effort at work, to improving morale, reducing turn-over, attracting better workers etc. From this perspective, better working conditions would pay for themselves through higher labour productivity (Raff and Summers, 1986).

The same argument could be applied directly to the generation of innovation, when innovation is a routine output of firms developed in specific R&D departments. In such cases, according to the theory of efficiency wages, better wages might lead directly to more innovation. Moreover, good working conditions and higher identification of workers with the goals of the firm might incentive small innovations at the plant level. In fact, often firms have specific incentive programs to facilitate the involvement of workers in organizational and technological innovations aiming at improving productivity. From the same perspective, it could be argued that good employment conditions (one of the dimensions of job quality), and specifically job security, will make workers less innovation adverse, as their jobs will be protected from the potential negative impact of innovation on employment.

More recently, the literature on High Performance Work Systems, HPWS, extols the positive impact on firm performance of new non-hierarchical management systems. According to Pfeffer (1988), HPWS are characterized by seven key elements: (a) employment security; (b) selective hiring of new personnel; (c) self-managed teams and decentralization of decision making as the basic principles of organizational design; (d) comparatively high compensation contingent on organizational performance; (e) extensive training; (f) reduced status distinctions and barriers, including dress, language, office arrangements, and wage differences across levels; (g) extensive sharing of financial and performance information throughout the organization. These elements aim at creating "an organization based on employee involvement, commitment and empowerment, not employee control" (Tomer, 2001, 64). The review of the above mentioned list shows that many of the constitutive elements of the HPWS are positively related with job quality according to our model: autonomy, employment stability, wage, participation, etc. Although most of the empirical analysis of HPWSs has focused on its impact on firms and workers in the short run, obtaining conflicting results[15], there is a number of studies that look at its effect on innovation: Hefferenan *et. al*. (2008), Harden *et al.* (2006), Flood *et al.* (2008) and Fu *et al.* (2015), finding a positive relation between HPWS and innovation.

[15] As pointed by Boxall and Macky (2009) some authors argued that HPWS benefit both workers and firms (Appelbaum *et al.*, 2000) others question the gains for firms (Cappelli and Neumark, 2001; Way, 2002) or for workers (*e.g.* White *et al.*, 2003), while other question the value for both parties (*e.g.* Godard, 2004). For a survey of the literature see (Heffernan et al., 2011).

The second mechanism relating job quality and innovation is completely different. From this perspective, good working conditions translate into higher unit labour cost to the firm (not all the increase in labour cost is compensated by increase in productivity) putting pressure on firms to increase productivity through innovation. This second mechanism can be in operation in countries with high levels of trade union affiliation rates and labour leverage high enough to set good working standards across firms and industries (such as the Nordic states of the EU). By not allowing working conditions to be tailored to the specificities of low productivity firms, this policy expels *de facto* low productivity firms from the market, improving working conditions and acting at the same time as a powerful incentive to increase productivity through innovation as the only road to increase survival rates and profitability.

Summing up, the review of the existing literature on the relation between innovation and job quality shows the complexity of the nexus between both variables. On the one hand, innovation, working at different levels going from the overall increase in productivity and the generation of "innovation dividends" that can be used to improve job quality, to its impact on structural change and the transformation of the way workers do their jobs, had in the past a clear positive impact on job quality. On the other hand, job quality can affect innovation by improving the identification of employees with the goals of the firm and increasing their cooperation both at the level of generating and introducing innovations.

With this framework of reference, in the following section we will explore the interactions between job quality and innovation using the European Working Condition Survey that in 2010, on top of the usual and rich information about job quality, included a question about innovation at the level of the firm.

## 3. Job quality and innovation: data and first results.

### *3.1 The data.*

The European Working Condition Survey (EWCS) is the most important and detailed source of information about working conditions at the European level. The EWCS is funded, designed and coordinated by the European Foundation for the Improvement of Living and Working Conditions (Eurofound).[16]

[16] The Eurofound is an EU agency based in Dublin whose mandate is to gather knowledge to contribute to the planning and design of policies to improve the conditions of life and work of Europeans. The EWCS questionnaire is designed by a group of experts and policy makers on the area of work and employment, together with the Foundation research staff. The Foundation also prepares the principles for the sampling and fieldwork methodology, which are then part of the technical conditions of a tender.

One of the key advantages of the EWCS with respect to other surveys (especially, in comparison to Eurostat's) is the fact that the whole endeavour is funded, designed and coordinated centrally. This ensures a level of comparability which is higher than in other European labour market surveys. Another important advantage of the EWCS is a high degree of transparency and documentation of the whole research process. The sample of the EWCS is representative of all persons in employment in private households in all EU member states (and some European non-Member States, such as Turkey, the Former Yugoslavian Republic of Macedonia, Norway, Albania, Kosovo and Montenegro). The fieldwork procedures follow the same principles across Europe: in all countries, the sample is stratified by region and size of settlement, and the interviews are clustered by geographic proximity. The actual selection of households is based on the random-walk method, and within the selected household one employed individual is randomly selected.

The size of the sample for the latest EWCS for most countries is 1,000 cases per country.[17] This, in fact, is the main problem of the EWCS. This sample size allows for the production of good estimates of the overall incidence of the phenomena captured in the survey at the national level, but if ones wants to go deeper and break down the results within countries by gender, sectors, occupations or other variables, the number of cases used for specific estimations very quickly becomes too small and the estimation is unreliable. The analysis of this paper is restricted to the EU-15 states to allow for a reasonable manageability and interpretation of the results.[18]

As mentioned above, the EWCS is extremely rich in terms of information about working conditions, allowing the calculation of the JQI index described in Section 1. The EWCS also includes two questions about innovation (technological and organizational innovation) allowing the exploration of the relations between job quality and innovation, if at a very basic level due to the rough nature of the information on innovation gathered in the survey.

In order to analyse the relation between job quality and innovation we have calculated the aggregate JQI defined in Table 1. Throughout all the analysis we will provide information about the JQI and the values of its five different dimensions. The analysis of innovation will be much more "crude" due to the limitations of the EWCS in this respect. The EWCS only supplies binary information regarding whether the firm has (or has not) innovated in the last 3 years (and only in the 2010 wave of the survey),

[17] Exceptions were Germany and Turkey (target sample size of 2,000) and Italy, Poland and the United Kingdom (target sample size 1,500). Three other countries decided to finance bigger national samples resulting in a target sample size of 4,000 in Belgium, 3,000 in France and 1,400 in Slovenia. The total number of interviews in 2010 was 43,816.

[18] More details on the methodology and characteristics of the EWCS can be found at the Eurofound's website (http://www.eurofound.europa.eu/surveys/ewcs/index.htm), while the databases are freely available through the United Kingdom Data Service in Essex (http://ukdataservice.ac.uk/).

differentiating between *Technological Innovation*, TI ("New processes or technologies were introduced") and *Organizational Innovation*, OI ("Substantial restructuring or reorganisation was carried out")[19]. Although in the previous section we have limited our analysis to the different mechanisms relating technological innovation and job quality, without even mentioning organizational innovation, we have decided to include organizational change in our empirical analysis, as often the introduction of new technology goes hand in hand with the introduction of innovations in the organization of the firm (the correlation index is 0.90). In order to better grasp this interrelation, we have also considered a stricter indicator of innovation, conformed by those firms with positive answer to the question of both technological and organizational innovation (*Full Innovation*, FI). Table 2 reproduces these Indexes of Innovation for the EU (27) (percentage of workers declaring that new processes or technologies were introduced).

[19] We are fully aware that the way the question is posed in the survey covers any organizational change, and in that sense includes changes, such as downsizing, for example, that can be considered out of the scope of what is usually considered organizational innovation: "The distinguishing features of an organisational innovation compared to other organisational changes in a firm is the implementation of an organisational method (in business practices, workplace organisation or external relations) that has not been used before in the firm and is the result of strategic decisions taken by management." (OECD, pp. 51)

Table 2. Index of innovation. EU-27, 2010.

| | New processes or technologies were introduced **(TI)** | Substantial restructuring or reorganisation was carried out **(OI)** | Both **(FI)** |
|---|---|---|---|
| Sweden | 57,9 | 53,1 | 35,0 |
| Finland | 55,2 | 52,0 | 37,3 |
| Denmark | 54,0 | 50,1 | 34,3 |
| Malta | 48,4 | 42,4 | 32,4 |
| Cyprus | 47,3 | 39,6 | 33,5 |
| United Kingdom | 46,7 | 38,8 | 30,0 |
| Luxembourg | 46,2 | 34,0 | 24,9 |
| Netherlands | 45,8 | 37,4 | 25,0 |
| Belgium | 41,9 | 30,9 | 19,7 |
| Slovakia | 41,4 | 32,9 | 22,8 |
| Ireland | 41,4 | 35,4 | 26,0 |
| Germany | 41,3 | 30,5 | 22,9 |
| Austria | 41,2 | 30,5 | 24,1 |
| Latvia | 41,0 | 38,3 | 22,1 |
| Estonia | 39,8 | 39,0 | 24,5 |
| EU27 | 39,37 | 32,66 | 22,18 |
| Slovenia | 38,3 | 29,5 | 18,9 |
| Lithuania | 37,8 | 28,1 | 18,2 |
| Czech Republic | 36,3 | 33,7 | 20,4 |
| Portugal | 35,9 | 27,1 | 21,5 |
| Spain | 35,1 | 23,4 | 14,4 |
| Hungary | 33,3 | 26,0 | 15,3 |
| Italy | 32,8 | 23,7 | 16,0 |
| France | 32,6 | 31,9 | 21,2 |
| Greece | 27,8 | 23,0 | 18,5 |
| Romania | 27,2 | 29,9 | 12,2 |
| Poland | 26,0 | 17,4 | 9,9 |
| Bulgaria | 19,6 | 20,5 | 12,0 |

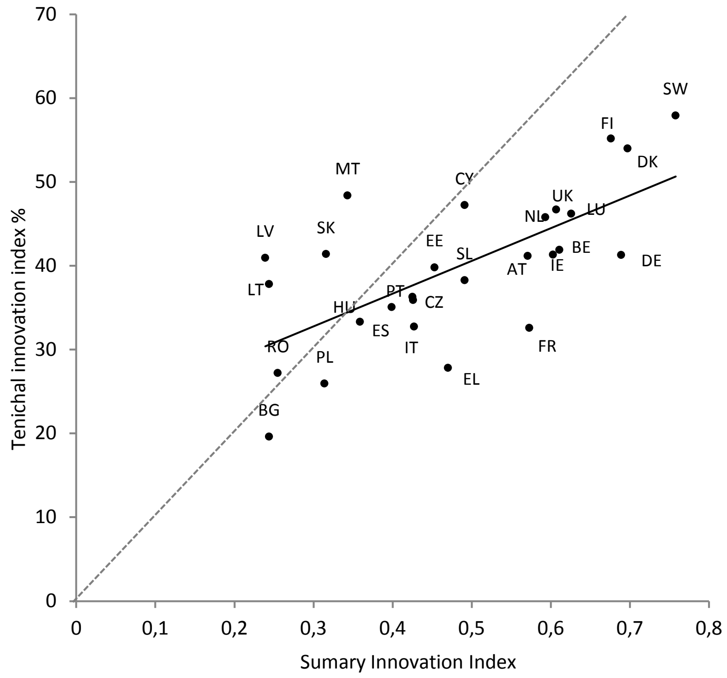
Source: Authors´analysis from EWCS microdata (Q15)

Before proceeding with the analysis of the interactions between job quality and innovation it is important to test to what extent the (simple) indicators of innovation that we are going to use in the analysis offer a reasonable account of the innovation activity of EU firms[20]. In order to do so, we will check whether the picture of innovation activity in European firms according to our innovation index, TI, is similar to that obtained using other more complex instruments such as the EU *Summary Innovation Index,* SII. In any case, before presenting the results of this comparison, it is

[20] The reliability of the JQI has been already tested in Muñoz de Bustillo et al. (2011) (2016).

important to acknowledge that the aims of both indexes are different, and so we should not expect a perfect match between the results obtained. The SII is a synthetic index of innovation constructed by the aggregation of 25 different indicators, allocated in 8 different dimensions and grouped in 3 blocks: *enablers* (main drivers of innovation performance external to the firm), *firm activities* (innovation efforts at the level of the firm), and *outputs* (effects of firms' innovation activities). The resulting indicator is built using secondary aggregated data from different sources, is relatively complex and covers many different aspects of innovation activity, from public expenditure in R&D, to international scientific publications to new doctorate graduates. In contrast, the indicator of innovation that we will use in the analysis of the interrelation of job quality and innovation is much more parsimonious. Nevertheless, as we can see in Figure 7, that reproduces the values of both indicators, there is a relatively high correlation between the Technical Innovation Index built from the EWCS microdata and EU Summary Innovation Index. The correlation index between the two indicators is 0,671 when using the global SII, and 0.754 when using only the firm activity dimension.

Figure 7. Summary Innovation Index and Technical Innovation Index from the EWCS in the EU-27, 2010




Source: Author´s analysis from Maastricht Economic and Social Research and Training Centre on Innovation and Technology (UNU-MERIT) (2011) and EWCS 2010 microdata.

Last, as a first approach to the relation between job quality and innovation, Table 3 presents the correlation coefficient between the Job Quality Index and Technological Innovation and Organizational Innovation Index by sector using individual level data from the EWCS-2010. From these results we can say that: (1) technological innovation has a stronger relationship with the quality of jobs than organizational innovation. In interpreting this result it is important to be cautious due to the lower quality of the indicator used, as it includes all kind of organizational changes; (2) The relation between innovation and job quality is clearly contingent to the type of activity, being higher in "Water supply, sewerage, waste management and remediation activities", "Administrative and support service activities", "Transportation and storage" or “Manufacturing”.

Table 3. Pearson correlation coefficient among Job Quality Index and Index of innovation by sector, EU(15), 2010.

| | New processes or technologies were introduced (TI) | Substantial restructuring or reorganization was carried out (OI) | Both Technological and organizational innovation were introduced | n |
|---|---|---|---|---|
| EU15 | 0.20 | 0.13 | 0.14 | 22,136 |
| Agriculture, forestry and fishing | 0.12 | 0.09 | 0.09 | 644 |
| Mining and quarrying * | **0.36** | 0.22 | 0.23 | 58 |
| Manufacturing | 0.20 | 0.14 | 0.14 | 2,578 |
| Electricity, gas, steam and air conditioning supply | 0.14 | 0.13 | 0.11 | 196 |
| Water supply; sewerage, waste management | **0.36** | 0.11 | 0.12 | 131 |
| Construction | 0.13 | 0.10 | 0.07 | 1,522 |
| Wholesale and retail trade; repair of motor | 0.11 | 0.07 | 0.07 | 3,600 |
| Transportation and storage | **0.21** | 0.15 | 0.17 | 1,097 |
| Accommodation and food service | 0.14 | 0.10 | 0.10 | 1,148 |
| Information and communication | 0.15 | 0.11 | 0.08 | 579 |
| Financial and insurance activities | 0.14 | 0.10 | 0.10 | 753 |
| Real estate activities | 0.09 | 0.07 | 0.12 | 197 |
| Professional, scientific and technica.. | 0.10 | 0.04 | 0.01 | 946 |
| Administrative and support service ac | **0.23** | 0.19 | 0.17 | 908 |
| Public administration and defense; compulsory | 0.14 | 0.06 | 0.05 | 1,382 |
| Education | 0.16 | 0.06 | 0.09 | 1,834 |
| Human health and social work activities | 0.14 | 0.04 | 0.09 | 2,765 |
| Arts, entertainment and recreation | 0.06 | -0.03 | -0.02 | 448 |
| Other service activities | 0.10 | 0.08 | 0.06 | 843 |
| Activities of households | 0.14 | 0.02 | 0.03 | 456 |

* Less than 100 cases
Source: Authors´ analysis from EWCS microdata

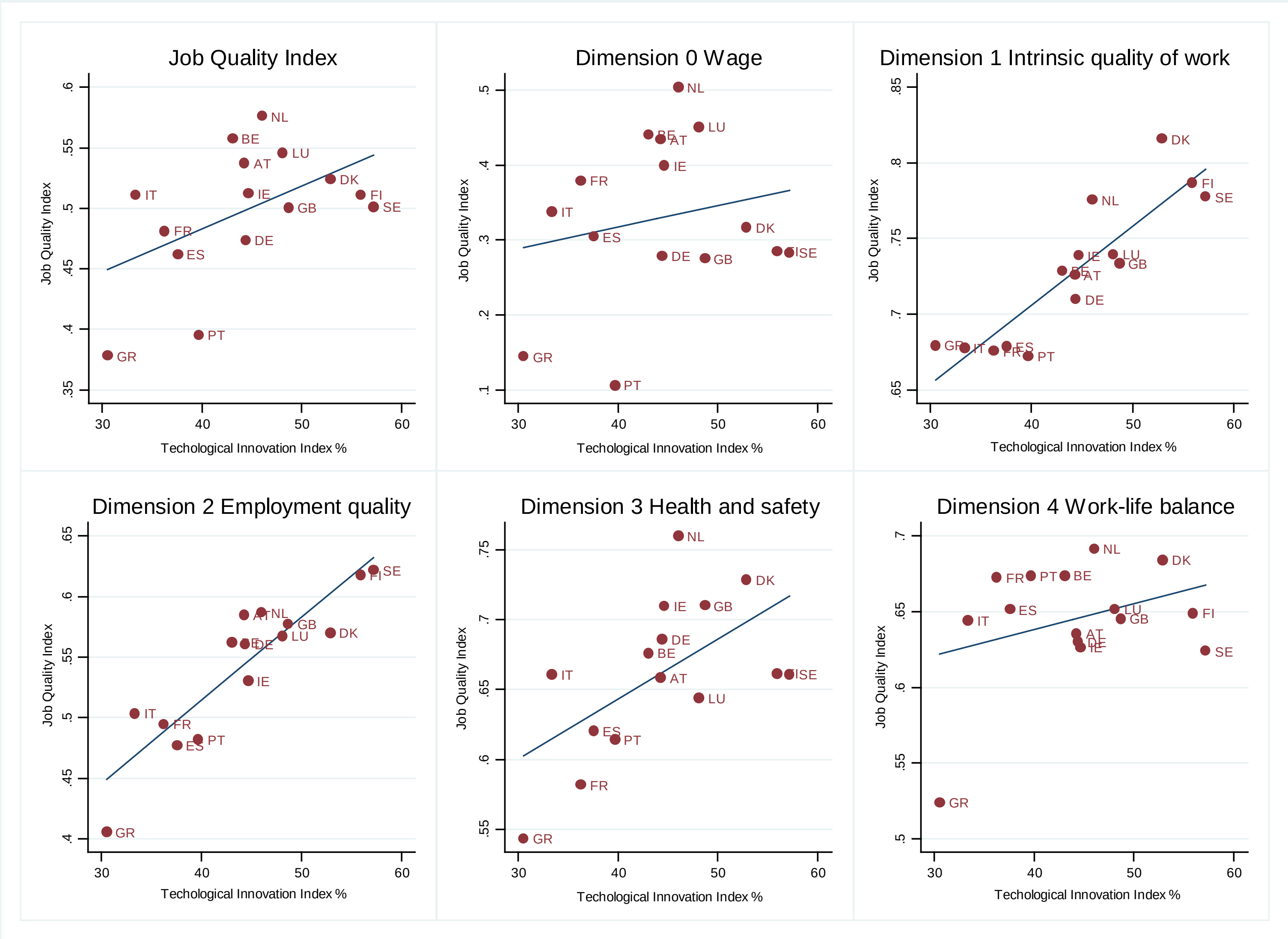
***3.1 Job quality and innovation at the country level.***

In order to evaluate the existence, direction and intensity of the relation between innovation and job quality in the EU-15 we will start by exploring the relationship between job quality and technical innovation at the country level. The results reproduced in Figure 8 show that, at least at country level, there is a direct relationship between technological innovation and job quality. Furthermore, this correlation is relatively strong with an $R^2$ of 0.336. In order to further study the nature of such a relation it is important to explore to what extent such a positive relation operates through all the dimensions of the JQI.

As we can see in Figure 8, although the five dimensions of the JQI show a direct relationship to technological innovation, it's clear that the intensity of such a relationship is very different for each of them. Technological innovation at the country level has a very weak correlation with the wage, probably because wages are more affected by other factors such as age, occupation, etc. Neither is the correlation between technological innovation and work-life balance particularly strong, probably affected at country level by other factors such as labor regulations and public policies as well as the sectoral composition of the economy. However, the correlation between innovation and quality of employment is very high for the dimensions of intrinsic quality of work and quality of employment, with an R-squared of 0.81 and 0.85 respectively.

Observing the location of different countries in the EU-15 in terms of the relation between innovation and job quality in Figure 8, we can conclude that there is a clear divide by region, a kind of regional clustering. On the one hand, the Mediterranean countries, including France, are located in the lower left corner of the graphics, that is, show a lower percentage of employees in establishments that have developed technological innovation in the last three years and have a lower quality of employment. In the opposite corner (top right), the Nordic countries are located – Denmark, Sweden and Finland– with high technological innovation and high job quality. For their part, the countries of Central Europe, and the UK and Ireland, are located in between the two extremes. Again, we note that the differences between countries are more marked regarding the dimensions of intrinsic quality of work, quality of employment and health and safety.

Figure 8. Innovation: new processes or technologies were introduced in current workplace during the last 3 years by Job Quality Index. EU15 countries, EWCS 2010.




JQI $R^2$ = 0.366; Dimension 0 $R^2$ = 0.069; Dimension 1 $R^2$ = 0.812; Dimension 2 $R^2$ = 0.855; Dimension 3 $R^2$ = 0.348; Dimension 1 $R^2$ = 0.187.

Source: author's elaboration from *European Working Conditions Survey* (2010)

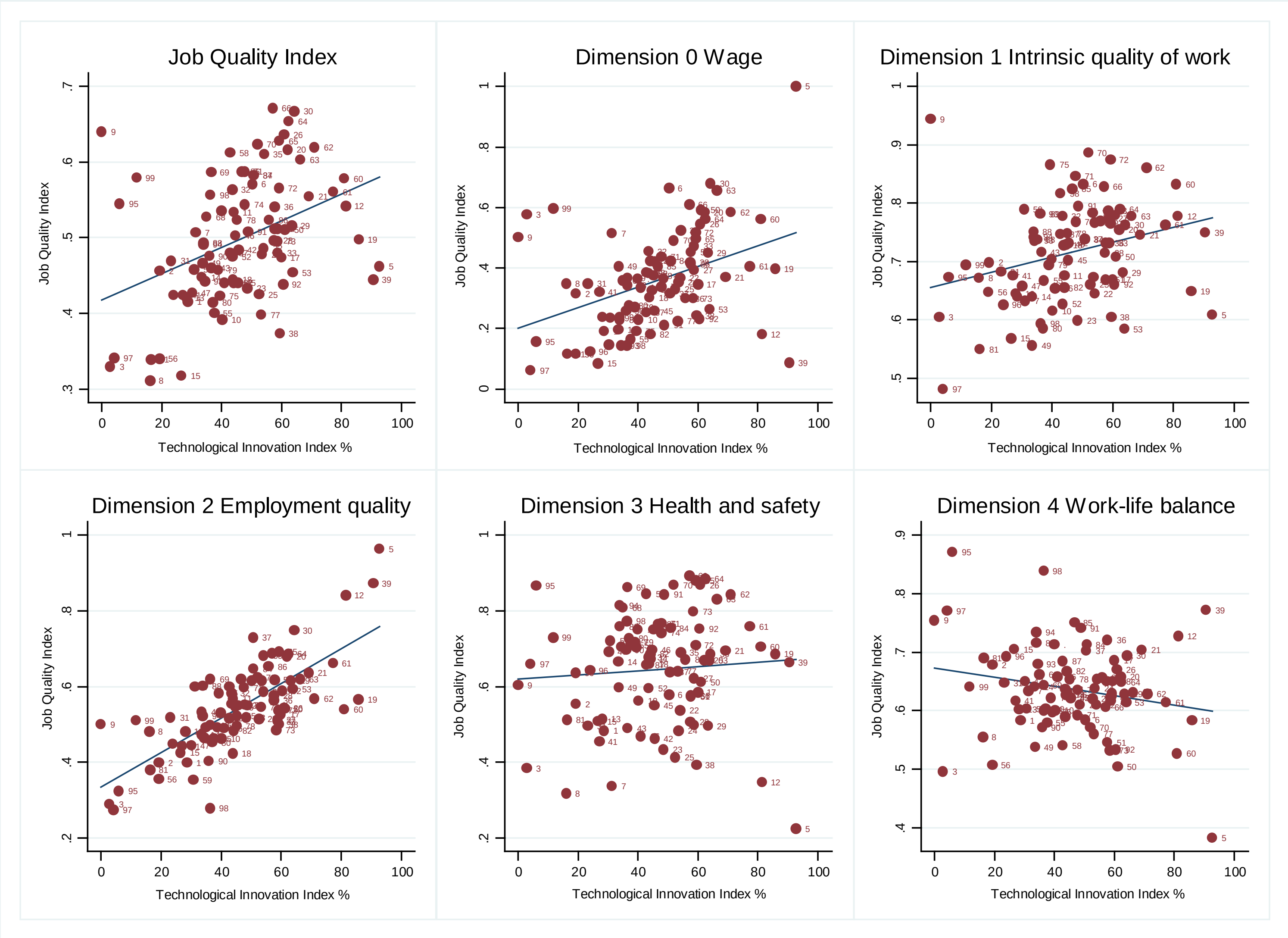
*3.2 Job quality and innovation at the sectoral level*

As we said before, to better understand the correlation between technological innovation and quality of employment it is also necessary to look at these two variables at the level of the different sectors of activity. Due to the limited sample size for most of countries in the EWCS, the analysis at the sectoral level will be limited to the whole EU-15. With that aim we have used the European Classification of Economic Activities (NACE) at two digits (see Annex 1). At sector level, again we observed a direct correlation between technological innovation and quality of employment, with an r-square = 0.158, significantly lower than the same relationship at country level.

More interesting is the analysis of the different dimensions of JQI at the sector level (Figure 9). Now, the wage dimension shows a stronger correlation than when analyzed at country level. Those sectors with a higher percentage of workers in "innovative companies" (firms that have introduced technological innovations in the last 3 years) are associated with higher wage levels. By contrast, the dimensions "intrinsic quality of work" and "health and safety" doesn´t show a strong correlation with technological innovation at the sector level. It is also worth highlighting that the dimension "work-life balance", is negatively correlated to innovation at the sector level, although with a very weak inverse relation (R-squared = 0.041). That is, at the sector level greater technological innovation don´t translate in better work-life balance. Finally, we observe a high correlation (R-squared = 0.547) between technological innovation and “employment quality.” This is the dimension of job quality that has a stronger association with innovation both at sector and country level.

If we now look at the location of the different sectors in the biplots, Figure 9 show a group of sectors that stand out in terms of high technological innovation but have average levels of job quality (*e.g*. 5 Mining of coal and lignite; 19 Manufacture of coke and refined petroleum products; or 39-Remediation activities and other waste management services). While other economic activities (*e.g.* 97-Activities of Households as Employers of domestic personnel; or 3-Fishing and aquaculture), have both almost no technological innovation and low JQI. However, it can be observed that these sectors located in the extremes behave very differently in each of the dimensions of JQI. For example, "Mining of coal and lignite" has the highest level of "wage" and "employment quality", however this sector has extremely low job quality levels in "health and safety" and "work-life balance." The opposite case is for example in "Activities of Households as Employers of domestic personnel" with low job quality, low innovation, low wages and very low "intrinsic quality of work" and "employment quality" , but a medium-high level of job quality in dimensions such as "health and safety" and "work-life balance."

Figure 9. Innovation new processes or technologies were introduced in current workplace during the last 3 years by Job Quality Index. EU15 NACE codes sector, EWCS 2010.




JQI $R^2$ = 0.158; Dimension 0 $R^2$ = 0.156; Dimension 1 $R^2$ = 0.081; Dimension 2 $R^2$ = 0.547; Dimension 3 $R^2$ = 0.005; Dimension 1 $R^2$ =- 0.041.

Source: Author's elaboration from *European Working Conditions Survey* (2010)

### *3.3 Models of job quality and innovation*

According to the results presented in the previous section, there is a positive association between job quality, as measured by the JQI, and innovation (technological and organizational), both at the country and sector level. To further advance in our knowledge of the relation between the two variables in this section we will check if the correlation between innovation and job quality remains after controlling for the effects of other factors affecting job quality.

With that aim, we present three different models of linear regression with JQI as the dependent variable and a dummy variable representing technological innovation and organizational innovation together with different variables related to job quality as the independent variables. In Model 1 we introduce as control variables sociodemographic items (sex, age, education and country). In Model 2 we introduce variables related to the company and type of economic activity (size and sector). Finally, in Model 3 we introduce occupation as control variable and simultaneously we reinforce our technological innovation variable with two new variables dealing with the level of digitalisation of the job (probably the paradigmatic element of technological innovation in the 21st century): use of computers and the use of Internet/e-mail by the workers. The strong interactions between use of computers and occupation make it advisable to include both variables simultaneously in the same model.

The regression results confirm the existence of a significant and strong correlation between job quality and technological innovation (both the direct variable of TI and the indirect variables of working with computers and using Internet), now at an individual level for the EU-15. However, while technological innovation is positively correlated with the JQI in all 3 models, organizational innovation has no significant effect on the quality of jobs when we control for industry or occupation. Overall, Model 3 accounts for nearly 40% of variation in job quality among jobs ($R2 = 0.394$).

The effect of other variables should also be highlighted: (1) Controlling for other factors, being female implies lower job quality; (2) Age and educational level increases job quality; (3) Regarding firm size we observed that large companies have a higher job quality, but that is also true for the self-employed compared to medium-sized companies (10-49 employees); (4) In relation to the sector of activity, workers in Public administration and defense, in Education and, especially, in the Financial services show higher job quality that industry workers ; (5) In terms of the effect of the occupation, managers and other professional occupations show higher job quality.

Table 4. Determinants of job quality (linear regression), EU-15, 2010.

| | | Model 1 | | Model 2 | | Modelo 3 | |
|---|---|---|---|---|---|---|---|
| | | Coef. | Sig. | Coef. | Sig. | Coef. | Sig. |
| Technological Innovation (Yes) | | 0.044 | *** | 0.037 | *** | 0.017 | *** |
| Organizational Innovation (Yes) | | 0.007 | * | 0.004 | | -0.006 | |
| Female (male) | | -0.043 | *** | -0.048 | *** | -0.043 | *** |
| Age | | 0.014 | *** | 0.013 | *** | 0.012 | *** |
| Age-squared | | 0.000 | *** | 0.000 | *** | 0.000 | *** |
| Education | Primary | -0.083 | *** | -0.081 | *** | -0.047 | *** |
| | Secondary | *Ref.* | | *Ref.* | | *Ref.* | |
| | Terciary | 0.143 | *** | 0.126 | *** | 0.058 | *** |
| Country | Belgium | 0.074 | *** | 0.069 | *** | 0.063 | *** |
| | Denmark | 0.057 | *** | 0.055 | *** | 0.034 | *** |
| | Germany | *Ref.* | | *Ref.* | | *Ref.* | |
| | Greece | -0.093 | *** | -0.092 | *** | -0.091 | *** |
| | Spain | -0.004 | | -0.005 | | -0.006 | |
| | France | 0.011 | * | 0.006 | | 0.004 | |
| | Ireland | 0.035 | *** | 0.028 | *** | 0.014 | * |
| | Italy | 0.078 | *** | 0.073 | *** | 0.058 | *** |
| | Luxembourg | 0.065 | *** | 0.048 | *** | 0.035 | *** |
| | Netherlands | 0.117 | *** | 0.111 | *** | 0.088 | *** |
| | Austria | 0.100 | *** | 0.097 | *** | 0.079 | *** |
| | Portugal | -0.006 | | -0.008 | | -0.018 | * |
| | Finland | 0.004 | | 0.006 | | 0.007 | |
| | Sweden | 0.028 | *** | 0.020 | *** | -0.009 | |
| | United Kingdom | 0.033 | *** | 0.023 | *** | 0.012 | * |
| Establishment Size | 1 | | | 0.029 | *** | 0.029 | *** |
| | 2-9 | | | -0.005 | | -0.011 | *** |
| | 10-49 | | | *Ref.* | | *Ref.* | |
| | 50-249 | | | 0.014 | *** | 0.015 | *** |
| | > 250 | | | 0.049 | *** | 0.039 | *** |
| **Sector (Nace codes)** | Agriculture | | | 0.006 | | | |
| | Industria | | | *Ref.* | | | |
| | Construction | | | -0.015 | ** | | |
| | Wholesale, retail, food and accommodation | | | -0.006 | | | |
| | Transport | | | -0.006 | | | |
| | Financial services | | | 0.101 | *** | | |
| | Public administration and defence | | | 0.058 | *** | | |
| | Education | | | 0.054 | *** | | |
| | Health | | | 0.010 | * | | |
| | Other services | | | 0.013 | ** | | |
| Ocuppacions (Isco-08) | Armed forces occupations | | | | | -0.033 | |
| | Managers | | | | | *Ref.* | |
| | Professionals | | | | | -0.002 | |
| | Technicians and associate professionals | | | | | -0.036 | *** |
| | Clerical support workers | | | | | -0.087 | *** |
| | Service and sales workers | | | | | -0.104 | *** |
| | Skilled agricultural, forestry and fi.. | | | | | -0.069 | *** |
| | Craft and related trades workers | | | | | -0.109 | *** |
| | Plant and machine operators, and asse.. | | | | | -0.122 | *** |
| | Elementary occupations | | | | | -0.170 | *** |
| Working with computers | | | | | | 0.037 | *** |
| Using internet / email | | | | | | 0.057 | *** |
| Cons. | | 0.071 | *** | 0.078 | * | 0.230 | *** |
| Number of obs | | 21120 | | 20337 | | 20440 | |
| F | | 410.44 | | 277.81 | | 368.41 | |
| Prob > F | | 0 | | 0 | | 0 | |
| R-squared | | 0.29 | | 0.3164 | | 0.3941 | |
| Adj R-squared | | 0.2893 | | 0.3164 | | 0.3931 | |
| Root MSE | | 0.17289 | | 0.1695 | | 0.15974 | |

*** significant at 99%; ** significant at 97,5%; * significant at 95%

Source: Author's elaboration from European Working Conditions Survey (2010)

**4. Conclusions.**

As argued in the theoretical part of the paper, technological change and job quality are connected by different mechanisms going from technological change to job quality, such as productivity increase, changes in the type of tasks performed with direct implication on job quality and technologically driven structural change, but also from job quality to technological change. After reviewing these multiple mechanisms, in the second part of the paper we explore the intensity of such relations using the EWCS 2010. From the empirical analysis carried out, the following conclusions can be highlighted. First, regarding the analysis at the individual level, in the three models of job quality estimated in the paper, technological innovation in the firm appears as a significant correlate of job quality at the level of the individual job. The same is not valid for organizational innovation. The positive role of technological innovation on job quality is corroborated by the positive impact that the variables “working with computers” and “use of Internet” have on job quality. Second, the relation between job quality and innovation is also present at the country level. According to the analysis performed for the EU-15, there is a positive relation between job quality, as measured by the JQI, and innovation intensity (introduction of new technologies or processes in the last 3 years in the firm). This positive relation is explained mostly by the intrinsic quality of work, employment and health and safety dimensions, being much weaker in the rest of the dimensions considered (wage and work-life balance). Third, the analysis developed at level of activity (industry at NACE two digit) for the EU-15 shows that although the nature of the activity affects the innovation-job quality relation, the relationship is weaker than the one found at the country level earlier.

Before concluding these pages, it is important to stress that the paper has limited its scope to the analysis of the direct impact of technological change on job quality (and vice versa) for those workers that remain in employment after innovation takes place. The thorny and long-debated issue of the impact of technology on employment levels (i.e. whether technological innovation in the long or short term creates or destroys jobs) has been consciously largely kept out of the theoretical analysis (although it is partially addressed in section 2.2). In doing so we are aware that we are leaving out of the analysis one major element of impact on technology on job quality: the characteristics in terms of job quality of the jobs taken up by the workers made redundant by technological change. Obviously, the overall effect of technological change on job quality will depend of the combination of what happens to job quality in the innovating firms and what sectors (if any) take over the redundant employment (if any) associated with the technologically driven increase in productivity. The macroeconomic nature of many of the variables affecting the impact of technology on employment, make it convenient to leave its analysis for another paper.

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## ANNEX 1

### NACE codes

*A - Agriculture, forestry and fishing*

A1 - Crop and animal production, hunting and related service activities

A2 - Forestry and logging

A3 - Fishing and aquaculture

*B - Mining and quarrying*

B5 - Mining of coal and lignite

B6 - Extraction of crude petroleum and natural gas

B7 - Mining of metal ores

B8 - Other mining and quarrying

B9 - Mining support service activities

*C - Manufacturing*

C10 - Manufacture of food products

C11 - Manufacture of beverages

C12 - Manufacture of tobacco products

C13 - Manufacture of textiles

C14 - Manufacture of wearing apparel

C15 - Manufacture of leather and related products

C16 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials

C17 - Manufacture of paper and paper products

C18 - Printing and reproduction of recorded media

C19 - Manufacture of coke and refined petroleum products

C20 - Manufacture of chemicals and chemical products

C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations

C22 - Manufacture of rubber and plastic products

C23 - Manufacture of other non-metallic mineral products

C24 - Manufacture of basic metals

C25 - Manufacture of fabricated metal products, except machinery and equipment

C26 - Manufacture of computer, electronic and optical products

C27 - Manufacture of electrical equipment

C28 - Manufacture of machinery and equipment n.e.c.

C29 - Manufacture of motor vehicles, trailers and semi-trailers

C30 - Manufacture of other transport equipment

C31 - Manufacture of furniture

C32 - Other manufacturing

C33 - Repair and installation of machinery and equipment

*D - Electricity, gas, steam and air conditioning supply*

D35 - Electricity, gas, steam and air conditioning supply

*E - Water supply; sewerage; waste managment and remediation activities*

E36 - Water collection, treatment and supply

E36.0 - Water collection, treatment and supply

E37 - Sewerage

E38 - Waste collection, treatment and disposal activities; materials recovery

E39 - Remediation activities and other waste management services

*F - Construction*

F41 - Construction of buildings

F42 - Civil engineering
F43 - Specialised construction activities
*G - Wholesale and retail trade; repair of motor vehicles and motorcycles*
G45 - Wholesale and retail trade and repair of motor vehicles and motorcycles
G46 - Wholesale trade, except of motor vehicles and motorcycles
G47 - Retail trade, except of motor vehicles and motorcycles
*H - Transporting and storage*
H49 - Land transport and transport via pipelines
H50 - Water transport
H51 - Air transport
H52 - Warehousing and support activities for transportation
H53 - Postal and courier activities
*I - Accommodation and food service activities*
I55 - Accommodation
I56 - Food and beverage service activities
*J - Information and communication*
J58 - Publishing activities
J59 - Motion picture, video and television programme production, sound recording and music publishing activities
J60 - Programming and broadcasting activities
J61 - Telecommunications
J62 - Computer programming, consultancy and related activities
J63 - Information service activities
*K - Financial and insurance activities*
K64 - Financial service activities, except insurance and pension funding
K65 - Insurance, reinsurance and pension funding, except compulsory social security
K66 - Activities auxiliary to financial services and insurance activities
*L - Real estate activities*
L68 - Real estate activities
*M - Professional, scientific and technical activities*
M69 - Legal and accounting activities
M70 - Activities of head offices; management consultancy activities
M71 - Architectural and engineering activities; technical testing and analysis
M72 - Scientific research and development
M73 - Advertising and market research
M74 - Other professional, scientific and technical activities
M75 - Veterinary activities
*N - Administrative and support service activities*
N77 - Rental and leasing activities
N78 - Employment activities
N79 - Travel agency, tour operator and other reservation service and related activities
N80 - Security and investigation activities
N81 - Services to buildings and landscape activities
N82 - Office administrative, office support and other business support activities
O - Public administration and defense; compulsory social security
O84 - Public administration and defense; compulsory social security
*P - Education*
P85 - Education
Q - Human health and social work activities
Q86 - Human health activities

Q87 - Residential care activities

Q88 - Social work activities without accommodation

*R - Arts, entertainment and recreation*

R90 - Creative, arts and entertainment activities

R91 - Libraries, archives, museums and other cultural activities

R92 - Gambling and betting activities

R93 - Sports activities and amusement and recreation activities

*S - Other services activities*

S94 - Activities of membership organisations

S95 - Repair of computers and personal and household goods

S96 - Other personal service activities

*T - Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use*

T97 - Activities of households as employers of domestic personnel

T98 - Undifferentiated goods- and services-producing activities of private households for own use

*U - Activities of extraterritorial organisations and bodies*

U99 - Activities of extraterritorial organisations and bodies

**ANNEX 2**

**Probability of computerisation and JQI in 39 occupations**

| ISCO2 | Probability of Computerisation | JQI |
|---|---|---|
| Health professionals | 0,02173782 | 0,5911642 |
| Teaching professionals | 0,06215696 | 0,6233893 |
| Chief executives, senior officials and legislators | 0,08784149 | 0,6942878 |
| Science and engineering professionals | 0,09353647 | 0,6269547 |
| Production and specialised services managers | 0,12272096 | 0,6532809 |
| Hospitality, retail and other services managers | 0,13093289 | 0,5545289 |
| Legal, social and cultural professionals | 0,13465769 | 0,6182067 |
| Information and communications technology professionals | 0,15570292 | 0,6691521 |
| Administrative and commercial managers | 0,23084382 | 0,6705127 |
| Business and administration professionals | 0,30372510 | 0,6562188 |
| Health associate professionals | 0,34279804 | 0,4971154 |
| Protective services workers | 0,40273333 | 0,5272508 |
| Legal, social, cultural and related associate professionals | 0,43130939 | 0,5122097 |
| Personal care workers | 0,48106021 | 0,4086274 |
| Science and engineering associate professionals | 0,49869220 | 0,5626962 |
| Information and communications technicians | 0,50780246 | 0,5878749 |
| Electrical and electronic trades workers | 0,54347302 | 0,5013853 |
| Personal service workers | 0,55689109 | 0,3671352 |
| Business and administration associate professionals | 0,55727253 | 0,5943613 |
| Cleaners and helpers | 0,60510232 | 0,3250253 |
| Handicraft and printing workers | 0,61614064 | 0,4252262 |
| Drivers and mobile plant operators | 0,62042025 | 0,4257194 |
| Sales workers | 0,64028209 | 0,3889237 |
| Labourers in mining, construction, manufacturing and transport | 0,69220248 | 0,3281024 |
| Building and related trades workers, excluding electricians | 0,70069898 | 0,4219076 |
| Metal, machinery and related trades workers | 0,70161495 | 0,4273907 |
| Customer services clerks | 0,70916141 | 0,4702263 |
| Food processing, wood working, garment and other craft and related trades workers | 0,73228666 | 0,3974339 |
| Market-oriented skilled agricultural workers | 0,73944719 | 0,4378883 |
| Market-oriented skilled forestry, fishery and hunting workers | 0,74060898 | 0,4781792 |
| Refuse workers and other elementary workers | 0,78143061 | 0,3411435 |
| Other clerical support workers | 0,83506667 | 0,472204 |
| Stationary plant and machine operators | 0,85989215 | 0,3988743 |
| Food preparation assistants | 0,86000000 | 0,2745264 |
| Agricultural, forestry and fishery labourers | 0,87333333 | 0,3682381 |
| Assemblers | 0,89875000 | 0,3818407 |
| Numerical and material recording clerks | 0,92793694 | 0,4972787 |
| Street and related sales and service workers | 0,94000000 | 0,4798225 |
| General and keyboard clerks | 0,95820556 | 0,4913985 |

Source: Author´s analysis from Frey and Osborne (2013) and EWCS microdata.