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DOES INNOVATION REDUCE THE GENDER EMPLOYMENT GAP?

Evidence from EU member states, 1998 -2020

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Abstract

This thesis evaluates wether a change in investment in Research and Development will decrease Gender employment gap of students with tertiary education.We use national level panal data,covering all countries in the European Union using a time period between 1998 to 2020.The result indicate that increase in research and development wil decrease the gender employment gap in the short term.This thesis gives empirical evidendence the effect of research and development has on gender employment gap.And provides a new line of research given that previous research just focus on the effect of Innovationon and Employment.

Acknowledgements

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1. Introduction

Gender equality is not only a question of basic rights and social justice. It is also a major component of a modern and effective economy. Diversity of views, creativity, inclusion, knowledge, and an optimal use of all available resources are the basic building stones of competitive economies and well-functioning societies. One of the main underlying dynamics in a competitive economy is education and knowledge-intensity, where women have the possibility to be in the driving seat.

In the EU, over half of the population are women, and in general women have a higher level of education attainment than men. Yet the gaps between men and women with respect to participation in the labor market (employment) and earnings (wage) persist even in the most advanced EU member states. The good news is that over the last decades there has been a gradual trend of closing the gender employment and the gender wage gap, while the gender education gap has even been reversed.

The persistence of gender gaps is of course a complex problem with many simultaneous influencing factors. This study contributes to this line of research, focusing on a variable that has so far not been fully analyzed as such, i.e., innovation. In addition to cultural, social, economic, and legal factors, this study focuses on innovation, and more specifically if increased investment in research and development in a country contributes to the closing of the gender employment gap. As such, this focus is original. Previous studies on innovation have at the closest studied the effect of innovation on the gender wage gap, i.e. the effects of computerization and robotization on the gender wage gap.

This study is unique in its research question, in its geographic scope and its time perspective. However, it is also limited in its extension and analytical depth. It should be seen as a first step, as an indication of the importance of the design of investment in research and innovation for an optimal economic effect which mobilize and fully include both women and men.

2. Research question

This study analyses the relation between innovation and the gender employment gap at a macroeconomic level. *Does a higher level of innovation in a country contribute to closing the gender employment gap?* This research question has not been directly addressed in previous literature.

When considering progress towards gender equality, the study focuses mainly on demand-side factors of employment, i.e., the effects of structural changes in industry and occupations, although these factors are partly also related to changes in supply-side factors of employment as women and men gradually and partially adapt their education strategies to the changes in labor market as triggered by innovation.

The scope of the study is limited in time and space. The analysis covers a time over the last two decades: 1998-2020. Geographically, the study includes all current EU Member States (EU27). In this sense, it covers a larger time and space span than most previous studies on this subject.

3. Literature review

This study analyses the effects of innovation on the closing of the gender employment gap. Therefore, it is relevant to explore two broad strands of literature. First, the literature of gender employment and wage gaps, and in particular their relation to technological change. Second, the literature on innovation, and in particular the effect of innovation on employment.

3.1. Trends in the gender employment gap

Historically, the literature distinguishes between *gender education gap*, *gender employment gap* and *gender wage gap*. This study will focus on the *gender employment gap* (even though it will consider the reversed gender education gap and partly capitalize on relevant findings from previous studies on the gender wage gap).

Over the last decades, the *gender education gap* has been reversed in both the EU and in the US.[1] Women are now outperforming men educationally, with girls and women doing better at school and university than boys and men. According to the most recent analysis by Eurostat[2] in 2021 there were 18.5 million students inscribed in tertiary education[3] in the EU. Out of these students, 54.2 % were women.[4] This reversed gender gap also holds for the graduates: in 2021, 57.2 % of all tertiary education graduates in the EU were women. However, there are gender differences in the educational choices. In the field of engineering, manufacturing, and construction, 73.1 % of the students were men, while in the field of health and welfare, 72.1 % of the students were women. Likewise, ICT disciplines had three times more male students than female (see below on the STEM studies gap).

The gender employment and wage gaps persist, although both are declining (See Figure 1). In 2021, the *gender employment gap* was 10.8 % (slightly down from 11.5 % in 2019),[5] according to the EU labor force survey. In the EU, the highest gender employment gaps are found in Romania, Greece, and Italy (around 20 % gap), which are also the countries with the lowest employment rates. Lithuania and Finland have the lowest gaps (around 2 %). Since the 1970s, there has been a steady trend of increase in women's labor market participation. The long-term trend is towards a convergence between male and female employment and activity rates. The cumulative headcount employment growth since 1998 has been 2:1 in favor of women. The gap has been decreasing in almost all EU member states.

Women and men continue to work in different types of jobs. In developed countries such as those in the EU, the increase in women's employment has been largely in sectors with the highest growth rates over the

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[1] The statistical analysis presented here comes from two studies by Eurofound, in collaboration with the European Commission. (Eurofound and the Joint Research Centre of the European Commission, 2021; Eurofound, 2016)

[2] Eurostat, using data for 2021

[3] Level 5-8 of ISCED, International Standard Classification of Education.

[4] The highest shares of female students were in Sweden, Malta, Poland and Estonia (with close to 60 %).

[5] Gender statistics - Statistics Explained (europa.eu)

last two decades, in health and residential care. Public administration, health and education, account for around 60 % of net recent (2011-2019) employment growth among women. At the same time, structurally declining sectors, such as agriculture and manufacturing, tend to be dominated by men.

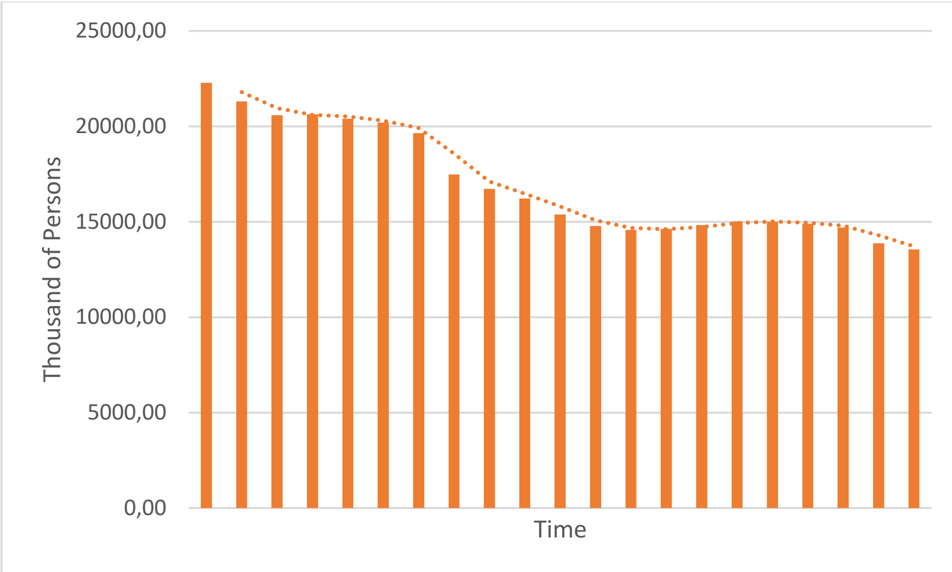
Other factors explaining the trend towards a decreasing gender employment gap are the gradual changes in social norms, cultural attitudes, and gender stereotypes, e.g., assigning to women a primary role in the home and as a care giver. This effect is reinforced by the greater adoption of household technology, the gradual increase in the availability of childcare, and legislation on parental leave. However, the presence of children (below three years old) is still a major determinant of a woman's decision to participate in the labor market. In the EU, the trend is a decline in the quantity of children per woman.

An interesting explanatory factor for the specific research question of this study is the ongoing demand-shift in the occupations of the private sector, where social and cognitive skills are gradually favored over physical skills. This demand shift interacts with a supply shift as women increase their educational level and outperform men at university. Women (and men) with higher education levels (i.e., ISCED 5-6) have a much higher likelihood of participating in the labor market. This effect is now particularly strong in Eastern European countries and newer EU member states (e.g. Malta, Bulgaria, Hungary, Lithuania, Poland, Romania, Slovenia and Slovakia).

Despite a rise in women's real wages, the *gender wage gap* persists. In 2021, the gender pay gap in the EU was 12.7 % (slightly down from 16.1 % in 2014). This means that women earn on average 12.7 % less per hour than men.[6] The gender pay gap is highest in the top job-wage quantile in almost all EU member states. More broadly, compared to men, women are overrepresented in temporary and part time jobs and in low-pay sectors and occupations. However, in a medium- to long-term perspective, Cortes et al. illustrate how also the gender wage gap has decreased substantially in the US and in Portugal over the period 1980-2019.[7]

Figure 1: Gender Employment Gap Trend from 1998 to 2020

[6] The gender pay gap situation in the EU (europa.eu)
[7] Cortes et al. 2020, page 907



3.2. Analysis of the effect of innovation on the gender employment and wage gaps

The previous academic analysis has mainly focused on the effect of technological change or innovation on the gender *wage* gap (while the studies occasionally also include findings on the effect on gender-relevant employment). These studies have not forcefully focused on innovation as such, but rather on specific indicators that are related to innovation, i.e., the gradual change in occupational tasks in the transition to a more knowledge-intensive economy, and related process innovations, including the adoption of computers or the adoption of industrial robots.

Petersen Rendall (2017) shows in a longitudinal study of the US economy how innovation positively affected female labor force participation (employment), while contributing to reversing the gender education gap and closing the gender wage gap. Over a long-term period, innovation and technical change triggered a broader structural change in the industry and the economy favoring the emergence of occupations requiring a higher level of knowledge and skills ("brain"), while employment tasks which require physical strength ("brawn"), found mainly in the agriculture and manufacturing sectors, decreased. In other words, innovation drives a change in the characteristics of the demand for labor. This structural demand-side change benefitted women, since women have a competitive advantage in intellectual "brain" tasks relative to physical "brawn" tasks. At the same time, this structural change also influenced the supply-side of women's employment dynamics, since it incentivized women to study at college (thereby contributing to reversing the gender education gap). According to the study, the supply-side dynamics was further strengthened by the gradual invention and adoption of household appliances, which increased "home productivity" and thereby liberated women.

In a similar line of research, Ngai and Petrongolo (2017) show the structural transformation of the economy, with the rise of the service economy over the last decades, has narrowed the gender employment and wage gaps. The structural change of the economy expanded the service sector (relative to the agriculture and manufacturing sectors) in which women were overrepresented (partly based on their comparative advantage in "brain" skills relative to "brawn" skills).

Aksoy, Öscan and Philipp (2021) analyzed the effect of robotization (the adoption of robots in manufacturing) on the gender pay gap in 20 European countries over the period 2006-2014. They found that, overall, robotization increased the gender pay gap. A ten percent increase of robotization lead to a 1.8 % increase in the gender pay gap. These results are mainly driven by the effect in countries where the initial gender equality was low, which are predominantly – but not exclusively - countries in Eastern Europe. At the contrary, in countries where the initial gender inequality was low, and where the initial level of robotization was high, e.g., Belgium, Germany, the Netherlands, Spain and Sweden, the study found no statistically significant effect of robotization on the gender wage gap (and neither any significant effect on the share of female workers in manufacturing).

The main explanatory factor for the positive effect in the former group of countries was, according to the authors, a positive effect of robotization on the male earning in medium- and high-skilled occupations (a result of higher productivity), given the initial male predominance in the higher occupational hierarchy.

These findings are also interesting as they are contrary to what could be expected, given that robots replace "brawn" skills, which weaken the comparative advantage of men in manufacturing. The two main explanatory factors are related to the type of educational skills and the level of hierarchy of employment. Men are still overrepresented in occupations requiring STEM skills, which are those benefitting most of the robot-driven productivity gains. In other words, the adoption of robots increase value added and productivity, which raise wages of high-skilled workers, in particular workers with relevant STEM skills and those higher in the hierarchy, and men are overrepresented in both categories.

Other studies have analyzed the relation between computerization (another kind of process innovation, just as robotization) and the gender wage gap. Nedelkoska et al (2021) use data from the US over the period 1930-2019 with detailed information on occupational tasks. Overall, the authors found a positive effect, i.e., computerization increased the gender wage gap. This conclusion is the result of two subsequent but contrary effects. On the one hand, computerization reduced the gap by attracting more women into better-paid occupations, but at the same time, the higher returns to computerization favored men's average wages even more.

The study of Nedelkoska et al is also interesting since it distinguishes between changes of tasks *within* occupations and the changes of tasks resulting from professional moves *between* occupations. Since the 1980s, women in the US have to a greater extent moved out of occupations with a high routine content (e.g., clerical and secretarial) into occupations with a high analytical and interactive content (including managerial, medicine, business administration professionals and teachers). Women moved into jobs that had adopted computers, and since these jobs were better paid, that dynamics decreased the wage gap by 3.3 %. However, most changes in task content triggered by the computerization came from transformations of the tasks *within* occupations, and this trend has been slightly more frequent in jobs dominated by men. In particular, the adoption of computers led to a faster wage growth in particular for some jobs dominated by men, e.g. engineering jobs, which increased the wage gap by 5.8 %. Consequently, overall, the adoption of computers increased the gender wage gap.

Cortes et al. (2021) analysed the impact of technological change (mainly digitalisation and process innovation) on the gender wage gap in Portugal and the US under the period from mid-1980s to 2019. In their explanatory models, the authors find that technological change impact the gender wage gap through differentiated occupational tasks. Women suffered less from technology-driven changes in terms of employment, since they had lower employment shares in declining routine manual jobs compared to men. In other words, women were less exposed to automatization given that they to a less extent worked in routine-dominated occupations, which were the jobs most directly negatively affected by technology. Women were better positioned than men to deal with the changing task demands in the labour market, either because they had an initial advantage in performing tasks which are not being automated and higher-paid, or because they were more willing or able to switch to these occupations than men.

Going beyond technical innovation or adoption of new technologies as such, it is relevant to consider the literature of the overall relation between overall economic growth and gender equality, since innovation is closely correlated to economic growth. Some studies (Galor and Weil, 1993) point at a positive feedback loop between economic growth and women's wages, while there is by the same token a trade-off effect between women's level of wages and household fertility. Capital accumulation positively affects women's relative wages, which at the same time decreases fertility since it stimulates women's decision to participate in the labor market. Furthermore, increased wages for women reduces fertility rates, since it raises the cost of having children relative to the total household income. This dynamic is driven by growth via changes in the relative factor prices. Klasen and Minasyan (2017) analyzed the reverse relation, i.e., the effect of gender gaps on economic growth. They presented an overview of the literature on the subject up to 2017. The authors conclude that the gender gaps induced efficiency cost in the economy in European countries. Gender gaps impose distortions in the economy, e.g., they reduce the pool of talents, which employers can draw from.

Concerning the specific relation linking innovation with gender dynamics, previous studies have mostly had a reverse focus than the analysis presented in this paper, i.e., instead of focusing on the effect of innovation on the gender gap they have focused on the effect of the gender gap on innovation. This field of study has detected and defined additional gender-based gaps, e.g. a "gender ownership gap" (explaining the differences in the propensity to innovate comparing female-owned and male-owned firms)[8] or a "female-male innovation gap" (pointing at an average lower level of innovation activity in firms where women are top managers.)[9] This line of research includes as well studies analysing the background factors driving the different strategies of men and women when confronted with innovation. Some authors stress "institutional" factors linked to the social, political, and economic environment of women[10], while others affirm that innovation policy and research have a gender-blind vision.[11]

3.3. Characteristics of innovation

The literature on innovation distinguishes between input to innovation (innovation expenditure) and output of the innovation process, where it differentiates between product innovation and process innovation. Some

[8] Biscione et al. 2022
[9] Strohmeyer and Tonoyan, 2005
[10] Carrasco, 2014
[11] Belghit-Mahud, et al. 2016

studies focus on the relative importance and effect of individual innovations, counting mainly breakthrough innovations or "general purpose technologies", while other studies start from a broader interpretation of innovation including system innovations and complexity. The reduced interpretation of innovation focuses on technologies that have produced a high economic value added in the market and subsequently been diffused throughout industrial sectors and society at large. The clearest examples are different digital product innovations, such as the semiconductor, the internet, or the smartphone, which have had a "swarming" or large diffusion effect across society since the 1990s, accelerating over the last decade. Today, new innovations in the energy sector (e.g., renewable energy technologies, smart grids, batteries, and hydrogen) may equally diffuse broadly, affecting a large number of industrial sectors. The long-term effect of this diffusion is to increase productivity and competitiveness (while changing the economic and labor-demand structure). The broader definition of innovation includes product, process, social and organizational innovation, which are correlated in complex systems, e.g., the mobility system or the energy system. Innovation in this sense is a systemic change from one stage of a system to another (Schot and Geels, 2007).

This master thesis study adopts the more focused definition of innovation, concentrating on product and process innovation related to research and development, i.e., a continuous trend towards a more knowledge-intensive economy (manufacturing and services). Since the focus is on the relation between innovation and employment, the relevant innovation process is the continuous "injection" of knowledge (measured with investment in research and development as a proxy) in both industry and services, changing the structure of demand on labor and skills.

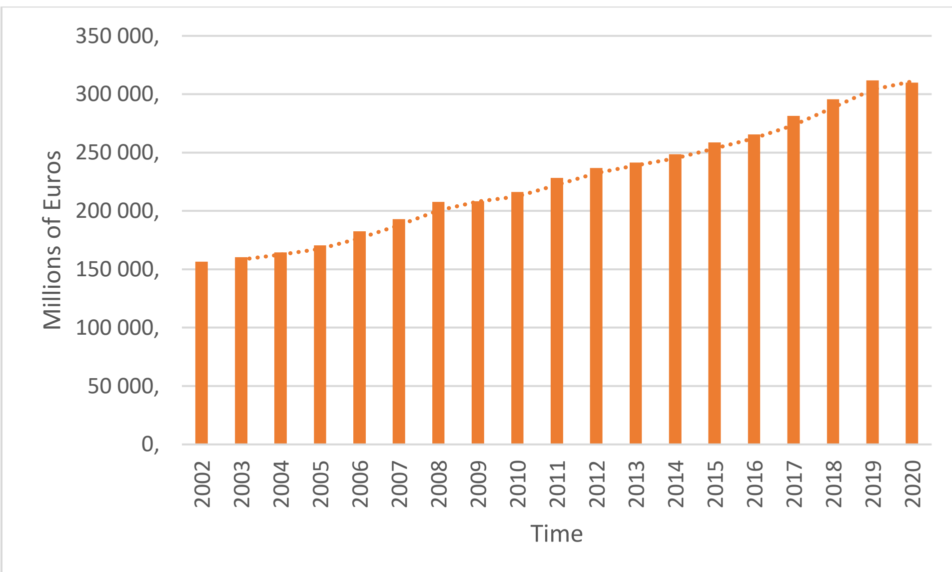
It is important to understand the rationale for firms to engage in innovation, given the cost of R&D expenditures. The overall rationale is to increase or maintain competitiveness and growth. Therefore, firms will tend to innovate more when active in highly competitive markets. (Aghion, Akcigit and Howitt, 2015) Innovation can improve the quality of products and even create temporary monopoly positions. The anticipated size of the market for a product will affect the size of the investment in research and development (R&D).(Hashi and Stojcic, 2013) The availability of high-skilled labor will also influence the possibility of firms to innovate. (Hall and Kramakz, 1998) Process innovation can increase productivity. While there is no clear conclusion on the relation of innovation to firm size, the age of firms tends to influence the type of innovation. Existing firms tend to focus on incremental innovation (improving current technologies), (Aghion, Akcigit and Howitt, 2015) while new entrants and younger innovative firms tend to produce more "radical" innovations (Freeman and Soete, 1997; Coad, Segarra and Teruel, 2016).

Innovation has additional characteristics, which are also relevant for the current study:

First, due to agglomeration effects, innovation tends to be concentrated in space, around metropolitan areas which count on the availability of investment capital, skilled labor, knowledge spillovers from other firms and a large and demanding market. Distribution effects depend to a large degree on absorptive capacity. (Aghion and Jaravel, 2015; Carlino and Kerr, 2015)

Second, the labor demand generated by innovation tend to require a higher level of education and skills, in particular a larger demand for employees with university studies and competences in STEM (studies in science, technology, engineering and mathematics) (US National Academies of Science, 2005). In the EU, the EU policy has focused on increasing gender equality in STEM and its reinforcement at national level (EU STEM coalition, 2023). Today, while the overall gender education gap is reversed, less than a third of female students choose to study higher education courses in subjects like math and engineering, according to the World Economic Forum (2020). In EU 28, there were almost twice as many male as female STEM graduates in 2021.[12] The STEM variable is not only related to employment prospects but also to expected wages.[13] STEM occupations are normally high-paying, non-routine jobs, which are still predominantly employing men and they are experiencing higher wage gains from advancing technology.

Figure 2: Trend of Expenditure of Research and Development from 1998 to 2020



3.4. Effects of innovation on employment

Most of the previous studies on the relation between innovation and employment have focused on empirical data on firm-level. There are relatively fewer studies on the macro-level. Some studies have a longitudinal dataset, but with shorter time spans than 20 years and with older data. Finally, even though some studies do introduce cross-country comparisons, these are often limited to 3-4 countries.

In general terms, the case studies find a positive relation between innovation and employment. While product innovation has a positive effect on employment through sales growth, process innovation may have a negative effect on employment. The aggregate employment growth would hence be the difference

[12] The highest gender gaps in STEM studies were in Spain and Bulgaria. Eurostat, 2021. Statistically, STEM is a collective category for tertiary studies in science, mathematics, computing, engineering, manufacturing and construction. In 2021, the total population of students in STEM studies represented only 1.85 % of people aged 20-29 years old.
[13] Sée Cortes et. al. (2021), page 908

between sales growth and labor productivity growth. Econometric studies show that the negative employment effects of labor productivity increase are more than compensated by the positive effects of increases in sales, implying an overall increase in employment. (Lachenmaier and Rottmann, 2011; Woltjer, van Galen and Logatcheva, 2021)

Product innovation is in almost all studies positively related to employment. (Harisson et al., 2014; Peters et al., 2014; Crespi and Tacsis, 2013) Product innovation creates new or expanded demand for products and a higher value for consumers. It creates additional sales because it supplies better products or even new products, which generate additional demand. (Audretsch, Coad and Segarra, 2014; Geroski and Machin, 1992) However, product innovation also "cannibalizes" on old existing products, becoming obsolete. The compensation effect of additional sales (and hence employment) of product innovation must therefore out-weigh the cannibalization effect. (Dachs et al, 2017). From an industry-level perspective, product innovation can also have a negative externality on the sales of competing firms (the business stealing effect).

However, since in most markets, innovative firms compete globally, this negative effect influences less total sales in the domestic market. Product innovation can also create scale efficiencies (with a positive effect on labor productivity). Therefore, CDM studies also find a positive relation between product innovation and firm productivity. (Mohnen and Hall, 2013)

Process innovation can be positively related but also negatively related to employment. The reason is that process innovation affects both labor productivity and sales (the expansion effect). The objective of process innovation is to improve the efficiency of production. Therefore, process innovations have a positive effect on labor productivity (see Harrison et al., 2014; Evangelista and Vezzani, 2012), which reduces the demand for labor. However, since process innovation also increases efficiency, it tends to reduce unit cost prices, creating opportunities for a decrease in price, which generates extra demand and sales (price effect). (Harrison et al. 2014; Vivarelli, 2014). If the price elasticity of demand is higher than 1 for individual firms, which is normally the case in competitive markets, then the overall effect of process innovation on employment would be positive. (Lachenmeier and Rottmann, 2011)

In short, process innovations increase labor productivity with a decrease in demand for labor, but this is normally compensated for by the increase in sales (and hence employment) stemming from product innovation. This was the findings of Lachenmaier and Rottmann (2011), who studied longitudinal data from German manufacturing firms 1982-2002. Woltjer, van Galen and Logatcheva (2021), using CIS data from industrial firms in the Netherlands, found a positive effect on employment from both product and process innovation (the labor productivity effect of the latter was compensated by the increase in sales).

Apart from the quantitative effect of innovation on employment, there is also a qualitative effect. Both product and process innovation affect the *skills profile* of the employment demand. The increased level of knowledge-intensity in the production process and the adoption of new technologies produce a shift in the labour demand favouring an increased demand for high-skilled employees at the cost of the demand for low-skilled employees. Aldieri, Makkonen and Vinci (2021) conclude this in a study using regional level data in Finland over the period 2000-2013. In the short term, a growth of 1 % in R&D investment triggers an increase of 0.031% in the employment share of high-skilled employees. In the long term, the positive effect on high-skilled employees increases, while the initial negative impact of innovation on the demand for low-skilled employees is partly compensated. In their conclusions, the authors stress that the results are conditioned by the Finnish empirical base, and that further comparative analysis across countries is needed to factor-in different institutional settings, technology levels and flexibility of the labour market.

As the digitalisation of the economy has grown since the early 2000s, another strand of innovation literature focuses on employment impact of process innovation in terms of automatization (see also the literature on the gender wage gap). One of the main findings of these studies is the fact that the impact of automatization differs depending on the skills profile of the job occupations. For instance, Acemoglu and Autor (2011) showed that digital technologies have, since the 1980s, led to a decline in the demand for labour in so-called routine tasks, i.e., tasks that are rules-based, subject to being codified and embodied in digital technology. This can be occupations such as assembly work, but also clerical and administrative work. At the contrary, many non-routine tasks have experienced increases in labour demand.

4. Data and variables

4.1. Measuring innovation

Innovation can be measured at firm level, at industry level, and at macro level. This study will focus on the macro level, i.e., country level. However, the research hypothesis is inspired also by the existing literature on innovation at firm level and at industry level.

The most complete source of data at macro level, i.e., at national level for each EU member state, is Eurostat, which produces data covering all EU Member States covering time spans (with small variations) over 20 years. The OECD and the World Bank also produce data, but these organizations do not cover all EU member states. In addition, some case studies use country-specific or private data sources and surveys, such as the business survey collected by the Institute for Economic Research in Munich (Ifo), Germany.

In this research, this study has used Eurostat data, since at macro level it covers all EU member states with a high data quality standard. Following the two definitions of innovation - the focus on R&D in the Frascati manual and the broader definition of innovation (including process innovation) in the Oslo manual – two Eurostat datasets are possible to use in the econometric models.

This study has opted for GERD (Gross domestic expenditure on R&D). This is the official EU indicator on investment in R&D at macroeconomic, country level. For cross-country comparisons, GERD is usually normalized by real GDP, giving the R&D intensity indicator. This indicator was established at the Barcelona summit 2002 and in line with the overall EU Lisbon agenda strategy of 2000 to become the most competitive and knowledge-intensive economy by 2010. Even though the GERD indicator measures investment in R&D, it statistically a reliable proxy for the overall knowledge-intensity in the whole economy. This indicator can be interpreted as measuring both the *input* to innovation (total public and private investment in Research and Development over a year) and the *output* of innovation (considering that part of private investment in R&D is partly a result of a leverage effect of public R&D investment). It is also closely interrelated with highly skilled human resources. Being a ratio of GERD to GDP in a country, the R&D intensity indicator measures the ratio of the economy that is invested in R&D,[14] following the Frascati manual definition of R&D.[15]

The data for this variable is extracted from Eurostat of the indicator GERD by sector of performance and source of funds. This variable includes the amount of expenditure spent on research and development to all sectors including private and public sector and sourced by all funds. When comparing across countries, this indicator can be constructed (normalized) as the percentage of the national Gross Domestic Product (GDP).

In this study, this variable is going to be lagged given that the impact of research development is not immediate. The data are based on national surveys of business enterprises, public research organizations, higher education institutions and non-for-profit organizations, identifying how much resources they have dedicated to R&D activities over the last year. The information is collected, and quality checked by national statistical offices, which then send the data to Eurostat for harmonization and a last data quality verification.

This study covers data from the Eurostat database on the 27 EU member states during the years 1998-2020. The data is produced by different databases. The R&D data are collected by national statistical authorities, which retrieve the data through national questionnaires, which are carried out in accordance with the guidelines of the Frascati Manual of 2015. At national level R&D data are compiled mostly by the national statistical authorities: national statistical institutes, but also by research councils and ministries, agencies, science policy offices, professional associations, national documentation centers, and universities/higher education institutions. The data are collected through sample or census surveys, from administrative registers or through a combination of sources.

4.2. Measuring the Gender Employment Gap of Population with Tertiary Education

The data on employment is also extracted from the Eurostat at national and EU level.

The gender employment gap is defined statistically as the difference between the employment rates of men and women of working age (20-64 years). In 2021, the gender employment rate in the EU was 10.8 %, meaning that the proportion of men of working age in employment exceeded that of women by 10.8 %.[16]

The employment gap between male and women population is collected using the indicator Employment rates by sex, age, and educational attainment level (%). The data that we received in this dataset is measured as a percentage of total population.

[14] In 2021, the R&D intensity in the EU was 2.27 %. In absolute numbers, all EU member states, as well as other developed countries in the world, tend to increase their GERD every year, driven by a global competition in a knowledge-intensive economy. In 2021, the EU GERD was Euro 328, up from Euro 312 in 2019. R&D expenditure - Statistics Explained (europa.eu) The EU Member States, which invest the highest ration of their economy in R&D are Sweden, Finland, the Netherlands and Germany, with an R&D intensity over 3%. This intensity is a good indication of the structure of the economy in these countries, where firms are larger and globally competitive with a high-level of technology and value added in their products and services.

[15] GERD is the sum of BERD (Business expenditure on R&D), HERD (Higher Education expenditure on R&D and GOVERD (other government expenditure on R&D). In the countries with a high R&D intensity, BERD tend to dominate with up to two third of total investment in R&D.(for more information see the European Commission's SRIP reports on research and innovation, e.g. Innovation, 2022)

[16] In 2021, the EU employment rate for men of working age was 78.5 %, exceeding that of women (67.7 %), which gives a gap of 10.8 percentage points.

This indicator is based on the European Labor Force Survey data, using the definitions elaborated by the International Labor Organization (ILO). The employment indicators produced and published by Eurostat also allow for a breakdown by level of education attainment of the workforce. This data is also based on the European Labor Force Survey, which use the International Standard Classification of Education (ISCED) level to successfully distinguish completion of an education program being validated by a qualification body officially recognized by relevant national education authority. The ISCED levels are divided into ISCED 0-2 (less than primary, primary, and lower secondary education), ISCED3+4 (upper secondary and post-secondary non-tertiary education), and ICED5+ (tertiary education).

From this dataset, we calculate our dependent variable, which measure the difference between employment between men and women who have the same level of studies. The focus is primarily on the effect of graduates with tertiary level meaning IESCD level5+. Previous literature indicated that the higher educated population is the most affected by changes in Research and Development, since most occupations which are affected by Research and Development require medium and high skill. Subsequently, we will factor in the difference between employees with less than primary and lower- secondary education as well as employees with upper and post-secondary non-tertiary education as robustness checks.

In Eurostat, the 'LFS main indicators' section presents a selection of the main statistics on the labor market. They encompass indicators of activity, employment, and unemployment. Those indicators are based on the results of the European Labor Force Survey (EU-LFS), in a few cases integrated with data sources like national accounts employment or registered unemployment. As a result of the application of adjustments, corrections, and reconciliation of EU Labor Force Survey (EU-LFS) data, the 'LFS main indicators' is the most complete and reliable collection of employment and unemployment data available in the sub-domain 'Employment and unemployment'. General information on the EU-LFS can be found in the ESMS page for 'Employment and unemployment (LFS).[17]

4.3. Controls

Control for Sector of Production

This analysis uses the indicator "Employment in technology and knowledge-intensive sectors" at the national level, as a variable to control in which industry the country concentrates more of its production. This will be measured by the employment in each sector. The analysis is going to assess relevant industry sectors, i.e., high-tech manufacturing sectors, low-tech manufacturing sector, high knowledge-intensive sectors, and low knowledge-intensive sectors. This will allow a control of the difference is the industrial and economic structure of the countries in our sample, which is particularly important for the less developed countries of the sample, focusing mainly on the production of manufacturing products. To grasp a more precise analysis, two sectors have been selected to control manufacturing: low- and high-tech manufacturing. The more developed countries have a production characterized by a focus on knowledge-intensive sectors. Finally, the analysis will include the difference between the services: those which require a higher level of knowledge, and the services which only need a lower level of knowledge.

Control for Full time

[17] Detailed information on the main features, the legal basis, the methodology and the data as well as on the historical development of the EU-LFS is available on the EU-LFS (Statistics Explained) webpage.

We control for women that work full time given that according to Azcoy (2021) in countries as the Netherlands and Germany, there are large portions of female employment, which are only part time employed. In order to understand better the effect of full-time employed female workers on the gender employment gap, we use this variable. This variable is calculated by the following equation:

$$\frac{WomenEmployedFullTime}{TotalFullTimeEmployment} * 100 \qquad (2)$$

Control Unemployment

Unemployment rate of population with tertiary education.

Control for STEM

Based on our literature review, this study controls the share of the population that work on Science, Technology, Engineering and Mathematics (STEM). To grasp this, and given insufficient data on STEM at Eurostat, a proxy indicator is used: Human Resources in Science and Technology as a % of Total Population

Control for GDP per capita growth

GDP is a basic measure of the overall size of a country's economy. Statistically, it is defined as the sum of the final uses of goods and services (all uses except intermediate consumption) measured in purchasers' prices, minus the value of imports of goods and services.[18]

The reason this indicator is used in this study is because for most EU member states, GDP is closely correlated with an economy based on technology and knowledge-intensity. In most industrialized countries there is a positive relation between the level of knowledge-intensity of the economy and the size of its economy. This implies that the firms of the country compete globally in high-tech and medium-high-tech products and services.

The literature review also included articles indicating a positive relation between economic growth and gender equality. (Galor and Weil, 1993, in chapter 3) However, there are clear exceptions to this relation, for instance in countries dependent on export of raw material or high-value but low- or medium-tech content, e.g., countries were the revenues from the oil and gas industry constitute a larger part of the GDP (which is the case for Norway in Europe).

An additional difficulty for using GDP in this study is the fact that to a certain degree, GDP is influenced by the gender gap, as showed in the literature review (Klasen and Minasyan, 2017, in chapter 3.

Table 1: Control variables

[18] Glossary:Gross domestic product (GDP) - Statistics Explained (europa.eu)

	Source
Graduates of tertiary education percentage of total employment	Eurostat 2023
Gross Expenditure of Research and Development	Eurostat 2023
Employment on High Manufacturing Sector	Eurostat 2023
Employment on Low Manufacturing Sector	Eurostat 2023
Employment on Total Knowledge Intensive Services	Eurostat 2023
Employment on Knowledge Intensive High Technology Services	Eurostat 2023
Employment on Total Less Knowledge Intensive Services	Eurostat 2023
Women which works full time jobs	World Bank 2023
Total Unemployment of population with tertiary education	Eurostat 2023
GDP per capita growth	World Bank 2023
Human ressources in science and technology proxy	Eurostat 2023

Table 1: Variable List and Sources

4.4. Descriptive Statistics

This section gives an overview of the summary statistics of our dataset. These statistics it shown in the Table below. The first line is the dependent variable. The second line is the main independent variable. The rest of the list shows the control variables.

Table 2: Descriptive Statistic

	Obs	Mean	Std. Dev.	min	max
Gender Employment Gap of Highly Educated Population	609	6.7	3.7	-3.5	18.2
GERD	603	1.4	0.9	0.2	3.9
GDPpercapita	459	2.5	3.4	-11.7	23.2
High Technology Manufacturing Sector	568	1.2	0.8	0.1	4.1
Low Technology Manufacturing Sector	602	7.7	3.1	1.1	17.3
Employment on Total Knowledge Intensive Services	602	34.3	8.8	11.1	58.3
Employment on Knowledge Intensive High Technology Services	602	0.9	1.2	5.4	
Employment on Total Less Knowledge Intensive Services	602	31.7	4.6	18.2	46.5
Female working Full Time	609	78.5	16.1	24.4	98.1
Total Unemployment of Population with Tertiary Education	440	4.9	2.9	1	20.9
Human Ressources in Science and Technology Proxy	565	40.6	9.5	17.2	65

5. Theoretical Framework

5.1 The Model

Previous literature on the impact of innovation and technical change on the gender gaps provides guidelines to construct the model used for this paper. The relation between the two variables is inspired by the model of Aksoy (2021). Panel data is used to estimate this model. The equation below serves as a base model, where a variable representing the Gender Employment gap is set as a dependent variable and the Gross Expenditure on Research and Development is set as an independent variable.

$$GEGT_{(ct)} = \beta_0 + \beta_1 GERD_{c(t-2)} + \beta_2 Controls_{ct} + \gamma_{ct} + \delta_{ct} + u_{ct}$$

i represents the country identifier, i=1…,27
t represents the time identifier, t=1, ..., 23 years from 1998 to 2020.

The dependent variable GEG is the Gender Employment gap between the employees that have obtained tertiary education in country c and year t.

The independent variable is Gross Expenditure of Research and Development is measured as a percentage of GDP. This variable is lagged by 2 years (the reason for this lag is the fact that it normally takes at least two years for an investment in R&D to fully materialize in new product or process innovation).

We control for: Total Unemployment rate, Total Female employment with Full Time jobs (% of Total population), GDP per Capita Growth (%) based on local currency, Total employment of population that work on STEM (% of Total Population), control for employment in different manufacturing and service sector (as a % of Total Population).

Cn-1 are the dummy variables Country. The number of Country variables included in the model is equal to the number of countries minus 1. P1, P2, ..., PT-1 are the dummy variables for Time, and we have T-1 time periods beta j are the coefficients of the explanatory variables. Gamma represents the coefficient of dummy variable Country. Delta t represents the coefficients of the dummy variables Time.\item UI is the error term.

This model follows a linear regression. Meaning that our parameter such as GERD can be expressed as a one-unit change of GERD, which leads to a coefficient(beta) change in economic performance. (Guajarati,2004) In order to estimate this model, we use a 2-way Fixed effect model, where we set time dummy variables as well as regional dummy variables. The country fixed effect will be used to consider the time variant fixed effect, and the time fixed effect will be used to take account time invariant fixed effects.

5.2 Assumptions

The analysis controls for the following variables: women that work full time jobs in the labor force as a percentage of total employment, unemployment of population with tertiary education as a percentage of total employment GDP per capita growth, annual percentage growth rate of GDP per capita based on constant local currency, as well as human resources in science and technology. The latter serves as a proxy of female share of graduates from Science, Technology, Engineering and Mathematics (STEM) programs, tertiary (%). The main data sources are Eurostat and the World bank.

Assumption of Homoscedasticity

The assumption of homoscedasticity is going to be violated when using panel data concerning countries over time. There is meant to be heterogeneity in this unit. However, the estimation techniques concerning panel data includes heterogeneity. In this study, the model will use the differential intercept dummy technique to solve this heterogeneity problem, while allowing the fixed effect intercept to vary among the countries. The study include 26 country dummy variables in our model to solve this problem. One of the country dummies is dropped to avoid falling in a dummy variable trap. The model does allow for country specific fixed effects, given that we must consider the different country characteristics that are present in the model. This account for the different informal and formal institutions in the countries in the sample, which will affect the difference between female and male employment. The model also allows for time fixed effects, given that employment changes over time, influenced by factors such as economic booms, regressions, and employment policies imposed by unions or the state. Therefore, the model includes 22 time dummies to account for the time span from 1998 to 2020. By including time and fixed effects, we convert a 2-way fixed effect model.

The 2-way fixed effect model: Regressions

The regression analysis allows gaining more knowledge of how investment in research and development influence gender employment. Before showing the result of our model, it is important to understand how the model was constructed. The first step was to construct an Akaike information criterion to figure out how many lags to put in our main independent variable, Gross Expenditure on Research and Development. The second step was to see if any variable bias is omitted by including the control variables on the model.

AIC

To decide on the number of lags, several information criteria are used, such as Akaike Information Criteria, Bayesian information criterion and Hanna-Quinn information criterion. These criteria reveal how well a model fits the data. The optimal number of lags is the one that gives the lowest value of the chosen criteria. According to the Table 3 below, the best fitted model is when the main independent variable Gross Expenditure on Research and Development is lagged by 2 years.

Table 3: Results of Criteria Model

	Information criterion		
Number of Lags	AIC	HQIC	SBIC
1	.0997349	.1084234	.1220359
2	.0303401*	.0390286*	.0526411*
3	.049371	.0580595	.071672
4	.0501153	.0588038	.0724162

The star indicates the lowest value

6. Hypothesis and expected results

As illustrated in chapter 3, existing, and recent literature have mainly focused on the effect of innovation (or "technological change") on the gender wage gap, or – concerning employment - the effect of gender inequality on innovation performance. Relatively less studies have focused on the effect of innovation on the gender employment gap (which persists in European countries). Possibly, researchers consider that the effects on the gender employment gap is a more self-explaining correlation. However, previous studies also include several factors pointing at the fact that a positive effect of technological change on closing the gender employment gap cannot be taken for granted.

Moreover, previous studies have mainly focused on process innovation, and on the change in occupational skills derived from computerization, robotization, and the like. A more in-depth definition of innovation opens for a conceptualization of innovation, which embraces both product and process innovation. The literature on innovation tends to converge on a net job creation stemming from innovation (the combined effect of product and process innovation), at least in the medium- to long-term. Therefore, this study uses the investment in R&D at macroeconomic level (GERD) as the main proxy for innovation since this indicator is closely related to both product and process innovation.

Based on these conclusions from the existing literature on both gender and innovation, we elaborate an empirical model focusing on the effect of innovation on the gender employment gap in EU member states over the last two decades, testing the following hypothesis:

Increased investment in innovation leads to a reduction of the gender employment gap.

Innovation would have a positive effect on employment, including an increase in the total number of jobs available in the labor market for both men and women. Since in most EU member states, the proportion of female tertiary education graduates is higher than that of men, innovation would have a more positive effect on female employment than male employment, i.e., a negative coefficient meaning that more investment in GERD leads to a closing of the gender employment gap. Women perform better at school and university than men and they have a comparative advantage education and cognitive skills over physical skills and strength. Furthermore, and following previous studies, innovation would influence structurally the demand for high-skilled labor. Therefore, the employment effects of innovation are likely to be higher in EU member states and regions with a relatively larger proportion of the labor force having finalized tertiary education studies.

However, the contrary effect may also happen, in countries with a high level of technology in the work environment and an advanced level of industrialization. The proportional increase of labor demand on women may be lower than that of men, since advanced innovation and technology development will demand proportionally more STEM[19] skills, which statistically more men than women have chosen to study. This proportion will differ between EU member states and over time. Previous studies on the effects of robotization and computerization have found such an effect on the gender gap, but mainly when focusing on the gender *wage* gap (less evidence is available on the gender *employment* gap).

[19] Higher education studies in Science, Technology, Engineering and Mathematics.

Another counter-argument to the hypothesis is based on what could happen in countries with a higher proportion of low-skilled labor force (more common in some Eastern European countries). In such a setting, innovation will mainly occur following technology adoption in low- and medium-tech industries, where process innovation dominates over product innovation. Innovation may then have a negative effect on overall employment, since investment in R&D may trigger a decrease of labor demand of low-skilled employees, and an overall short-term decrease in labor demand due to the substitution of labor by capital (e.g., automatization of processes).[20]

7. Main Results

This section introduces the results of the model. The table below displays the first results.

Table 4: Main results

	(OLS Robust)	(2 Way FEM)	(2 lags)
GERD	.14	.029	
	(.49)	(.54)	
$GERD_{t-1}$			-.83
			(.65)
$GERDn_{t-2}$			.97
			(.77)
GDP per Capita	.031	.033	.03
	(.021)	(0.04)	(0.04)
HTM	1.09**	1.28***	1.39 ***
	(.43)	(.44)	(.45)
TKIS	-.034	-0.15	-.13
	(.036)	(.10)	(0.11)
Female Full time	-.18**	-0.35**	-.29**
	(.077)	(.14)	(.14)
Unemployment	-.0785	-.055	-.076
	(.0665)	(.076)	(.08)
Stemproxy	.012	-.071	-.064
	(.045)	(.087)	(.089)
Constant	15.14***	19.6946***	20.31***
	(3.75)	(4.78)	(5.71)
Country FE	No	Yes	Yes
Year FE	No	Yes	Yes
Robust se	Yes	Yes	Yes
Lag GERD	No	No	Yes
Obs	515	515	504
Groups	27	27	
$R^2 Within$	0.1294	0.2114	0.1894

Standard errors in parantheses * p¡0.1*p¡0.05**p¡0.01***
GERD-Gross Expenditure on Research and Development
HTM-High Technology Manufacturing
TKIS-Total Knowledge Intensive Sector

Column 1 presents the result of OLS regression model with robust standard error where the main independent variable is *Gross Expenditure of Research and Development (GERD)*. The analysis also included other control variables. However, it does not account for either time fixed effects or country fixed effects, which means that the results exposed may suffer some bias.

[20] See the analysis of related variety in Finland, made by Hartog, Boschma and Sotarauta, 2012.

To overcome this issue, the next columns include country and time fixed effects. The results for GERD shows a negative relationship with our dependent variable Gender Employment Gap - although it is a statistically insignificant result.

In the third column, GERD is lagged by 2 years given that this is the correct number derived from the information criterion table (see Table 3). The analysis also includes GERD lagged by 1 year, which would mean that an increase in gross expenditure on R&D means that there is a short-term decrease of the gender employment gap. However, this result is also statistically insignificant. Nevertheless, the third line presents the result of the main independent variable lagged, and this result is positive but insignificant.

Overall, the results presented here do not fully correspond to the expected result in the hypothesis, as based on previous research presented in the literature review.

Table 5: Other Main Results

	(OLS Robust)	(2 Way FEM)	(2 lags)
GERD	-0.442	-0.210	
	(0.505)	(0.617)	
$GERD_{t-1}$			-1.028*
			(.616)
$GERDn_{t-2}$			0.913
			0.802
GDP per Capita	0.041*	0.0339	0.0332
	(0.022)	(0.036)	(0.034)
HTM	0.984	1.106**	1.240 **
	(0.323)	(0.454)	(0.479)
LTM	-0.351	-0.297	-0.296
	(0.217)	(0.262)	(0.2662)
TLKIS	0.0170	-0.0592	-0.0984
	(0.0858)	(0.1231)	(0.128)
KIHTS	-0.1466	-0.244	-0.189
	(0.304)	(0.371)	(0.363)
Female Full time	-0.205**	-0.347**	-0.282**
	(0.0815)	(0.152)	(0.151)
Unemployment	-0.119*	-0.095	-0.115
	(0.068)	(0.072)	(0.076)
Stemproxy	-0.057	-0.109	-0.095
	(0.043)	(0.080)	(0.080)
Constant	21.592***	22.765**	24.696**
	(6.384)	(8.852)	9.615
Country FE	No	Yes	Yes
Year FE	No	Yes	Yes
Robust se	Yes	Yes	Yes
Lag GERD	No	No	Yes
Obs	515	515	504
Groups	27	27	
R^2 *Within*	0.161	0.213	0.201

Standard errors in parantheses * p<0.1*p<0.05**p<0.01***
GERD-Gross Expenditure on Research and Development
HTM-High Technology Manufacturing Sector
LTM-Low Technology Manufacturing Sector
KIHTS-Knowledge Intensive High Technology Services
TLKS-Total Less Knowledge Intensive Services

The Table above expand the results by including more specific controls on employment in different industry sectors of production. Here employment in the following industry sectors is controlled for: High

Technology Manufacturing, Low Technology Manufacturing, Total Less Knowledge Intensive Sectors, Knowledge intensive High Technology Sectors. This result is also composed of the same three regressions as the previous regression. When checking if there is a difference in the information criteria, the results are the same as in the first table. Therefore, the same number of lags are introduced in the variable GERD, which is 2 lags. However, the results in table 5 differ from the result in table 4. The new result shows a negative and significant relationship between GERD and the Gender Employment Gap of Tertiary Education when lagged by 1 year. When lagged by 2 years, there is a positive but now insignificant relationship between the same two variables.

8. Robustness checks

Robustness of Heterogeneity across countries (see also table in appendix)

The sample is separated into countries with a high initial level of gender inequality and low initial level of inequality. This separation is based on the gender gap index used by Hausman et al 2006. Table A1 presents the scores of all our countries in the sample. The countries with classification 1 are part of the first group with high GCI score, and the countries with low CGI score are part of the second group. Based on the results in (Table A2) there is a difference in the effect of GERD between the two groups. The group with the highest GCI Score has a negative and significant effect in the first year and a positive significant result the second year. This means that the results are mainly driven by the group with higher GCI scores in 2006.

An additional analysis is performed by splitting the sample into Eastern and Western European sub-samples. This analysis shows that innovation has a negative significant result when the variable is lagged by 1 year and a positive insignificant result when lagged by 2 years. On the other in the Eastern European subgroup, there are insignificant results. This provides an indication that the initial economic level of the two groups of countries will influence the impact of innovation on Gender Employment Gap

Robustness checking the Total Employment Gap

Finally, the robustness check uses total employment levels instead of employees with tertiary education to verify if the results differ when using the difference of total employees. The results show that the coefficient of GERD lag by 1 year is larger but insignificant using the full labor force. This means that the effect differs when using the total labor force instead of using only the students with tertiary education.

9. Discussion and policy implications

The overall finding in this study is that in the short term (1-years lag) there is a negative effect of innovation on the gender employment gap in the EU, i.e., more investment in GERD contributes to closing the gender employment gap. This is clearer when controlling for women in full-time employment. It is also interesting to note that the robustness checks give a clearer effect (both short-term and medium-term) for Western European countries and for countries with a higher gender equality (see also chapter 10 appendix).

These first findings are likely linked to the fact that innovation is theoretically correlated with a structural change in the economy, increasing proportionally more the demand for skilled labor with a tertiary education degree and a high-level of conceptual and creative skills. In all EU member states, the gender education gap is reversed, and women outperform men in higher education with a larger share of bachelor studies graduates and graduates at master level.

This interpretation is further backed up by the negative effect of Knowledge-Intensive Services, indicating that there the positive relation between GERD and employment in Knowledge-Intensive Services benefit women more than men. In other words, since women are to a higher proportion employed in the service sector, the upgrading of the skills requirements in the service sectors possibly triggers higher employment of women compared to men. Given that the general trend in the EU is a growing service sector compared to the manufacturing and agriculture sector (dominated still by men), the finding in this study could imply a substantial contribution to the closing of the gender employment gap.

The results from the Tables above also point to a statistically significant positive effect of GERD on employment in high-tech manufacturing. Since these sectors are still dominated by male employees, closely related to labor demand for STEM studies skills (where women are under-represented), this dynamic is contributing to increasing the gender employment gap. However, it is surprising that the STEM proxy is not significant (not in Table 4 nor in Table 5).

It is possible that this dynamic is partly explaining the effect of GERD on the gender employment gap in the medium term. However, this effect is not statistically significant and should therefore be interpreted with caution. If innovation triggers a process of economic change, which in the short-term triggers an expanding knowledge-intensity in the service sector, this will likely contribute to closing the gender employment gap. However, if in the medium-term, this dynamic is overtaken by an expanding high-tech manufacturing sector (favoring male employment), the overall employment effect of innovation risks aggravating the gender employment gap.

Here, clearly a more detailed analysis is needed. Another way of explaining the difference between the lag of 1 year, compared to a lag of 2 years, could be that more women are employed directly in research and development activities (in the public and the private sectors). The immediate effect of increased investment in R&D would then benefit foremost women. Such an interpretation can be supported also by the significant negative effect for the variable Female full time employment (in both Table 4 and 5). When additional investment comes for research and innovation, the employers (in the public and private sectors) would mainly channel these funds to full-time employed researchers while increasing the number of those employed full-time.

In broad terms, if these limited signs of an effect of innovation on closing the gender employment gap are confirmed, this would have clear consequences on the design of innovation policy. In the future, the design of innovation policy should be closer associated with a gender sensitive employment policy design to fully explore this potential for an inclusive and effective economy. Today, most literature and attention of innovation seem to focus on competitiveness and growth, not on its possible effects on closing the gender gap.

10. Conclusions

This study is unique in several senses. The research question has not been explicitly targeted in any previous studies since studies on the effect of innovation on gender gaps mainly have focused on the gender wage gap. Moreover, the geographical scope chosen, focusing on the EU 27 countries, is unique, given that most of the previous studies in this line of research are using US data. Finally, the time span allows for a solid statistical base, with a long-term data series of over 20 years.

The main research question focused on the possible contribution of innovation in closing the gender employment gap. *Does innovation contribute to closing the gender employment gap?* In other words, the analysis is not only including the possible effect of innovation on overall employment, but on the specific question, whether this employment creation favor women.

Recognizing that innovation is a complex dynamic, this analysis uses the officially most applied proxy for innovation, namely gross expenditures on research and innovation. This indicator is closely correlated with the level of knowledge-intensity of a national economy.

Based on an extensive literature review, we launch the hypothesis of a negative effect of innovation on the gender employment gap, i.e., an increased investment in GERD would reduce the gender employment gap. Previous studies provide arguments both in favor and in counter of this hypothesis.

The results of our regression and controls present an indication of a negative effect of the independent on the dependent variable, indicating that innovation would contribute to the closing of the gender employment gap – at least in the short-term. Our results point at knowledge-intensive services and full-time employed women. This would provide a new dimension to innovative policy design and open-up for a new instrument in the efforts to close the persisting gender employment gap in the EU.

However, caution is needed in the interpretation, given that there seems to be a discrepancy between the short- and medium-term effect of innovation. The negative effect of innovation on the gender employment gap is not confirmed in the medium-term (i.e., with a two years' time lag between the investment in R&D and its impact on gender employment). The results show a clear positive effect of innovation on employment in high-tech manufacturing sectors, which are in general characterized by a broad use of STEM skills. This would disfavor women, since women are still underrepresented in STEM studies and careers.

In conclusion, these first results indicate the possible existence of two parallel and counteracting effects of innovation on gender employment: an increase in employment in knowledge-intensive services and in research activities, mainly favoring women, and an increase in employment in high-tech manufacturing, mainly favoring men. The overall effect of innovation on the gender employment gap would depend on the relative strengths and time spans of these two parallel effects. To determine this, more research would be needed, possibly comparing in more detail the industrial structure of each EU member state, concerning the relative weight and time trends in knowledge-intensive manufacturing and services.

11.References

Acemoglu, D., Autor, D. (2011) “Skills, Tasks and Technologies: Implications for Employment and Earnings”, Handbook of Labour Economics, volume 4, part B, pages 1043-1171, Science Direct

Aghion, P., Akcigit, U., Howitt, P., (2015)” The Schumpeterian Growth Paradigm”, Annual Review of Economics 7, pp. 557-575

Aghion, P., Jaravel, X. (2015), “Knowledge Spillovers, Innovation and Growth”, The Economic Journal, volume 125, Issue 583, pp. 533-573

Aksoy, C.G, Özcan, B., Philipp, J., (2021) “Robots and the gender pay gap in Europe”, European economic review, 134 (2021) 103693

Aldieri, L., Makkonen, T., Vinci, C.P, (2021),” Spoils of innovation? Employment effects of R&D and knowledge spillovers in Finland”, Economics of Innovation and New Technology, 30:4, pp. 356-370, Routledge, DOI: 10.1080/10438599.2019.1703754

Audretsch, D., Coad, A., Segarra, A., (2014) “Firm Growth and Innovation”, Small Business Economics 43, pp.743-749

Belghit-Mahut, S., Lafont, A-L., Yousfi, Q. (2016), Gender gap in innovation: a confused link?”, Journal of Innovation Economics and Management, 159-177

Benavente, JM., Lauterbach, R., (2008) “Technological Innovation and Employment: complements or substitutes?”, The European Journal of Development Research 20, pp. 318-329

Biscione, A., Boccanfuso, D., Felice, A., (2022) “The innovation gender gap in transition countries”, Economia Politica, 39, 493-516

Calvino, F., Virgillito, M.E. (2018), “The Innovation-Employment Nexus: A Critical Survey of Theory and Empirics”, Journal of Economic Surveys 32, pp.83-117

Carlino, G., Kerr, W. (2015), “Agglomeration and Innovation”, Handbook of Regional and Urban Economics, volume 5, pp. 349-404

Carrasco, I. (2014) “Gender gap in innovation: an institutionalist explanation”, Management Decision, vol. 52, number 2, Esmerald Group Publishing Limited

Coad, A., Segarra, A., Teruel, M. (2016), “Innovation and Firm Growth: Does Firm Age Play a Role? “, Research Policy 45, pp.387-400

Cortes, G.M., Oliveira, A., Salomons, A. (2021), “Do technological advances reduce the gender wage gap?, Oxford Review of Economic Policy, Volume 36, Number 4, 2020, pp. 903–924

Crespi, G., Tacsir, E., (2013), “Effects of innovation on Employment in Latin America”, UNU-MERIT Working Papers Series, Volume 2013-01, Maastricht: United Nations University

Dachs, B., Hud, B., Koehler, C., Peters, B. (2017), “Innovation, Creative Destruction and Structural Change: firm-level evidence from European countries”, Industry and Innovation 24, pp. 346-381

Evangelista, R., Vezzani, A. (2012), “The Impact of Technological and Organizational Innovations on Employment in European Firms”, Industrial and Corporate Change 21, pp. 871-899

Eurofound and the European Commission Joint Research Centre (2021), “European Jobs Monitor 2021: Gender gaps and the employment structure”, European Jobs Monitor series, Publication Office of the European Union, Luxembourg

Eurofound (2016), “The gender employment gap: challenges and solutions, Publication Office of the European Union, Luxembourg

European Commission (2022), “Science, Research and Innovation performance of the EU 2022 report”, Directorate-General for Research and Innovation, Official Publication Office of the European Union, 4 July 2022

European Commission (2022), “European Innovation Scoreboard”, Directorate-General for Growth, Publication Office of the European Union, 4 July 2022

European Commission (2022), “EU Industrial R&D Scoreboard”, Joint Research Centre, Seville, Publication Office of the European Union.

European Commission, Eurostat (2021), “Tertiary education statistics – statistics explained”, Publication Office of the European Union

European Commission (2011), “Innovation Union Competitiveness report”, Directorate-General for Research and Innovation, Publication Office of the European Union

EU STEM coalition, (2023), “Recommendations on increasing the scale and impact of EU initiatives in STE(A)M education”, position paper, stemcoalition.eu/

Freeman, C., Soete, L. (1997), Economics of industrial innovation, London: The MIT Press

Galor, O., Weil, D., (1993) “The gender gap, fertility and growth”, National Bureau of Economic Research, NBER working paper series nr 4550

Geroski, P., Machin, S. (1992), “Do Innovating Firms Outperform Non-Innovators?”, Business Strategy Review 3, pp. 79-90

Gujarati, D. (2004) Basic Econometrics. 4th Edition, McGraw-Hill Companies, New York.

Hall, B., Kramakz, F. (1998), "Effects of Technology and Innovation on Firm Performance, Employment, and Wages", Economics of Innovation and New Technology 5, pp.99-108

Harrison, R., Jaumandreu, J., Mairesse J., Peters, B. (2014), 'Does Innovation Stimulate Employment? A Firm-Level Analysis Using Comparative Micro-Data from Four European Countries", International Journal of Industrial Organization 35, pp.29-43

Hartog, M., R. Boschma, and M. Sotarauta, (2012). "The Impact of Related Variety on Regional Employment Growth in Finland 1993–2006: High-Tech Versus Medium/Low-Tech." Industry and Innovation 19 (6): 459–476.

Hashi, I., Stojcic, N, (2013), "The Impact of Innovation Activities on Firm Performance Using a Multi-Stage Model: Evidence from the Community Innovation Survey 4", Research Policy 42, pp. 353-366

Hausmann, Ricardo. "The global gender gap report 2009." World Economic Forum, 2009.

Jabaa, E. PârĠachi, I., Chistrugă, B., Balana, C.B. (2013) "Gender employment gap in EU before and after the crisis"

Klasen, S., Minasyan, A., (2017), "Gender Inequality and Growth in Europe", Intereconomics: Review of European Economic Policy, vol. 52, issue 1, 17-23

Lachenmaier, S., Rottmann, H. (2011), "Effects of innovation on employment: a dynamic panel analysis", International Journal of Industrial Organization, Volume 29, Issue 2, pp. 210-220.

Mohnen, P., Hall, B. (2013), "Innovation and Productivity: An Update", Eurasian Business Review 3, pp. 47-65

Ngai, L. R., Petrongolo, B., (2017), "Gender Gaps and the Rise of the Service Economy", American Economic Journal: Macroeconomics 2017, 9(4): 1–44 https://doi.org/10.1257/mac.20150253

Nedelkoska, L., Matha, S.G, McNerney, J., Assumpcao, A., Diodato, D., and Neffke, F., (2021) "Eight Decades of Changes in Occupational Tasks, Computerization and the Gender Pay Gap"

Peters, B., Dachs B., Duenser, M., Hud, M., Köhler, C., Rammer, C. (2014), Firm Growth, Innovation and the Business Cycle, Background report for the 2014 Competitiveness Report, volume 110577, Mannheim: ZEW Expertise's, ZEW-Leibniz Centre for European Economic Research

Petersen Rendall, M. (2017), "Brain versus Brawn. The Realization of Women's Comparative Advantage", Working Paper nr 491, Institute for Empirical Research in Economics, University of Zürich, ISSN 1424 0459

Schot, J., Geels, F., “Typology of Sociotechnical Transition Pathways”, Research Policy (2007), 36 (3), 399–417

Strohmeyer, R., Tonoyan, V. (2005), “Bridging the gender gap in employment growth. On the role of innovativeness and occupational segregation”, The International Journal of Entrepreneurship and Innovation, 6 (4), 259-273

Vivarelli, M. (2014), “Innovation, Employment and Skills in Advanced and Developing Countries: A Survey of Economic Literature”, Journal of Economic Issues 48, pp.123-154

Woltjer, G., van Galen, M., Logatcheva, K. (2021), “Industrial Innovation, Labor Productivity, Sales and Employment”, in International Journal of the Economics of Business, Volume 28, Issue 1, pp. 89-113.

World Economic Forum (2020), “3 things to know about women in STEM”, Gender Inequality, February 11, 2020. Weforum.org/agenda/2020

US National Academies of Science, Engineering, and Medicine, (2007), “Rising Above the Gathering Storm. Energizing and Employing America for a Brighter Economic Future”

Törnqvist, L., Vartia, P., Vartia, Y.O., (1985) “How should relative changes be measured?”, American Statistician 39 (1), 43–46

12. Appendix

Table 6: Gender Gap Index Scores

Gender Gap Index Scores		
Country	CGI score 2006	Classification
Italy	0.645	0
France	0.652	0
Greece	0.654	0
Hungary	0.669	0
Czech Republic	0.67	0
Slovakia	0.68	0
Romania	0.68	0
Poland	0.69	0
Bulgaria	0.687	0
Portugal	0.692	0
Slovenia	0.674	0
Luxembourg	0.667	0
Cyprus	0.643	0
Malta	0.651	0
Estonia	0.694	1
Lithuania	0.708	1
Belgium	0.708	1
Latvia	0.709	1
Netherlands	0.732	1
Spain	0.731	1
Germany	0.752	1
Finland	0.795	1
Sweden	0.813	1
Denmark	0.756	1
Austria	0.698	1
Croatia	0.714	1
Ireland	0.733	1

Table 7: *Robustness of Heterogeneity across countries by Gender Equality Index*

Heterogenity by Gender Equality Index		
Subsample	High GCI Score (Higher Gender Equality) (1)	Low GCI Score (Lower Gender Equality) (2)
GERD Lagged 1 Year	-1.68231*	0.167
	(0.893)	(1.003)
GERD Lagged 2 Year	2.194**	0.611
	(0.845)	(1.165)
GDP per Capita	-0.04	0.620
	(0.408)	(0.610)
Observations	249	255
Country Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Controls	YES	YES height

Standard errors in parantheses * p<0.1*p<0.05**p<0.01***

Table 8:*Robustness of Heterogenity across countries by East and West*

Subsample	West (1)	East (2)
GERD Lagged 1 Year	-2.709**	-1.556315
	(1.185)	(0.998)
GERD Lagged 2 Year	3.084495 ***	1.255563
	(1.144764)	(1.018381)
GDP per Capita	0.0123404	0.0841136
	(0.0284663)	(0.0420007)
Observations	228	234
Country Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Controls	YES	YES

Standard errors in parantheses * p<0.1*p<0.05**p<0.01***

Table 9: *Male and Female Employment*

Subsample	Male Employment (1)	Female Employment (2)
GERD Lagged 1 Year	-0.618	0.409
	(0.6518)	(0.601)
GERD Lagged 2 Year	0.417	-0.496
	(0.822)	(1.059)
GDP per Capita	-0.008	-0.04
	(0.043)	(.0312)
Observations	504	504
Country Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Controls	YES	YES

Table 10: *Using Gender Employment Gap of the Total Employment*

Subsample	West (1)	East (2)
GERD Lagged 1 Year	-2.709**	-1.556315
	(1.185)	(0.998)
GERD Lagged 2 Year	3.084495 ***	1.255563
	(1.144764)	(1.018381)
GDP per Capita	0.0123404	0.0841136
	(0.0284663)	(0.0420007)
Observations	228	234
Country Fixed Effects	YES	YES
Year Fixed Effects	YES	YES
Controls	YES	YES

Standard errors in parantheses * p<0.1*p<0.05**p<0.01***