Master thesis

The effect of innovation on unemployment and its evolution

A mixed methods analysis investigating the evolutionary relationship between regional innovation and labour markets within the European Union

by

Quentin van Nieuwenhuizen
5638003

Utrecht University
Human Geography – Economic Geography
Track Business and Location
Supervisor: Sergio Gabiel Petralia
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Abstract

Evolutionary economic geographic literature seeks to place the concept of innovation within a path-dependent context where the complexity and relatedness of activities and knowledge regionally determine a region's probability of successfully specializing in a new activity. As the spatial fragmentation of innovation increases, research needs to investigate how innovation will affect society. This research seeks to apply the evolutionary perspective of innovation on its effect on regional labour markets. Doing so provides knowledge for policymakers, employers, and employees to deal with challenges and opportunities on the labour market. Scientifically this research further substantiates the legitimacy of this evolutionary perspective whilst combining it with more traditional economic research on labour markets. Through an evolutionary revisitation of Okun's Law which states that cyclical economic growth is related to labour market developments; this research investigates the relationship between regional innovation and unemployment and its evolution. It does so for the NUTS-2 regions of the European Union and the EEA between 2015 and 2019. Building on data of the European Commission, a quantitative analysis finds that regional innovation and human capital negatively affect unemployment and its evolution. At the same time, regional innovation and human capital also seem to decrease inequality on regional labour markets regarding unemployment. Three case studies have been drafted to investigate what determinants shape these dynamics. The key takeaway of these case studies is that regional context, local capabilities, geography, and labour market policies are key determinants of the relationship between regional innovation and labour markets. However, this research fails to investigate the relationship between regional innovation and the occupational structure of labour markets. Therefore, further research on regional innovation and labour markets is needed.

Foreword

This master's thesis has been written during a graduate internship at Technopolis Group. The research has been aligned with the PILLARS program which investigates the evolution of regional labour markets for the European Commission's Horizon 2020 program. During this internship, I have had the pleasure to be supervised by dr. Anastasiia Konstantynova whilst working together with Tatjana Guznajeva, Ana Oliveira, and Juanita Garcia Gutierrez. This internship has been made possible by my academic supervisor dr. Sergio Gabiel Petralia. I would like to thank you all for your cooperation and expertise as this thesis would not have been possible without you. Lastly, I would also like to thank my girlfriend and my family for their unconditional support during the writing of this thesis and my studies over the past years. I am very much looking forward to the beginning of my career and the eventual continuation of my research on innovation and regional labour markets.

Abbreviation list

AI – Artificial intelligence
EU – European Union
EEA – European Economic Area
IT – Information Technologies
NEET - Percentage of the population aged 15-24 not in education, employment or training
NEG – New Economic Geography
OECD – Organization for Economic Co-operation and Development)
RIS – Regional innovation system
RCI – Regional Competitiveness Index
SE – Standard error
SME – Small and Medium-sized Enterprises
VET – Vocational training and education

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Introduction

The process of innovation and its societal implications have been shaping the world at an increasing pace since the industrial revolution. Understanding the effects of innovation is therefore more important than ever. One of the growing fears about innovation is its impact on labour markets and technology-driven unemployment (Somers et al., 2022). This fear is substantiated by the definition of process innovations, which states that "process innovation means producing the same amount of output with less labour […], the direct impact of process innovation is job destruction when output is fixed" (Vivarelli, 2015). However, as innovation is a complex and broad concept, its effects are often difficult to measure. Combining Vivarelli's quote with the fact that "Innovative firms tend to be more productive, create more jobs, employ more skilled workers (meaning that they employ more educated workers and offer more on-the-job training) and hire more female workers" (Richiardi & Postolachi, 2017; page 120) shows that the relationship between innovation and labour markets is not straightforward. The different dynamics occurring between innovation and labour markets, therefore, require extensive investigation to assist employees, employers, and policymakers.

Current research on the relationship between innovation and labour markets focuses on the resilience of labour markets in periods of recession, where labour market resilience is positively impacted by innovation on a regional level (Reveio et al., 2022). At the same time, case studies within the EU have found knowledge accumulation within occupational groups to be linked to the quality of social networks in a region and contributing to better labour market conditions (Pieroni et al., 2007; De Laurantis, 2006). The literature investigating the relationship between innovation and labour markets further focuses on interdependent processes in the face of external shocks (Muštra et al., 2020). An example of this is the finding that low-skilled jobs are more at risk of job destruction and transformation in periods of recession (Scarpetta, 2018). To summarize a part of the body of literature on the relation between innovation and labour markets and their development, it is ample to say that innovation (or innovative performance of regions) is related to labour markets and their development on a regional scale. However, the existing body of literature fails to consider the evolutionary processes behind regional innovation. These evolutionary processes have been found to be fundamental elements in the spatial analysis of innovation systems by Boschma and Frenken (2018). Further research of Balland et al., (2020) have found complex – and innovative – activities and employment to cluster in urban centers. As a result, the increasing rate at which knowledge concentrates leads to increasing inequalities between regional labour markets. This emphasizes the need to further investigate the relationship between innovation and labour markets from an evolutionary economic geographic perspective.

As current literature on the relationship between innovation and labour markets and their development is focusing on periods of recession, it is necessary to examine how this relation compares during a period of expansion. Furthermore, the scientific community would benefit from elaborating on the relationship between innovation and labour markets and their development from an evolutionary economic perspective. As this would enable labour markets to be seen from a path-dependent perspective which could explain the evolution of labour markets over time and predict their evolution.

At the same time, "New capabilities, driven by technological innovation, will create an important number of new job opportunities and new markets while existing jobs or tasks disappear or are re-designed." (van den Broek, 2017). This implies that regions and their labour force are subject to innovation and that the externalities arising from innovation shape the future of the supply and demand of labour. This leaves policymakers, employers, and

employees with the challenge to understand and react to factors influencing regional labour markets. Especially as the occupational structure of many regions has already been subject to shifts and job creation polarization per occupational group. As Kergroach (2017) argues, the shift to Industry 4.0 will – and has already started – to fundamentally reshape the labour market, leaving a gap in the middle-skilled occupational groups. And substantiating the need to gather evidence and knowledge that can help understand the impact of technological change on labour market transformations.

Societally, this implies that gaining more insights into the relationship between innovation and labour markets can assist policymakers, employees, and employers to arm themselves against the increasing structural development of the labour market, caused by innovation. Simultaneously, more knowledge on the evolution of labour markets over time and the dynamics that shape these processes provides tools for policymakers to formulate proactive labour market policies, which have been proven more effective than reactive labour market policies (de Groen et al., 2017).

The aim of this research will be to extend the knowledge base required for inclusive labour market policies. Filling the current gap in research between evolutionary economic geography, the functioning of regions, and current labour market challenges. The goal of addressing this current gap is to provide policymakers and academics with tools and information that contribute to social protection for workers in occupational classes prone to job destruction and transformation, whilst simultaneously providing knowledge on good practices and opportunities arising from the local context of regions that have proven to harvest the potential benefits of innovation on their labour market.

To realize this research, the following main research question has been formulated: *To what extent is regional innovative capacity related to regional labour markets and their transformation over time in the EU between 2015 and 2019? And what are the key determinants that shape this regional dynamic?*

To answer this question, the following sub-questions have been formulated:

- Are innovation and unemployment subject to similar spatial patterns in a period of expansion?
- Do regional innovation systems negatively affect unemployment and its evolution in the EU during a period of expansion?
- Does regional human capital negatively affect unemployment and its evolution in the EU during a period of expansion?
- Do regional case studies provide insights into the dynamics at play in the relationship between innovation and unemployment?

Theoretic framework

Research that has focussed on the link between regional innovative capacity and labour markets and their resilience often seeks to place this relationship in the context of external shocks. Indeed, Filipetti, et al. (2020) and Revelu et al. (2021) have found a positive relationship between performance in Innovation and labour market resilience in the wake of the 2008 financial crisis in the European Union. This research builds around the rationale that local capabilities enable regions to adapt and recover more effectively. Combining this rationale with research on the evolutionary perspective of regions and their development, this theoretic review

seeks to formulate a framework that will examine the relationship between regional innovative capacity and unemployment in regions, the evolution of unemployment in regions, and the polarization within regional labour markets.

Regional innovation

New Economic Geography seeks to explain the existence and persistence of agglomerations. By looking at economic agents and their rational decisions it derives conclusions on differences between regions through equilibrium analyses (Boschma & Frenken, 2006). An important focus of the NEG-turn lies in the Regional Innovation System. This literature explains the clustering of innovative activities through the relations between organizations. These relations and the activities of these organizations are subject to localized capabilities for the production and transmission of tacit knowledge (Boschma & Frenken, 2018).

Regions have been found to be the principal sites of innovation and innovative production. Through the creation, survival and performance of firms and industries, regions are key for understanding the process of innovation. However, regions are also very much uneven when it comes to the creation and support of knowledge structures. In fact, this is where regional path-dependence plays a major role (Gertler, 2005). As Balland and Rigby (2017) have found, tacit and complex knowledge concentrate unevenly in space. And where knowledge is becoming increasingly important to gain a competitive advantage, complexity and tacit knowledge become ever more "sticky". Further research of Balland, et al. (2020) investigating the concentration of knowledge and complex activities concludes that the degree to which activities vary in complexity explains the scale at which they agglomerate. This is due to the deep division of knowledge that is required by these activities. At the same time this leads to the conclusion that regions and their innovative performance are subject to path-dependent process, shaped by the local context.

Hidalgo and Hausmann (2009) elaborate on the concept of economic complexity, by comparing capabilities to blocks that can be used to build with. The purpose of this analogy is to explain the outcomes of this build. If a region has a certain number of different capabilities or blocks, this will determine the possibilities of what can be built. According to their research, this simple comparison explains differences in wealth and production outcomes between regions and countries. Within economic geography, the concept of economic complexity is interchangeably linked with the principle of relatedness. The latter can be described as the function of the probability a region has to enter an economic activity depending on the number of related activities in that region. Where two activities are related when they require similar capabilities. This principle allows for the understanding of regional paths leading to diversification. A major finding through this principle of relatedness is that learning appears to pay off when mastered and that regions that have knowledge-intensive economies have higher growth potential (Hidalgo et al., 2018).

Combining the principle of relatedness and economic complexity provides the notion of related variety and allows for the prediction of diversification patterns within regions (Boschma & Frenken, 2018). In practice, this has led to the development of the smart specialization strategy of the European Union, where research and development funds are allocated strategically to regions according to their related variety (Boschma, 2015). The relevance of these concepts combined with smart specialization strategies has been further substantiated by Balland et al. (2019), acknowledging the risks and rewards of this approach. On one side, they prove the benefits of focusing on technological complexity. But on the other side, they do state the need

to consider other dimensions than only the technological one, which is generally quantified by patent or trademark applications in a region.

Although being only one of the numerous theories that seek to explain the diversification paths of regions, the smart specialization approach builds on a substantiative basis of academic literature. Acknowledging the prior limitation of its technological focus, this dimension does allow for the creation of a so-called product- or knowledge-space, which makes use of social network analysis to create a network of relatedness between products, knowledge, or technologies. This approach seeks to explain patterns of specialization and locates regions or countries either on the periphery or center of a network, which conditions the probability of their success when attempting to diversify in a related or unrelated activity (Hidalgo et al., 2007). This proves that regional technological and industrial path dependence is proven to exist and is quantifiable through the local capabilities of the region.

To assess a region's level of innovativeness through its technological relatedness and knowledge complexity, patent data is commonly used. The advantage of patent data is the fact that it provides a historical repository of generalized technological classes whilst indicating the data and geographical location of the application (Ejermo, 2009). However, an increasing set of academics criticizes the use of patent data as it lacks the ability to fully include knowledge-intensive business services (Gotsch & Hipp, 2012), as well as the overall service sector and SME activity (Mendonca et al., 2004). This means that the use of patents is more suited for in-depth analysis of a region's innovation system and its regional diversification patterns, but that trademark data allows for a broader analysis of a region's innovative performance.

EU policy has for a long time exclusively focussed on the importance of reaching R&D expenditure goals, set at 3% of the national GDP. However, RIS literature is gaining importance within the academic and policymaking communities as it seeks to explain the clustering of innovative activities through the relationships between organizations that foster innovation. It builds on the localized capabilities of a region to explain the regional advantages that allow for the production and transmission of tacit knowledge. By doing so it combines the concept of path dependence and the importance of local capabilities for regional innovative capacity (Boschma & Frenken, 2018). Research examining the functioning of RIS finds that the main determinants of RIS consist of regional innovation initiatives, knowledge-intensive business services, and value chain information sources (Lau & Lo, 2015). Other researchers rather differentiate two dimensions, firstly the knowledge base and secondly the organizational/institutional context. The knowledge base consists mainly of academic knowledge and its application to economic activity resulting in comparative advantage. Whereas the organizational/institutional context consists of the mix of firms and organizations in a region and the local innovation culture, which is characterized by the clustering of different institutions contributing to knowledge generation. Examples of these institutions are universities, technology transfer agencies, and vocational education and training (VET) organizations (Asheim et al., 2011).

The general aim of RIS literature focuses on the creation of regional comparative advantage. Linking the concepts of regional comparative advantage and the specialization opportunities offered through the concept of related diversification, Hoen and Oosterhaven (2006) state that "a regional or national specialization in the production of certain goods […] will inevitably lead to export specialization". Combining this with the concept of technological complexity and research on high-tech exports indicating its importance within the RIS (Braja & Gemzik-Salwach, 2020), allows to conclude that exports in medium-high- and high-tech manufacturing

are an important indicator of a region's innovative capacity. However, it does not yet give any insight into the institutional/organizational context of a region.

This context, together with the innovation culture is characterized by the mix of types of organizations in a region. A crucial part of this mix, getting increasing attention from EU policymakers is SMEs. Being subject to very different dynamics than bigger firms and multinational enterprises, SMEs provide important insights into the presence and strength of regional networks (Tödtling & Kaufmann, 2001). At the same time, it is notable that SME activity almost exclusively builds on knowledge and networks that are present within the region it operates (Huggins & Johnston, 2009). This means that if SMEs in a region engage in innovative activities, this innovative activity is rooted in this region and thus attributable to the local capabilities present in that region. Because of this SMEs can be found to be representative of the regional innovation culture and overall institutional and organizational context within the region. This is underlined by Hervás-Oliver et al. (2021) who state that: "Collaboration and networking, both at the firm and institutional level, are fundamental for the generation and diffusion of knowledge […] in SMEs."
Summarizing this literature on regional innovation and RIS, it is notable that a few different relevant characteristics of innovation are to be distinguished, namely:

- Innovative output, in the form of intellectual property rights that provide an overview of the absolute innovative activity in a region; and medium-high- and high-tech exports that provide insights into the competitive advantage and knowledge complexity of a region.
- The organizational and institutional context contributes to innovation in a region, shaping the local knowledge networks and allowing for the creation and exchange of tacit knowledge. A good representation of this context is the presence of innovative SMEs.

Regional labour markets and unemployment

Labour markets are the meeting point between labour demand and labour offer. They are a critical indicator of a region's economic situation and crucial for economic growth. One of the key elements of a labour market is unemployment. Unemployment is a crucial determinant of local wages, whilst together forming the two building blocks of a labour market. At the same time, the relevance of regional unemployment is proven as it is an indicator of regional absorptive capacity regarding growth. In fact, academic research on labour markets finds that within the EU, "regional unemployment is always related to demand or output aggregates" (Nickell, 1998 in Herwart & Niebuhr, 2011). This quote and the according research are built upon Okun's law. A pioneer in the analysis of unemployment, its effects, and its drivers, Okun (1962) has found that there is a cyclical relation between economic growth and unemployment. In fact, recession and expansion periods fundamentally shape the evolution of unemployment. Revisitations of Okun's law are numerous and all confirm the persistence of this cyclical relation. However, only a few take into account innovation as one of the drivers of economic growth.

Zagler (2003), focuses his revisitation of this theory on economic growth being connected to a resource constraint and the decision to willingly invest in innovation. Whilst doing so he finds national economic output and unemployment to be correlated under the condition that this output is integrated into an innovation-based endogenous economic growth model. This proves that there is an initial relationship between innovation and unemployment development.

Cappelli et al. (2021) have found that technological and human capital were positively correlated with unemployment resistance during the 2008 economic crisis in the EU, on a regional level. This study builds upon evolutionary economic processes shaping technological resistance. However, it focuses solely on a period of recession. This prohibits the researchers from fundamentally relating technological and human capital with unemployment evolution. An important conclusion they were able to make nonetheless, is that this relation was less effective when it came to the resistance of unemployment for women. These findings have been substantiated by research from Nagvi et al. (2020) who find that innovation in complex activities such as renewable energy is positively related to a decrease in unemployment in the long run. Combining Okun's law, the evolutionary economic narrative of Capelli et al, (2021), the highlighted relation between unemployment and economic growth of Nickell (1998), and the literature on innovation and regional innovation systems allows to state that regional innovation has a negative effect on the evolution of regional unemployment.

It must be noted, however, that academics have failed to find a consensus on the relationship between innovation and unemployment. In fact, a second strain of literature focussing on this relation, finds innovation, technological development, and processes such as digitization and automation to increase unemployment (Yildrim et al., 2022). This is attributable to substitution on the labour market, job displacement, and job transformation. Academics, and policymakers, find this to be one of the most difficult challenges of modern times. Pyka (2017) argues that dedicated innovation systems focussing on innovation in emerging sectors should be a focal point to mitigate job losses in the wake of a lock-in of sectors dependent on fossil fuels. His research finds robotics and AI to replace jobs that need to be made up for by new employment in these emerging sectors. However, as has been reviewed within innovation literature, the probability of a region diversifying successfully in an emerging sector is dependent on its current set of local capabilities.

As the performance of regional innovation systems is likely to result in lower unemployment, a threefold of hypotheses can be formulated, the first two with regards to innovative output and the third regarding the organizational context:

Hypothesis 1: *Regional innovative systems have a negative effect on unemployment and its evolution in a period of expansion.*

> ***Hypothesis 1a:*** *Exports in medium and high-tech manufacturing have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 1b:*** *Intellectual property rights such as Trademark applications have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 1c:*** *The presence of innovative SMEs in a region has a negative effect on unemployment and its evolution in a period of expansion.*

At the same time, whether it concerns low- or high-qualified individuals, there will be a need to re- and up-skill to adjust to new positions on the labour market. However, low-skilled individuals participate less in training and have less task flexibility. (Sanders & de Grip, 2004), and individuals with low educational qualification have the lowest intention to participate in training or learning activities (Kyndt et al., 2011). Simultaneously Balsmeier & Woerter (2019) find that innovation reduces employment for low-qualified individuals and increases employment for high-qualified individuals on a regional level.

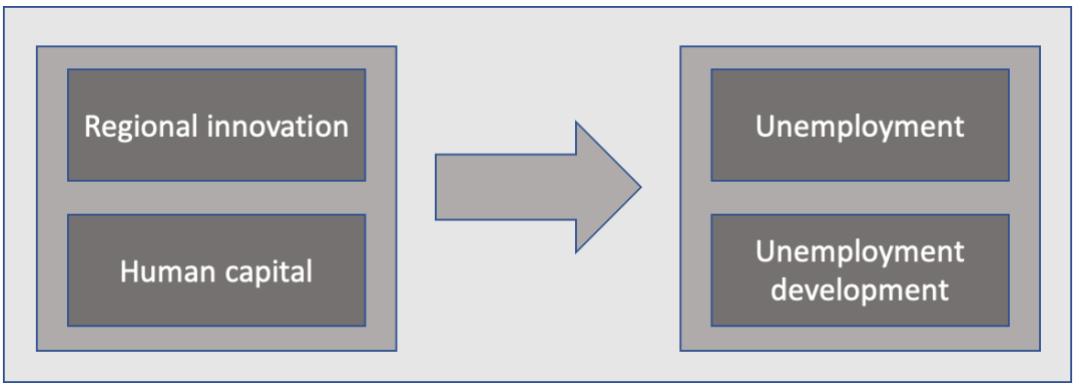
This proves the importance to include human capital in the analysis. The rationale of this is that to optimize the advantages of innovation within regional labour markets, human capital is crucial regarding absorptive capacity and the implementation of innovative activities. As innovation and human capital affect unemployment and its evolution within regions, it is important to note that the processes that shape these independent variables are thus also affecting labour markets. In fact, as innovation concentrates in space and does so increasingly (Balland et al., 2020), path-dependent processes shape the structural changes on labour markets and thus do so increasingly as could be argued. Tessarin et al. (2022) find indeed that the concept of related diversity applies to occupational structures of regions. Meaning that a region is more likely to diversify into a new occupation when its local labour market is home to related occupations. However, it is important to note that there are different impacts of innovation on the structural change within labour markets, as product innovations tend to increase the number of high-skilled jobs in a region, and process innovations tend to decrease the number of low-skilled jobs in a region, whilst simultaneously services appear to have the most important effect on labour market polarization through the (Cirillo, 2018).

As regions with high education attainment levels and occupational structures holding more complex occupations are more likely to have lower unemployment rates in the wake of innovation. This argument leads to the formulation of the following two hypotheses on the relationship between human capital and unemployment:

Hypothesis 2: *Regional human capital has a negative effect on unemployment and its evolution in a period of expansion.*

> ***Hypothesis 2a:*** *Regional educational attainment levels have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 2b:*** *Regional shares of employment in technology and knowledge-intensive sectors have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 2c:*** *Regional percentages of the population aged 15-24 not in education, employment, or training have a positive effect on unemployment and its evolution in a period of expansion.*

Figure 1 Conceptual model



Methodology

Unit of analysis

The research area that has been chosen for this study is the European Union. Some countries of the European Economic Area (EEA) have also been added. Not all countries of the research area have been added due to the availability of data. The countries that have been included are the following: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Germany, Greece, Spain, Finland, France, Hungary, Ireland, Italy, Lithuania, Luxemburg, Latvia, Malta, the Netherlands, Poland, Portugal, Russia, Sweden, Slovenia, Slovakia, and the United Kingdom. Although the United Kingdom is formally no longer included in the European Union, it was a member during the research period.

The territorial aggregation used to perform this research on a regional scale is the 2nd level of regionalization according to the Nomenclature of Territorial Units for Statistics or NUTS-2 level. This regional aggregation level has been created by the European office for statistics Eurostat and is managed under the supervision of the European Commission. The main characteristic prevalent in the creation of these regions is population size. NUTS-2 regions have a minimum of 800,000 and a maximum of 3 million people living in them. This level of aggregation has been chosen because of the degree of uniformity provided by the population size within the units of analysis and the fact that most EU regional data is issued through Eurostat.

As can be seen in Appendix 1 – *Table 1 Unit of analysis - Regions and NUTS codes*, a total of 266 regions have been used for this research. A few regions have been merged due to inconsistencies in NUTS classification between datasets. The following mergers have been made:

- The Austrian regions Niederösterreich AT12 and Wien AT13 have been merged to Merged Austrian regions* AT00.
- The Belgian regions Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest BE10, Prov. Vlaams-Brabant BE24 and Prov. Brabant wallon BE31 have been merged to Merged Belgian regions* BE00.
- The Czech regions Praha CZ01 and Stredni Cechy CZ02 have been merged to Merged Czech regions* CZ00.
- The German regions Berlin DE30 and Brandenburg DE40 have been merged to Merged German regions* DE00.
- The Hungarian regions Budapest HU11 and Pest HU12 have been merged to Budapest* (merged Hungarian region) HU10.
- The Dutch regions Flevoland NL23 and Noord-Holland NL32 have been merged to Merged Dutch regions* NL00.

Data collection and manipulation

The variables that have been used have been compiled from three different data sources. The Regional Competitiveness Index (European Commission, 2020) has been consulted as well as the X for the trademark data and the Labour Force Survey (European Commission, 2023) for the data on unemployment. All three datasets hold the same NUTS-2 classification, namely the 2016 version. However, within the RCI dataset, the authors have merged some of the regions into larger metropolitan areas as this would otherwise conflict with some other indicators used in their analysis. These mergers have been applied to the complete dataset for the consistency of the data.

The data of the merged regions has been weighed according to the population of the constituent regions: The following equations have been applied to merge the data. where β corresponds to the account of the region's weight and γ is the resulting data frame of the merged region and variable ι in year α:

$$\beta_{\chi} = \ population\ of\ region\ \chi\ in\ year\ \alpha \ / \ total\ population\ of\ constituent\ regions\ in\ year\ \alpha$$

$$\gamma_{\alpha} = \ \iota\beta_{\chi 1} + \ \iota\beta_{\chi 2} + \cdots + \ \iota\beta_{\chi i}$$

Operationalization of concepts

The concepts indicated in *Figure 1 Conceptual model* will be operationalized as can be seen in *table 2 Operationalization of concepts*:

Table 2 Operationalization of concepts

Dependent variable	Unemployment	I Total unemployment rate 2018 II Difference between male and female unemployment 2018 III Difference between high and low education unemployment 2018
Dependent variable	Unemployment evolution	IV Total unemployment evolution 2015-2019 V Male unemployment evolution 2015-2019 VI Female unemployment evolution 2015-2019 VII Total low education unemployment evolution 2015 – 2019 VIII Total high education unemployment evolution 2015-2019
Dependent variable	Unemployment polarization	IX Difference between male and female unemployment evolution 2015-2019 X Difference between low and high education unemployment evolution 2015-2019
Independent variable	Regional innovation	- Exports in medium-high/high tech manufacturing - Innovative SMEs - Trademark applications in 2015
Independent variable	Human capital	- Higher education attainment - Employment in technology and knowledge-intensive sectors - NEET

The full operationalization table including the variable names, the description of the variables, and information on the datasets can be found in Appendix 2 – *Table 3 Variable table.*

Data

Table 4 Frequency table shows the descriptive statistics of the variables for the dataset. These statistics will be used to compare the relative performance of the regions that will be investigated as case studies. At the same time, these statistics allow for the comparison of the relative performance of the regions that had the lowest and highest unemployment rates in

2018, as well as the most favourable and least favourable unemployment evolution between 2015 and 2019.

Table 4 Frequency table

	Unemp 2018	Unemp 2019/2015	TM applic	Share techexp	Innov, SME	Educ level	Emp in KIS	NEET
N	256	264	261	249	251	265	251	261
Missing	1	2	5	17	15	1	15	5
Mean	7.163	0.673	298.039	0.572	0.398	29.927	3.497	11.504
Median	5.3	0.612	160	0.58	0.4	29.1	3.08	10.6
Variance	32.426	0.028	194026.2	0.036	0.063	84.185	3.437	31.462
Minimum	1.5	0.31	2	0	0	11.7	0.78	3.6
Maximum	35.1	1.19	3735	0.99	2	54	10.77	33.7
Percent 25	3.4	0.534	60	0.49	0.2	22.85	2.16	7.35
50	5.3	0.681	160	0.58	0.4	29.1	3.08	10.5
75	8.45	0.8	349.5	0.68	0.6	36	4.32	14.05

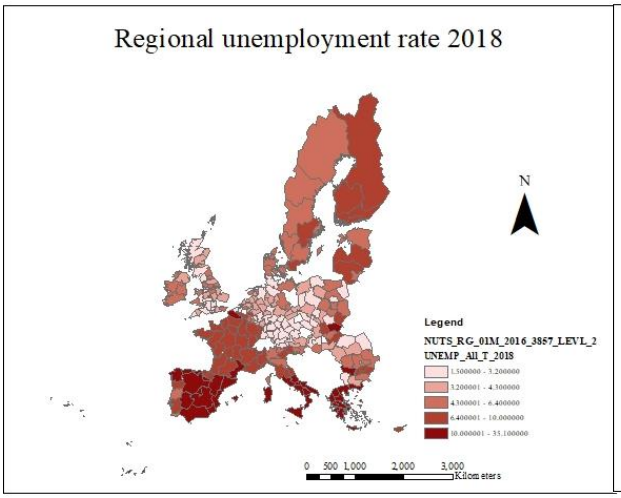
In fact, as can be seen in Appendix 3 descriptive statistics, *tables 5 to 8* show that in fact the five regions with the lowest unemployment rates in 2018 all score (far) above average for all the relevant indicators for innovation and most regions score relatively well for the human capital indicators. At the same time, the five regions with the highest unemployment rates in 2018 all scored relatively poorly regarding the innovation and human capital indicators human capital. Looking at the unemployment evolution between 2015 and 2019, the regions that have the most favourable scores, all score far above average for at least one of the innovation indicators and score average to above average for the human capital indicators. The regions that have the least favourable scores, score rather below average regarding their innovation indicators and rather low regarding their human capital indicators. This

To further investigate the spatial distribution of the indicators, maps have been drawn of unemployment rates and their evolution in the EU. Maps 1 and 2 show the distribution of unemployment in 2018 and its evolution between 2015 and 2019. At the same time, maps have been drawn of the independent variables. Map 3 shows the regional exports in medium-tech and high-tech manufacturing in 2017 and Map 4 shows the regional employment rates in technology and knowledge-intensive sectors. Maps 5-8 show the spatial distribution of the other independent variables, these maps can be found in *Appendix 4.* All data in the maps have been classified in quantiles to standardize the classification as this allows for the same number of regions in every class.

Map 1 shows that regional unemployment rates are lowest in the Central, Central-Eastern and North-Western regions of the research area. At the same time, unemployment rates are highest in the Southern and Northern regions of the research area.

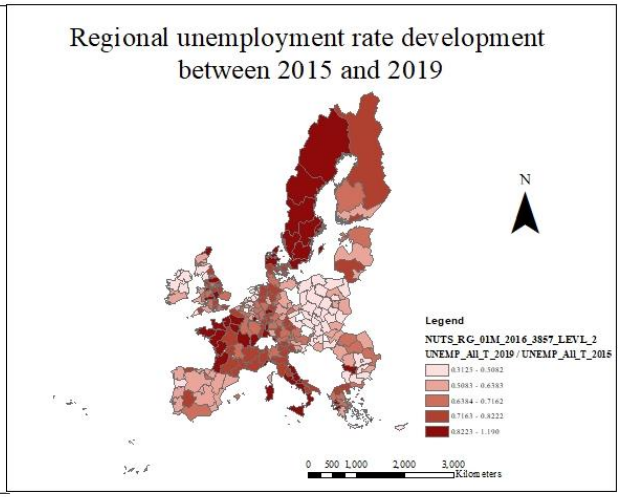
Map 2 shows the regional unemployment rate of 2019 standardized by the unemployment rate of 2015 depicting the regional unemployment rate evolution. It shows that this evolution is most favourable in the Central-Eastern and the South-Western regions and least favourable in the Northern and South-Eastern regions of the research area, together with the Western French regions.

Map 1 Regional unemployment rates in the research area in 2018



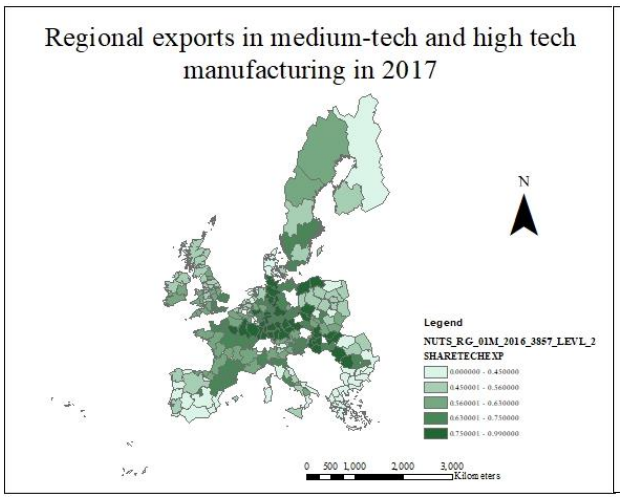
Source: European Commission, 2023

Map 2 Regional unemployment rate evolution in the research area between 2015 and 2019



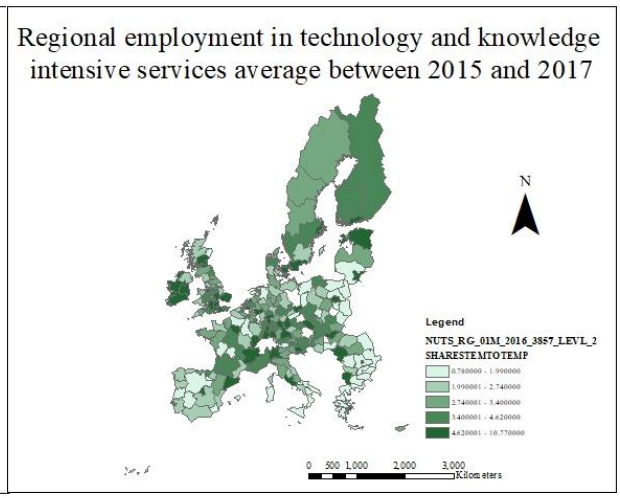
Source: European Commission, 2023

Map 3 Regional exports in medium-tech and high-tech manufacturing in the research area in 2017



Source: European Commission, 2020

Map 4 Regional employment in technology and knowledge intensive sectors in the research area, on average between 2015 and 2017



Source: European Commission, 2020

Map 3 shows the regional exports in medium-tech and high-tech manufacturing in 2017. These exports are the highest in the Central and Western regions of the research area. These exports are the lowest in the Southern, South-Eastern, and North-Eastern regions of the research area.

Map 4 shows the regional shares of employment in technology and knowledge intensive sectors on average between 2015 and 2017. Although being more fragmented than the other maps, the regions that have the highest shares of employment in technology and knowledge intensive sectors on average between 2015 and 2017 seem to concentrate in the central and Western parts of the research area. The regions with the lowest shares of employment in technology and knowledge intensive sectors on average between 2015 and 2017 are the Southern and Eastern regions of the research area.

These maps show that unemployment, its evolution, and the innovation and human capital indicators show clear spatial patterns. As the Southern and Eastern parts of the research area

present high unemployment and low exports in medium-tech and high-tech manufacturing in 2017, low presence of innovative SMEs in 2017 (*Map 5*), low employment in technology and knowledge-intensive services, and low proportions of tertiary-educated populations aged 25-64 (*Map 7*), whilst simultaneously having high percentages of NEET in their 15-24 population (*Map 8*). Trademark applications appear to be more skewed in space, although the South-Eastern part of the research area clearly has less (*Map 6*). Overall, the Northern, Western, and Central parts of the research area have lower unemployment rates and score higher for the innovation and human capital indicators, whilst scoring lower for the NEET variable.

As these maps show what appears to be the geographical co-location of lagged low unemployment rates with high innovative performance and high concentrations of human capital in the years before, one could argue that innovation and human capital negatively affect unemployment in the research area. However, the unemployment evolution, measured as the unemployment rate of 2019 standardized by the unemployment rate of 2015 does not yet show any clear relationship with the independent variables.

Methodology

To further investigate the relationship between the independent and dependent variables and to provide an answer to the hypotheses formulated in the theoretical framework (which can be found in Appendix 5) a multiple regression analysis has been performed. A multiple regression analysis is a statistical analysis technique that allows for the prediction or the identification of a relation between two or more independent variables and a dependent variable Y (Hox, 1999). The following formula is used for the analysis where μ is the dependent variable, and $X_1 + \cdots X_n$ are the *n* independent variables:

$$\mu = a + b_1X_1 + b_2X_2 + \cdots + b_nX_n$$

A total of 10 regression models have been included in this analysis. The first three models investigate the relation between the independent variables and the unemployment rate in 2018, the difference between the male and female unemployment rates in 2018 and the difference between the unemployment rates of the population that have a low and high educational attainment level in 2018.

To investigate the relationship between the independent variables and the evolution of unemployment and the evolution of unemployment polarization regression analyses with fixed effects have been performed. To do so, the unemployment rates have been transposed per aggregation. This has been done for the years 2015 to 2019. The fixed effect is included at the regional level. To include the fixed effects, dummy variables have been created per region. These variables have been included in the regression analysis but have been left out of the output of the models. The 10 models can be found integrally found in Appendix 6 – Table 9 Regression output – all models. These models include the B score, the standard error (SE), the t score, and the significance p. Whereas the regression tables in the result section include only the B score followed by the significance level of the variables.

Results

Unemployment

This chapter will discuss the results of the regression analyses. As has been elaborated on the methodology section, a total of 10 regression models seek to provide an answer to the hypotheses that can be found in Appendix 5. The first three models can be found in *Table 9* and seek to provide an answer for the first part of the hypotheses evaluating the effect of the independent variables on the region's unemployment rate in 2018.

In *Table 9*, Model (I) shows that there is a significant effect of all independent variables on the total unemployment rate of regions in 2018. Where exports in medium-high/high-tech manufacturing, innovative SMEs, and higher employment in technology and knowledge-intensive sectors have a negative effect on total unemployment and NEET has a positive effect on total unemployment. This confirms the first part of hypotheses 1a, 1c, 2b, and 2c. However, educational attainment levels and Trademark applications have a positive effect on the unemployment rate in 2018. This rejects and even contradicts hypotheses 1b and 2a significantly.

Table 9 Regresion models (I) – (III)

	Dependent variable		
	All unemployment 2018		
		Difference between	
	(I) Total	(II) Male and Female	(III) Low- and highly educated
Tech exports	-6.839***	0.376**	3.013**
Employment in KIS	-0.422*	-0.002	0.286**
Innovative SMEs	-2.723**	-0.004	-1.200
Education level	0.126***	0.005	-0.093***
NEET	0.504***	0.001	-0.123***
TM applications	0.001**	3.391E-6	-0.001**
R Square	0.555	0.082	0.320
Observations	236	229	172

* $p < 0.05$, ** $p < 0.01$, *** $p \leq 0.001$

Models (II) and (III) show the effect of the independent variables on the difference between male and female unemployment (II) and the difference between low and high-educated unemployment (III). For (II), only exports in medium-high/high-tech manufacturing have a significant relation with the difference in male and female unemployment. As the variable has a positive effect on the difference between male and female unemployment this shows that when a region has a higher share of its exports in medium-high/high-tech manufacturing it is more likely to have more unemployed males than females. However, as the model has an R Square of only 0.082, the model is not strong enough to explain the variance between the difference in male and female unemployment on a regional level in 2018.

For (III) all independent variables but innovative SMEs are significant. Exports in medium-high/high-tech manufacturing and employment in technology and knowledge-intensive services have a positive effect. This shows that regions that have higher shares of their exports in medium-high/high-tech manufacturing and of their employment in technology and knowledge-intensive services have more low educated unemployment than high educated unemployment. At the same time Education level, Trademark applications, and NEET have a negative effect. And thus, regions with higher educational attainment levels, trademark applications, and NEET have higher shares of highly educated unemployed people than low-educated unemployed.

Albeit not answering any of the hypotheses models (II) and (III) provide information on the dynamics of regional unemployment in 2018. Where innovation and human capital arguably increase inequality on local labour markets.

Unemployment evolution

In *Table 10* Models (IV), (V), (VI), (VII), and (VIII) show the effect of the independent variables on the evolution of the region's unemployment rates between 2015 and 2019. Where (IV) shows the total unemployment rate evolution, (V) the male unemployment rate evolution, (VI) the female unemployment evolution, (VII) the low-educated unemployment, and (VIII) the highly educated unemployment.

Table 10 Regression models (IV) - (VIII)

	Dependent variable				
	Unemployment evolution 2015-2019				
	All	Gender		Education level	
	(IV) Total	(V) Male	(VI) Female	(VII) Low	(VIII) High
Tech exports	-4.432***	-3.162*	-7.190***	-6.050**	-7.618***
Emp. in KIS	-1.173***	-0.870***	-1.532***	-0.901***	-0.908***
Innovative SMEs	6.085***	3.290**	9.405***	-4.979*	7.952***
Education level	0.002	-0.003	-0.053	0.168**	0.002
NEET	0.507***	0.486***	0.580***	0.667***	0.233***
TM applications	0.001***	0.001***	0.001**	0.001**	0.001***
FE Region	Yes	Yes	Yes	Yes	Yes
R Square	0.924	0.895	0.943	0.874	0.925
Observations	1140	920	935	890	895

* $p < 0.05$, ** $p < 0.01$, *** $p \leq 0.001$

Model (IV) shows that regional unemployment rates decrease between 2015 and 2019 when regions have higher shares of exports in medium-high/high-tech manufacturing and employment in technology and knowledge-intensive sectors and a higher share of NEET. This allows for the validation of the second part of hypotheses 1a, 2b, and 2c. However, the presence of innovative SMEs and higher Trademark applications significantly increase regional

unemployment rates, contradicting hypotheses 1b and 1c. Educational attainment levels are not found to be significant in the total unemployment rates of regions between 2015 and 2019.

Looking at models (V) and (VI), the independent variables hold the same significant effects as for model (IV). However, exports in medium-high/high-tech manufacturing and employment in technology and knowledge-intensive sectors have a higher negative effect on the evolution of female unemployment than on the evolution of male unemployment. At the same time, the presence of innovative SMEs and higher shares of NEET in the 15-24 population of a region have a higher positive effect on the evolution of female unemployment than on the evolution of male unemployment. This shows that the effects of the independent variables are stronger for the evolution of female unemployment than for the evolution of male unemployment, arguably increasing inequality.

For models (VII) and (VIII), exports in medium-high/high-tech manufacturing, employment in technology and knowledge-intensive sectors, NEET and Trademark applications hold the same significant effects as for model (V), although for model (VII), the presence of innovative SMEs has a negative effect and educational attainment level holds a positive significant effect on the evolution of low-educated unemployment. Where the presence of innovative SMEs keeps a positive effect on the evolution of highly educated unemployment in model (VIII). The force of the similar effects of the independent variables is also different between the two models. In fact, exports in medium-high/high-tech manufacturing and employment in technology and knowledge-intensive sectors have a higher negative effect on the evolution of highly educated unemployment than on the evolution of low-educated unemployment. Again, this leads to believe that the independent variables increase inequality on regional labour markets.

Table 11 Regression models (IX) and (X)

	Dependent variable	
	Difference in unemployment evolution 2015-2019 between	
	(IX) Low- and highly educated	(X) Male and female
Tech exports	3.269***	-0.077
Employment in KIS	0.413***	-0.032***
Innovative SMEs	-5.238***	0.294***
Education level	-0.194***	0.008***
NEET	-0.302***	0.010***
TM applications	0.000	-2.924E-5*
FE Region	Yes	Yes
R Square	0.924	0.710
Observations	885	915

* $p < 0.05$, ** $p < 0.01$, *** $p \leq 0.001$

In *Table 11*, Models (IX) and (X) show the effect of the independent variables on the difference in unemployment evolution 2015-2019 between the low- and highly educated population of a region (IX) and the male and female population of a region (X). When an independent variable in model (IX) has a negative effect, low-educated unemployment has increased regarding highly educated unemployment in a region between 2015 and 2019. If an independent variable in model (IX) has a positive effect in model (IX), highly educated unemployment has increased regarding low-educated unemployment in a region between 2015 and 2019. In model (X), when an independent variable has a negative effect, male unemployment has decreased regarding female unemployment in a region between 2015 and 2019. If an independent variable has a positive effect, male unemployment has increased regarding female unemployment in a region between 2015 and 2019.

Model (IX) shows that exports in medium-high/high-tech manufacturing and employment in technology and knowledge-intensive sectors have a significant positive effect on the difference in unemployment evolution 2015-2019 between the low- and highly educated population of a region. Meaning that higher shares of exports in medium-high/high-tech manufacturing and employment in technology and knowledge-intensive sectors arguably increase inequality within regional labour markets, substantiating this prior finding in Models (XII) and (XIII). At the same time the presence of innovative SMEs, higher educational attainment levels and higher shares of NEET have a positive effect on the difference in unemployment evolution 2015-2019 between the low- and highly educated population of a region. Arguably contributing to a decrease in inequality.

Model (X) shows that employment in technology and knowledge-intensive sectors and Trademark applications have a negative effect on the difference in unemployment evolution 2015-2019 between male and female unemployment. Meaning that male unemployment has decreased in regions holding higher shares of these independent variables. At the same time, the presence of innovative SMEs, higher educational attainment levels and higher shares of NEET have a positive effect on the difference in unemployment evolution 2015-2019 between male and female unemployment. Meaning that higher shares of innovative SMEs, higher educational attainment level and more NEET increase the male unemployment rates in a region.

Hypotheses results

Hypothesis 1: As has been formulated in the theoretic framework, regional innovation systems are shaped by innovative output and the regional organizational/institutional context. Exports in medium and high-tech manufacturing have a negative effect on regional unemployment rates in the EU in 2018, representing the innovative output of a region. The presence of innovative SMEs in a region has a negative effect on regional unemployment rates in the EU in 2018, representing the regional organizational/institutional context. The first part of hypothesis 1 can is thus accepted. As regional innovative systems have a significant negative effect on unemployment rates.

The second part of the hypothesis cannot be accepted however, as only exports in medium and high-tech manufacturing have a negative effect on the evolution of regional unemployment rates in the EU between 2015 and 2019. This means that hypothesis 1a is accepted and thus it is accepted that exports in medium and high-tech manufacturing have a negative effect on unemployment and its evolution in a period of expansion.

Hypothesis 2: Hypothesis 2b and 2c are both accepted. This means that hypothesis 2 is accepted also and thus regional human capital has a negative effect on unemployment and its evolution in a period of expansion.

Case studies

Three case studies have been realized to investigate the nature of the relationship between innovation and human capital on unemployment and its evolution within a region. The cases for the case studies have been selected based on their innovation performance group of the Regional Innovation Scoreboard and their performance on labour market indicators of the Regional Competitiveness Index, which classifies regions according to the performance of their RIS. The Regional Innovation Scoreboard distinguishes 4 innovative performance groups. Innovation leaders, strong innovators, moderate innovators, and emerging innovators (European Commission et al., 2021). The relative performance of regions has been calculated by comparing the data with an earlier version of the Regional Innovation Scoreboard issued in 2013. By doing so, innovative performance over time can be observed. Aside from the relative innovative performance, the labour market statistics of RCI have also been compiled and compared between 2013 and 2019. This allows to see whether the regions have made significant improvements on their labour market with regards to unemployment and labour productivity as this provides insight into the absorptive capacity of innovation in the labour market. 3 regions have been selected:

- Köln (DEA2) – Innovation leader. The region significantly improved its international scientific co-publications, business process innovators, TM applications, and sales of new-to-market and new-to-firm innovations between 2014 and 2021 according to the Regional Innovation Scoreboard, and its labour productivity and unemployment rate between 2013 and 2019 according to the RCI.
- Pays de la Loire (FRG0) – Moderate innovator. The region has significantly improved its number of IT specialists, product process innovators, design applications and employment in knowledge in intensive activities between 2014 and 2019 according to the Regional Innovation Scoreboard, and its unemployment rate between 2013 and 2019 according to the RCI.
- Dolnośląskie (PL51) – Emerging innovator: The region has significantly improved its population share that has completed tertiary education, digital skills, R&D expenditures in the business sector, and the number of IT specialists between 2014 according to the Regional Innovation Scoreboard.

To realize the case studies desk research and interviews have been performed. The desk research has focused on policies stimulating innovation in the region through the regional innovation system and on human capital stimulation within the region. The interviews have been conducted with local labour market and innovation experts, including policymakers, researchers and employees of semi-public organizations working in the field of incubation and acceleration of innovative start-ups. The interviews have been structured as semi-structured interviews. A total of nine interviews have been conducted in person, and two questionnaires containing the same questions as the interviews have been filled in by participants that could not liberate time. The full list of interviewees as well as the summaries of the interviews can be disclosed upon request. Three interviews have been held for the Köln region, of which one in written form. Four in-person interviews have been held for the Pays de la Loire region. And four interviews have been conducted for the Dolnośląskie region, of which one in written form. The shared structure/questionnaire of the interviews can be found in *Appendix 7*

Structure/questionnaire of the interviews. However, personalized questions were drafted according to the background of the interviewees to benefit their specific expertise.

Köln (DEA2) – Innovation Leader

The Köln (DEA2) region is highly urbanized, its capital is Cologne, Germany's 4th biggest city, with a total of 1.086 million inhabitants. The region's population is aging, although its young population is also growing due to an influx of domestic and foreign immigrants that are attracted to the region's reputable universities and dynamic business environment. The region has one of the strongest economies in the EU. It has a highly diversified economy and is very attractive to highly skilled migrants. Historically, the region has always been an important industrial and logistics hub, with the Rhine River flowing through it. The region has been a financial center since the Middle Ages and has since further diversified into insurance. Other key industries in the region are the automotive industry, media and communication, and ICT. The region has a very dynamic start-up culture, especially concerning complex industries such as fintech, digital healthcare, and cybersecurity. Other key innovative sectors of the region include Artificial Intelligence, Augmented Reality, Internet of Things, Robotics, Micro and Nano Electronics, and Big Data and data analytics (European Commission, n.d.).

The unemployment rate in 2018 in Köln is low compared to the research area's average (3.7% to 7.2%). At the same time, the region has a high percentage of its employment in knowledge and technology-intensive services, a high share of exports in medium-high/high-tech manufacturing, very high Trademark applications, and low NEET. Its innovative SMEs coordinating together, and its tertiary educational attainment level are average.

Table 12 Descriptives Köln DEA2

Unemp 2018	Unemp 2019/2015	Emp in KIS	Share tech exp	Innov. SMEs	Educ level	NEET	TM applic
3.7	0.7	4.97*	0.77*	0.4	29.7	6.4**	1227*

* Top 25%, ** bottom 25%

Key challenges on the region's labour market are skills mismatch within the region's older population, the integration of immigrants and refugees – often forced into precarious and non-standard employment – and the aging labour force and overall demographic development of the region.

Regional policymakers actively promote initiatives that align the region's business promotion strategy with EU-wide challenges as it aspires to remain an innovation leader and wants to establish close cooperation with the EC and other EU stakeholders. An example of this is the Plastics Innovation Center which is a completely interconnected research and development environment. It is funded jointly between the federal state of North-Rhine Westphalia and the European Regional Development Fund. It has been conceived to contribute to the region's research and development and to the qualification of firms and the labour force in the field of digitization in plastics (Bibow, 2020). The project has built on local capabilities and collaboration with local organizations to contribute to the local cluster of excellence within the industry. Furthermore, cooperation with local universities ensures that development of learning and teaching concepts ensure the transfer of research results into university teaching and industrial practice and enabling future skilled workers to become qualified in the field of Plastics Industry 4.0 (Mason, 2020).

However, considering the innovative nature of the region, the vulnerable groups on the labour market are facing increasing difficulties keeping up. Especially as these vulnerable groups are fundamentally less inclined to be engaged in training aimed at up- and re-skilling which would eventually contribute to their position on the labour market. Because of this, the region aims to guide unemployed people as much as possible in the process of up and re-skilling. This is done through to career-guidance and financial incentives, funding training and education (OECD, n.d.). Nevertheless, local experts that have been interviewed are pessimistic about these initiatives as the pace at which innovation increases the gap between high and low-skilled individuals in the region is not matched by public policy. In parts this is due to capacity but for another part this is attributable to the willingness of individuals to participate in lifelong learning programs.

The general labour policies of the region that focus on the relation between innovation and the labour market have a rather proactive nature. This is necessary to reach the region's goals in the wake of the dual green and digital transition. Within these transitions, the region has aligned its policies and overall strategies with its smart specialization strategy. This assures sustainable growth and inclusive job creation according to interviewees. Intensive collaboration between thematic areas focusing on its smart specialization strategy is necessary for this and success requires not only the collaboration between policymakers, experts from industry and politics and associations within and outside the region but will also include citizen participation (European Union, 2020).

The most important findings of the Köln region case study are the following:

- The industrial history of the region has vast implications for the restructuring of its labour force – challenges go hand in hand with the green transition.
- The region has a particular focus on the re- and up-skilling of its labour force and aims to include every working able individual on its labour market to leverage the region's automation and digitization opportunities.
- Low-qualified unemployed people remain one of the region's biggest challenges on the labour market – aligning training and education policies with policies aiming at structural change is a crucial narrative for the region. Increasing job quality for vulnerable groups will be one of its priorities to reach full employment.
- Vocational education and training programs in particular target vulnerable groups on the labour market. Counselors and local education providers are key actors in the integration of these groups into the labour market.
- Re-skilling people that are currently employed in SMEs is one of the biggest challenges in the region. Especially as a lack of participation in training and education programs of SME employees contributes to the widening skill gap in the region.
- The region seeks to engage increasingly in proactive labour market policies that aim to fundamentally increase the competitiveness of the region whilst closing the gap between low and high-skilled people. In this approach, the region also seeks to engage its geography, putting in place special policies for sub-regions that will be facing more challenging structural change in the coming years due to the green transition.

Overall, the lessons that can be learned from the Köln region show that although descriptive statistics show that the region is performing very well with regards to innovation, human capital and its labour market, vulnerable groups are most difficult to include in the positive relationship between innovation and unemployment. An important side note is that a large share of the region's firms have not yet digitalized or automized. According to local experts, this poses a major threat for the region's labour market when these firms will face the necessity to

innovative, as this will require extensive up- and re-skilling in the region's population that is least inclined to engage in the activities needed to do so. Proving the duality in the relation between innovation, human capital, and unemployment and its evolution.

Pays de la Loire (FRG0) – Moderate innovator

The Pays de la Loire region is a medium-urbanized region in the North-East of France, It is home to the country's sixth most populous city, Nantes. The region has a relatively young population compared to the rest of the EU (median age is 42.1 compared to 44.1). The region has a high young age dependency ratio (29.3% compared to 23.3% being the EU average). Furthermore, the region's population growth is attributable to immigration, as the region sees its migrant population growing by around 5% every year resulting in immigrants accounting for 0.6% of the region's population growth of the last decade (Chesnel & Féfeu, 2022). This influx of migrants can be explained by the region's attractive labour market which counts a lot of young people and a high degree of female labour. The unemployment rate of the region is historically low and amongst the lowest of the country. At the same time, the number of employees in the region has increased by 12.7% over the past decade (European Commission, n.d.a).

Compared to the EU, the unemployment rate in the region was above average in 2018. Namely 7.8% compared to the mean of 7.16%. Simultaneously, the region is performing rather average with regards to the regional innovation system variables, except for its Trademark applications. Its educational attainment level is above average, and its NEET is under average, proving that its human capital is relatively high.

Table 13 Descriptives Pays de la Loire FRG0

Unemp 2018	Unemp 2019/2015	Emp in KIS	Share tech exp	Innov. SMEs	Educ level	NEET	TM applic
7.8	0.83*	3.16	0.58	0.4	32.6	9.8	229

* Top 25%, ** bottom 25%

The biggest sectors of the region are agriculture, industry in which agri-food is most notable, manufacturing, and ICT. The latter of which is growing at an increasing rate. This growth is dealing with a lack of jobseekers, however. This is one of the main challenges on the region's labour market. In fact, all sectors are dealing with persistent and increasing recruitment difficulties. As the local labour office (Pôle Emploi) finds that 65% of all vacancies that are currently offered are difficult to fill. The highest demand on the labour market is situated on both ends of the qualification scale, as low and high-skilled individuals are sought-after, whilst middle-skilled people are less in demand (European Commission, n.d.a).

Although performing rather average with regards to innovation, the region has been considerably increasing its public and private R&D expenditure (28.1% increase between 2016 and 2019). Further public policy has been focusing on innovation to alleviate challenges of the labour market – through automation in the agricultural and agri-food sectors amongst others (Pays de la Loire, 2022). One of the focal points of the region has been the establishment of 6 specialized "Technocampuses" which form clusters of excellence in strategic sectors, aligned with the region's smart specialization strategy. These Technocampuses are a set of mutualized technological research platforms dedicated to advanced manufacturing. They collocate high-performance materials and industrial & academic players in their respective sectors. The goal of these campuses is to provide the ideal environment for the further development of industries

that build on the regional strengths and capabilities that are in line with smart specialization. By doing so, they enable the creation of inclusive employment in high and low-skilled occupations (Fournier, 2023). Simultaneously, local experts find that the growth of key sectors that have historically been present in the region and are thus engrained in the region's cultural heritage, contributes to the durability of employment. In fact, they experience that vulnerable groups are (re-)integrated in the labour market more easily when they experience a sense of cultural belonging through their employment.

Local experts are generally positive regarding the potential job displacement in light of technological transformation in the region. There are expectations that employment will, in fact, increase, particularly in low-skilled occupations. Labour demand in occupations such as farmers, breeders, foresters, and lumberjacks, is expected to rise 17% by 2030 (Jolly. 2023). Therefore, the key concern is not job displacement, but the lack of labour force. Some experts suggest that only by increasing the number of migrants, boosting labour productivity through training, extending working hours, or introducing a pension reform the region will achieve its potential. As these labour shortages coexist with a 7.8%-unemployment rate, one may assume that there is a potential mismatch between the stock of skills owned by job seekers and the skills that businesses are demanding. Moreover, people in vulnerable groups encounter obstacles in (re-)entering the labour market. This shows the necessity of active labour market policies in the region.

The region's labour market policies focus on the accessibility of education and training, removing barriers for people with disabilities, increasing mobility in the region, and providing financial assistance to individuals to facilitate their re-entry on the labour market. The Pays the Loire's authorities are considered highly responsive to exogenous shocks affecting the regional economy to prevent mass job displacements. The region has provided financial support to companies in need to strengthen the local business environment, avoid closures, and keep high levels of employment. An example of this can be found in the "PDL Redéploiement" program, which provides non-taxable loans without interest to companies in need (Pays de la Loire, n.d.).

The most important findings of the Pays de la Loire region case study are the following:

- The pace of innovation in the region is increasing. This is the result of both private and public investments and programs.
- The biggest challenge on the region's labour market is labour shortage and a mismatch in skills needed and offered. Reaching full employment is the main priority in the region.
- Industrial capabilities of the region are leveraged to promote both innovation and employment.
- Public funding supports SMEs and overall entrepreneurial activity by providing funds aimed at the digitization and automation of these companies. Re- and up-skilling schemes are also funded for SMEs in particular.
- Local experts believe that current evolutions on the labour market and within key industries in the region will reduce geographic inequalities on the region's territory. The main reason as to why this is believed is the increasing skill level of the lower-income population and the simultaneous growth and increase in innovativeness of industries located in more peripheral areas of the region.
- Investments in the education sector and professional development to support labour mobility are essential to address technological-driven labour market challenges. In view of limited public resources, Pays de la Loire has only subsidised training on key regional industries.

- The regional approach to support employers and employees during job transformation, based on individual career guidance, counselling and tailormade training, has been a case of success. Steering away as much as possible of a "one size fits all" policy, the region tries to optimize every individual's participation on the labour market, aiming to reach full employment and employer-employee matches.

Overall, the lessons that can be learned from the Pays de la Loire region show that unemployment and its measurement does not always reflect the situation on a labour market. As the region has an average unemployment rate, labour shortages would not be evident. However, the region is currently facing a skills mismatch and a lack of jobseekers. Attracting highly skilled migrants is one of the challenges faced by the region's policy makers. To deal with its labour market challenges and to increase its competitivity, the region makes use of investments in innovation, targeting key industries that have been historically engrained in the region. The different approaches of the region aim to systematically reduce vulnerability and increase the region's resilience to external shocks. One of the key takeaways of this case study is that innovation, through smart specialization, fundamentally contributes to resolving labour market challenges such as unemployment.

Dolnośląskie (PL51) – Emerging innovator

The Dolnośląskie is a medium-urbanized region in the South-West of Poland. It is home to the country's fourth most populous city, Wroclaw. The region has a relatively young population compared to the rest of Poland and the EU (the median age in the region is 42.4, whereas it is 44.1 in the EU). The region's population growth stems from migrants, especially young and middle-aged migrants. The region's crude migration rate is six times higher than the national average (9.1% to 1.5). These migrants are attracted by the region's well-developed and dynamic economy, its strong industrial activity, the presence of large corporations, natural resources (copper, brown coal, and rock material being the most prominent), its burgeoning entrepreneurial ecosystem, and good universities. Simultaneously, the combination of the region's diverse and dynamic business eco-system makes the region attractive for investors and foreign entrepreneurs. As a result, the region has become a leading manufacturer, logistics hub and innovation center in Poland.

Dolnośląskie has a low unemployment rate compared to the EU average. 3.3% as to 7.16% for the EU, placing the region in the lowest 25% of the EU. At the same time, the region scores quite well with regards to innovation. Its employment in knowledge-intensive services is in the top 25% of the research area, as well as its share of exports in medium-high- and high-tech manufacturing. Its innovative SMEs coordinating together are low and Trademark applications are average. Furthermore, its educational attainment level is average, and its NEET is slightly below average.

Table 14 Descriptives Dolnośląskie PL51

Unemp 2018	Unemp 2019/2015	Emp in KIS	Share tech exp	Innov. SMEs	Educ level	NEET	TM applic
3.3*	0.47	4.36*	0.84*	0.1	28.6	10	185

* Top 25%, ** bottom 25%

The region's biggest sectors are the automotive industry, electronics, chemical, food processing, furniture, and textile. However, in the last decade, sectors such as logistics, tourism and hospitality, financial services, construction, and real estate have been rapidly developing.

The bustling economic growth in the region is creating job opportunities across all skill levels. However, there are also some challenges on the regional labour market. In fact, the region has long been highly reliant on the exploitation of its natural resources. Its coal industry has formed the backbone of the region's economic growth during the second half of the 20th century. Currently transitioning away from the exploitation of fossil fuels, different areas in Dolnośląskie are facing various labour market challenges. Some of these include the need to up- and re-skill the working-age population. More systematic challenges consist of growth in other (new) sectors to accommodate the transition.

One of the strategies of the region to deal with its challenges in light of the coal transition has been to create specialized industrial zones. These industrial zones are located in less developed areas of the region and have reduced inequalities between the transition zones and the metropolitan area of Wroclaw. Having highly attractive financial climates that attract investors, these zones have stimulated the region's innovative capacity and resulted in economic development overall. To do so, they have built on key competencies that were already present in the region, such as simulation technologies, software as a service, internet of things, AI, Augmented and Virtual Reality, Big Data and data analytics, additive manufacturing, and laser-based manufacturing (Lasak & Frycz, n.d.).

Other factors that have contributed to inclusive job creation in the region, have been the stimulation of innovative SMEs through financial incentives and the support of the region's dynamic start-up eco-system. The strength of the SME and start-up eco-system lies in the cooperation between R&D centres and universities which is coordinated by regional policymakers in line with the region's smart specialization strategies (Zemska Et al., 2019).

One of the focal points of regional policymakers has been to attract foreign (human and financial) capital to the region. The goal of which has been to access technological development and disruptive innovation through global knowledge pipelines. However, accessing these disruptive technologies has also led to structural changes in the labour market together with the overall development of the services sector in the region (Mrozińska, 2017). This translates to new challenges for the region's labour market, mainly focused on job displacement and job transformation.

There are two main categories of policies focusing on the mitigation of job displacement in light of the dual transition the region is currently experiencing. Firstly, policies related to job losses and other consequences of mine closures in the region. These are focused on financial compensation and job replacement in other parts of the sector. Secondly, Policies on economic stimulation that result in the creation of new (alternative) jobs. These are focused on upskilling/reskilling. With the transition being more prevalent than ever at the moment, the region is currently actively cooperating with the EU to invest public funds in the re- and up-skilling of its labour market, whilst continuing to broaden the scope of opportunities for SMEs and overall entrepreneurial activity (European Commission, 2022).

Looking at job transformation in the region, policies seek to alleviate stress on the labour force through training and education programs. Employers and employees are financially assisted in the process of learning new skills and upgrading existing ones. However, people with lower educational attainment levels have more difficulties engaging in these activities (OECD, 2019). Inevitably posing a challenge for regional policymakers. To overcome this challenge and others challenges in light of job transformation, the region has aligned its education and training objectives with its smart specialization strategy. By doing so, it focuses on key strategic areas

that assure sustainable job transformation (Zemska Et al., 2019). At the same time increasing engagement of universities and other educational institutes focuses on lifelong learning.

The most important findings of the Dolnośląskie region case study are the following:

- The region has a highly dynamic business environment that supports the creation of inclusive jobs. The collaboration between R&D centers, universities, and firms leads to increasing innovativeness of the region, driving economic growth.
- The region seeks to align its business creation and support strategies with its smart specialization objectives in order to create not only inclusive but also sustainable jobs.
- The local entrepreneurial ecosystem and SME activity in the region ensure the creation of local knowledge pools. Whilst the competitiveness of the region's start-up culture is proof of the quality of the business/innovation ecosystem within the region.
- The transition the region is currently facing has historically created spatial inequalities. However, economic growth, and innovative activities, are currently enabled in areas that are less developed, leading to a closure of this gap.
- Decades of transition strategies in the region have resulted in strong local infrastructure throughout the region. This makes the region an attractive place to settle for international firms seeking to expand.
- Lifelong learning is one of the biggest challenges and simultaneously opportunities for the region, in light of innovation. Especially in light of automation and digitalization.

Overall, the lessons that can be learned from the Dolnośląskie region is that innovation creates opportunities for less developed regions, as it is an important source of economic growth. At the same time, this mechanism takes time and must be oriented on long-term benefits, as spatial inequalities may initially grow in the light of a transition that eventually benefits regional innovation. Another important lesson from the region is that creating strong international connections with other regions and firms is essential to foster innovation and job creation, this shows that innovation and labour markets may be subject to similar drivers.

Implications

One of the key findings of these case studies is that regional context shapes the effect of innovation on unemployment and overall labour market dynamics. In fact, local demographics, business environments, entrepreneurial ecosystems, and policies regarding innovation and labour markets are found to be important determinants of this relationship. It must also be noted that innovation offers opportunities and strengths for regions and their labour markets whilst simultaneously posing threats and weaknesses. A third finding of the case studies is that smart specialization appears to be an effective tool to align innovation with labour market challenges and opportunities. A fourth finding is that geography seems to matter in the relationship between innovation and labour markets. In fact, French labour market specialists noted that if it weren't for the coastal location of the region, it would not have been able to foster opportunities for its labour market through innovation. German labour market experts noted that the region's location on the Rhine River has historically provided opportunities for the region regarding its ability to reinvent itself and thus prevent a lock-in effect on its labour market. Polish experts have named the proximity to Germany and the Czech Republic as one of the most important contributors to the region's dynamic nature. A last key finding of these case studies is that policymakers need to actively include the regional innovation system and the opportunities and threats it poses when formulating labour market policies. This alleviates stress from job-displacement and job-transformation on labour markets.

Conclusion and discussion

The purpose of this research has been to examine to which extent regional innovative capacity is related to labour markets and their transformation over time and what the key determinants are that shape this regional dynamic. This research has been performed by using data of European NUTS-2 in combination with case studies in three selected NUTS-2 regions. Maps that have been drawn in the methodologic section show that innovation and unemployment are subject to similar spatial patterns in a period of expansion. The quantitative analysis performed through the regression models proves that regional innovation systems and regional human capital contribute to the reduction of regional unemployment rates. This analysis has also proved that regional innovation systems and regional human capital are correlated with decreasing inequality on local labour markets regarding unemployment. The regional case studies have proven that geography, smart specialization strategies, labour market policies and the overall regional context with its opportunities and threats regarding innovation and labour markets shape these dynamics.

In the introduction, a gap in current literature has been addressed, namely a lack of research on the relation between innovation and labour markets and their development. At the same time, it has been stated that the scientific community would benefit from the elaboration on the relationship between innovation and labour markets and their development from an evolutionary economic perspective. Not only has this relationship been proven from an evolutionary economic geographic perspective, it has also been linked with other evolutionary economic research. This research builds on the drivers of the smart specialization literature and expands the literature proving the benefits of the application of regional smart specialization strategies in the context of labour markets and their development. This broadens the scope to which smart specialization and its path-dependent dynamics can be applied.

For society, the implications of this research are first, that policymakers should align their policies seeking to foster innovation with their labour market policies. Secondly, these policies should focus on the regional context and the local capabilities present in the region. Besides reducing unemployment, innovation also reduces inequality over time. Especially when this innovation is caused by a comparative advantage through its related variety which leads to high exports in medium-tech and high-tech manufacturing for example. Thirdly, human capital is a key determinant of the relationship between innovation and unemployment and its development as it allows for the incremental application of innovation on the labour market. Proactive labour market policies should be combined with related diversification policies to allow for a region to enjoy the benefits of innovation on its labour market.

However, this research solely provides knowledge on the relationship between regional innovation and labour markets during a period of expansion. Further research should therefore aim to study this relationship for a longer period. Combining more longitudinal data on innovation with data on unemployment and its development to see how the evolution of regional innovation systems affects regional labour markets and their evolution. This would allow to fundamentally link innovation with unemployment and its evolution.

At the same time, the case studies have found that geography matters when it comes to the relationship between innovation and the evolution of unemployment. However, location and geographical properties have not been included in the analysis. Further research on this relationship should therefore include information on the typology of a region (e.g. coastal – peripheral – metropolitan, etc.).

As this research has found medium-tech and high-tech manufacturing exports and employment in technology-intensive services to negatively impact unemployment and its evolution, technological complexity, and related variety are arguably the most important factors within this relationship. Because of this further research should incorporate more elaborated data on intellectual property rights to find what sectors are the most influential in this relationship or whether this is depending on the region. The latter would substantiate the finding that local capabilities are one of the most important determinants of the relationship between innovation and unemployment and its evolution.

The introduction has stated that technological transformation and thus innovation will increasingly shape future labour markets and their occupational structure. Although this research has attempted to include educational and gender aggregations within unemployment measures, it has failed to integrate the occupational structure of labour markets. Further research should therefore seek to address the effect of innovation on the occupational structures of labour markets. This would provide policymakers with the required knowledge to effectively address labour market challenges in light of innovation and technological transformation.

Further limitations of this research include the fact this research has failed to consider the national differences between unemployment and its measurement. In fact, national context seems to play a role when looking at France which has higher unemployment rates than countries having similar economic and innovative development levels. Simultaneously, due to a lack of resources, this research has failed to include migration within the analysis, which can be expected to increasingly be interconnected with innovation and labour markets.

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Appendices

Appendix 1 – *Table 1 Unit of analysis - Regions and NUTS codes*

Table 1 Unit of analysis - Regions and NUTS codes

Region name	NUTS code
Merged Austrian regions*	AT00
Burgenland (AT)	AT11
Kärnten	AT21
Steiermark	AT22
Oberösterreich	AT31
Salzburg	AT32
Tirol	AT33
Vorarlberg	AT34
Merged Belgian regions*	BE00
Prov. Antwerpen	BE21
Prov. Limburg (BE)	BE22
Prov. Oost-Vlaanderen	BE23
Prov. West-Vlaanderen	BE25
Prov. Hainaut	BE32
Prov. Liège	BE33
Prov. Luxembourg (BE)	BE34
Prov. Namur	BE35
Severozapaden	BG31
Severen tsentralen	BG32
Severoiztochen	BG33
Yugoiztochen	BG34
Yugozapaden	BG41
Yuzhen tsentralen	BG42
Kypros	CY00
Merged Czech regions*	CZ00
Jihozápad	CZ03
Severozápad	CZ04
Severovýchod	CZ05
Jihovýchod	CZ06
Střední Morava	CZ07
Moravskoslezsko	CZ08
Merged German regions*	DE00
Corse	FRM0
Guadeloupe	FRY1
Martinique	FRY2
Guyane	FRY3
La Réunion	FRY4
Mayotte	FRY5
Budapest* (merged Hungarian region)	HU10
Közép-Dunántúl	HU21
Nyugat-Dunántúl	HU22
Dél-Dunántúl	HU23
Észak-Magyarország	HU31
Észak-Alföld	HU32
Dél-Alföld	HU33
Northern and Western	IE04
Southern	IE05
Eastern and Midland	IE06
Piemonte	ITC1
Valle d'Aosta/Vallée d'Aoste	ITC2
Liguria	ITC3
Lombardia	ITC4
Abruzzo	ITF1
Molise	ITF2
Campania	ITF3
Puglia	ITF4
Basilicata	ITF5
Calabria	ITF6
Sicilia	ITG1
Sardegna	ITG2
Provincia Autonoma di Bolzano/Bozen	ITH1
Provincia Autonoma di Trento	ITH2
Veneto	ITH3
Friuli-Venezia Giulia	ITH4
Emilia-Romagna	ITH5
Toscana	ITI1
Umbria	ITI2
Marche	ITI3
Lazio	ITI4

Stuttgart	DE11	Sostines regionas	LT01
Karlsruhe	DE12	Vidurio ir vakaru Lietuvos regionas	LT02
Freiburg	DE13	Luxembourg	LU00
Tübingen	DE14	Latvija	LV00
Oberbayern	DE21	Malta	MT00
Niederbayern	DE22	Merged Dutch regions*	NL00
Oberpfalz	DE23	Groningen	NL11
Oberfranken	DE24	Friesland (NL)	NL12
Mittelfranken	DE25	Drenthe	NL13
Unterfranken	DE26	Overijssel	NL21
Schwaben	DE27	Gelderland	NL22
Bremen	DE50	Utrecht	NL31
Hamburg	DE60	Zuid-Holland	NL33
Darmstadt	DE71	Zeeland	NL34
Gießen	DE72	Noord-Brabant	NL41
Kassel	DE73	Limburg (NL)	NL42
Mecklenburg-Vorpommern	DE80	Malopolskie	PL21
Braunschweig	DE91	Slaskie	PL22
Hannover	DE92	Wielkopolskie	PL41
Lüneburg	DE93	Zachodniopomorskie	PL42
Weser-Ems	DE94	Lubuskie	PL43
Düsseldorf	DEA1	Dolnoslaskie	PL51
Köln	DEA2	Opolskie	PL52
Münster	DEA3	Kujawsko-Pomorskie	PL61
Detmold	DEA4	Warminsko-Mazurskie	PL62
Arnsberg	DEA5	Pomorskie	PL63
Koblenz	DEB1	Lódzkie	PL71
Trier	DEB2	Swietokrzyskie	PL72
Rheinhessen-Pfalz	DEB3	Lubelskie	PL81
Saarland	DEC0	Podkarpackie	PL82
Dresden	DED2	Podlaskie	PL84
Chemnitz	DED4	Warszawski stoleczny	PL91
Leipzig	DED5	Mazowiecki regionalny	PL92
Sachsen-Anhalt	DEE0	Norte	PT11
Schleswig-Holstein	DEF0	Algarve	PT15
Thüringen	DEG0	Centro (PT)	PT16
Hovedstaden	DK01	Área Metropolitana de Lisboa	PT17
Sjælland	DK02	Alentejo	PT18
Syddanmark	DK03	Região Autónoma dos Açores (PT)	PT20
Midtjylland	DK04	Região Autónoma da Madeira (PT)	PT30
Nordjylland	DK05	Nord-Vest	RO11
Eesti	EE00	Centru	RO12
		Nord-Est	RO21

Attiki	EL30
Voreio Aigaio	EL41
Notio Aigaio	EL42
Kriti	EL43
Anatoliki Makedonia, Thraki	EL51
Kentriki Makedonia	EL52
Dytiki Makedonia	EL53
Ipeiros	EL54
Thessalia	EL61
Ionia Nisia	EL62
Dytiki Ellada	EL63
Sterea Ellada	EL64
Peloponnisos	EL65
Galicia	ES11
Principado de Asturias	ES12
Cantabria	ES13
País Vasco	ES21
Comunidad Foral de Navarra	ES22
La Rioja	ES23
Aragón	ES24
Comunidad de Madrid	ES30
Castilla y León	ES41
Castilla-la Mancha	ES42
Extremadura	ES43
Cataluña	ES51
Comunitat Valenciana	ES52
Illes Balears	ES53
Andalucía	ES61
Región de Murcia	ES62
Ciudad de Ceuta	ES63
Ciudad de Melilla	ES64
Canarias	ES70
Länsi-Suomi	FI19
Helsinki-Uusimaa	FI1B
Etelä-Suomi	FI1C
Pohjois- ja Itä-Suomi	FI1D
Åland	FI20
Île de France	FR10
Centre - Val de Loire	FRB0

Sud-Est	RO22
Sud - Muntenia	RO31
Bucuresti - Ilfov	RO32
Sud-Vest Oltenia	RO41
Vest	RO42
Stockholm	SE11
Östra Mellansverige	SE12
Småland med öarna	SE21
Sydsverige	SE22
Västsverige	SE23
Norra Mellansverige	SE31
Mellersta Norrland	SE32
Övre Norrland	SE33
Vzhodna Slovenija	SI03
Zahodna Slovenija	SI04
Bratislavský kraj	SK01
Západné Slovensko	SK02
Stredné Slovensko	SK03
Východné Slovensko	SK04
Merged United Kingdom regions*	Uk00
Tees Valley and Durham	UKC1
Northumberland and Tyne and Wear	UKC2
Cumbria	UKD1
Greater Manchester	UKD3
Lancashire	UKD4
Cheshire	UKD6
Merseyside	UKD7
East Yorkshire and Northern Lincolnshire	UKE1
North Yorkshire	UKE2
South Yorkshire	UKE3
West Yorkshire	UKE4
Derbyshire and Nottinghamshire	UKF1
Leicestershire, Rutland and Northamptonshire	UKF2
Lincolnshire	UKF3
Herefordshire, Worcestershire and Warwickshire	UKG1
Shropshire and Staffordshire	UKG2
West Midlands	UKG3
East Anglia	UKH1
Berkshire, Buckinghamshire and Oxfordshire	UKJ1
Surrey, East and West Sussex	UKJ2

Bourgogne	FRC1	Hampshire and Isle of Wight	UKJ3
Franche-Comté	FRC2	Kent	UKJ4
Basse-Normandie	FRD1	Gloucestershire, Wiltshire and Bristol/Bath area	UKK1
Haute-Normandie	FRD2	Dorset and Somerset	UKK2
Nord-Pas-de-Calais	FRE1	Cornwall and Isles of Scilly	UKK3
Picardie	FRE2	Devon	UKK4
Alsace	FRF1	West Wales and The Valleys	UKL1
Champagne-Ardenne	FRF2	East Wales	UKL2
Lorraine	FRF3	North Eastern Scotland	UKM5
Pays-de-la-Loire	FRG0	Highlands and Islands	UKM6
Bretagne	FRH0	Eastern Scotland	UKM7
Aquitaine	FRI1	West Central Scotland	UKM8
Limousin	FRI2	Southern Scotland	UKM9
Poitou-Charentes	FRI3	Northern Ireland (UK)	UKN0
Languedoc-Roussillon	FRJ1		
Midi-Pyrénées	FRJ2		
Auvergne	FRK1		
Rhône-Alpes	FRK2		
Provence-Alpes-Côte d'Azur	FRL0		

Appendix 2 – *Table 3 Variable table*

Table 3 Variable table

Variable name	Variable	Description	Dataset & source
Tech Exports	Exports in medium-high/high tech manufacturing.	Exports in medium/high technology products as a share of total product exports: measures the technological competitiveness of the EU, the ability to commercialise the results of research and development (R&D) 2017	Regional Innovation Scoreboard 2017, EC-DG GROW (European Commission, 2020)
Emp. In KIS	Employment in technology and knowledge-intensive sectors	as of % total employment average 2015-2017	Eurostat, Regional Science and Technology Statistics (European Commission, 2020)
Innov. SMEs	Innovative SMEs	SMEs with innovation co-operation activities as percentage of total number of SMEs 2017	Regional Innovation Scoreboard (European Commission, 2020)
Education lvl	Higher education attainment	Population aged 25-64 with higher educational attainment (ISCED5_6), % of total population of age group Average 2015-2017	Eurostat, LFS (European Commission, 2020)
NEET	NEET	Percentage of population aged 15-24 not in education, employment or training.= average 2015-2017	Eurostat/DG Regio – Based on the Community Innovation Survey (European Commission, 2020)
TM'applications	TM Applications 2015	Amount of Trademark applications in the year 2015	Eurostat, LFS (European Commission, 2023)
Total unemployment 2018	Total unemployment rate 2018	Total unemployment rate in the year 2018	Eurostat, LFS (European Commission, 2023)
Difference between male and female unemployment 2018	Difference between male and female unemployment rate in 2018	Male unemployment rate in the year 2018 divided by female unemployment rate in the year 2018	Eurostat, LFS (European Commission, 2023)
Difference between high and low education unemployment	Difference between high and low education unemployment rate in 2018	2018 unemployment rate of people that have completed less than primary, primary and lower-secondary education (ISCED 2011 levels 0_2) divided by the 2018 unemployment rate of people that have completed tertiary education (ISCED 2011 levels 5-8)	Eurostat, LFS (European Commission, 2023)
Total unemployment evolution	Total unemployment rate evolution	Transposed total unemployment rate of 2015 till 2019	Eurostat, LFS (European Commission, 2023)

	between 2015 and 2019		
Male unemployment evolution	Male unemployment rate evolution between 2015 and 2019	Transposed male unemployment rate of 2015 till 2019	Eurostat, LFS (European Commission, 2023)
Female unemployment evolution	Female unemployment rate evolution between 2015 and 2019	Transposed female unemployment rate of 2015 till 2019	Eurostat, LFS (European Commission, 2023)
Total low education unemployment evolution	Total low education unemployment rate evolution between 2015 and 2019	Transposed unemployment rate of people that have completed less than primary, primary, and lower-secondary education (ISCED 2011 levels 0_2) of 2015 till 2019	Eurostat, LFS (European Commission, 2023)
Total high education unemployment evolution	Total high education unemployment rate evolution between 2015 and 2019	Transposed unemployment rate of people that have completed tertiary education (ISCED 2011 levels 5-8) of 2015 till 2019	Eurostat, LFS (European Commission, 2023)
Difference between male and female unemployment evolution	Difference between male and female unemployment rate evolution between 2015 and 2019	Transposed male unemployment rate of 2015 till 2019 divided by the transposed female unemployment rate of 2015 till 2019	Eurostat, LFS (European Commission, 2023)
Difference between low and high education unemployment evolution	Difference between low and high education unemployment rate evolution between 2015 and 2019	Transposed unemployment rate of people that have completed less than primary, primary, and lower-secondary education (ISCED 2011 levels 0_2) of 2015 till 2019 divided by the transposed unemployment rate of people that have completed tertiary education (ISCED 2011 levels 5-8) of 2015 till 2019	Eurostat, LFS (European Commission, 2023)

Appendix 3 – Descriptive statistics

Table 5 Descriptives of the top 5 regions with the lowest unemployment rate in 2018

NUTS codes	Unemp 2018	Emp in KIS	Share tech exp	Innov. SMEs	Educ level	NEET	TM applic
CZ03	1.5	3.68	0.85	0.2	19.3	6	64
CZ00	1.66	6.9	0.85	0.3	32.3	4.8	237.83
DE25	1.8	5.39	0.82	0.2	29.3	5	434
DE14	1.9	5.11	0.82	0.3	30.8	4.1	507
DE23	1.9	5.22	0.77	0.2	24.7	4.7	285

*Table 6 Descriptives of the top 5 regions with the highest unemployment rate 2018**
**left out the 4 highest as they had almost no independent variable data (the highest are FRY5 Mayotte, ES63 Ciudad de Ceuta, EL53 Dytiki Mkadonia and ES64 Ciudad de Melilla)*

NUTS codes	Unemp 2018	Emp in KIS	Share tech exp	Innov. SMEs	Educ level	NEET	TM applic
EL63	24.1	0.99	0.15	0.4	23.1	17.3	15
FRY4	24	1.57	-	-	20.6	24.4	-
ES43	23	1.27	0.27	0.2	26.0	17.4	71
ES61	23	2.20	0.39	0.2	29.0	18.2	750
FRY1	22	1.66	0.15	0.4	20.6	20.5	15

Table 7 Descriptives of the top 5 regions with the most favorable unemployment evolution between 2015 and 2019

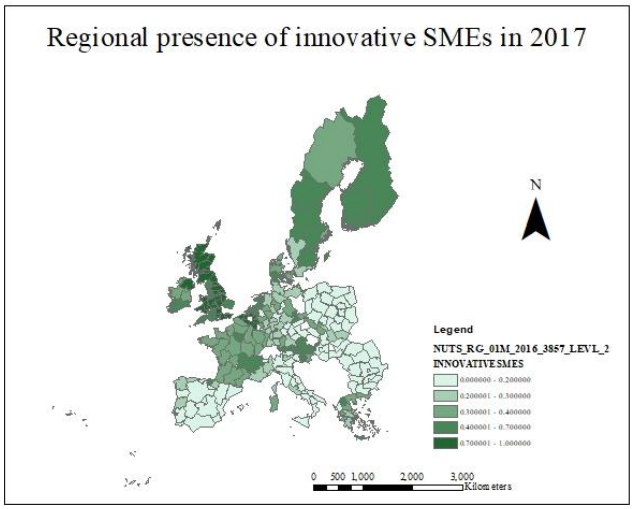
NUTS	Unemp 2019/2015	Emp in KIS	Share tech exp	Innov. SMEs	Educ level	NEET	TM applic
PL43	0.31	1.98	0.48	0.1	22.9	12.6	104
BG42	0.32	1.87	0.27	0.1	21.7	18.8	144
CZ05	0.33	4.52	0.78	0.4	19.1	6.7	84
PL22	0.33	2.34	0.68	0.1	26.9	8.8	246
BG41	0.34	7.75	0.27	0.1	39.1	9.6	305

Table 8 Descriptives of the top 5 regions with the least favorable unemployment evolution between 2015 and 2019 *left out the most unfavorable (FRY5 Mayotte) as it does not have any independent variable data*

NUTS	Unemp 2019/2015	Emp in KIS	Share tech exp	Innov. SMEs	Educ level	NEET	TM applic
SE21	1.05	2.09	0.51	0.5	33.6	5.4	170
ITC3	1.04	3.58	0.74	0.2	19.6	16.0	181
ITF3	1.01	2.09	0.55	0.1	15.2	29.3	409
UKM5	1.00	1.93	0.53	0.8	49.2	7.4	38
FRD1	1.00	2.54	0.65	0.4	25.2	10.9	69

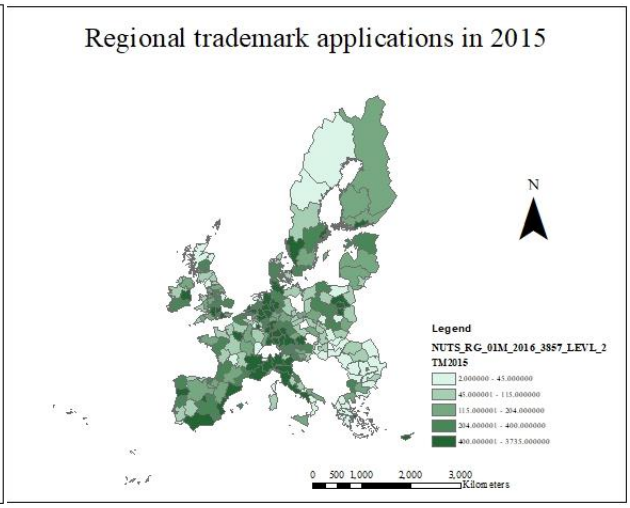
Appendix 4 – Maps

Map 5 Regional presence of innovative SMEs in the research area in 2017



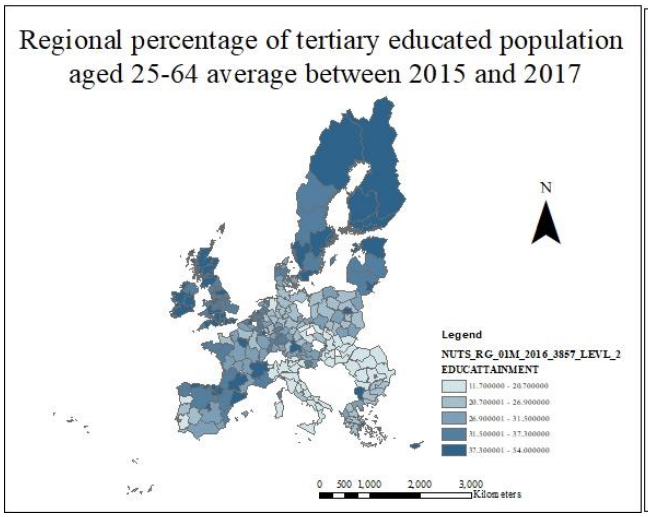
Source: European Commission, 2020

Map 6 Regional Trademark Applications in the research area in 2015



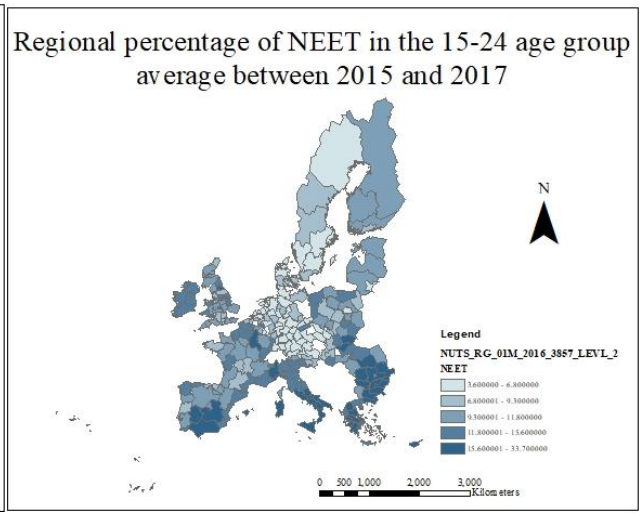
Source: European Commission, 2023

Map 7 Regional percentage of tertiary educated population aged 25-64 in the research area, on average between 2015 and 2017



Source: European Commission, 2020

Map 1 Regional percentage of NEET in the 15-24 age group in the research area, on average between 2015 and 2017



Source: European Commission, 2020

Appendix 5 – Hypotheses and sub hypotheses

Hypothesis 1: *Regional innovative systems have a negative effect on unemployment and its evolution in a period of expansion.*

> ***Hypothesis 1a:*** *Exports in medium and high-tech manufacturing have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 1b:*** *Intellectual property rights such as Trademark applications have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 1c:*** *The presence of innovative SMEs in a region has a negative effect on unemployment and its evolution in a period of expansion.*

Hypothesis 2: *Regional human capital has a negative effect on unemployment and its evolution in a period of expansion.*

> ***Hypothesis 2a:*** *Regional educational attainment levels have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 2b:*** *Regional shares of employment in technology and knowledge intensive sectors have a negative effect on unemployment and its evolution in a period of expansion.*
>
> ***Hypothesis 2c:*** *Regional percentages of population aged 15-24 not in education, employment or training have a positive effect on unemployment and its developments.*

Appendix 6 – *Table 9 Regression output – all models*

Table 9 Regression output - All models

Model	Variable	B	SE	t	P
I Total unemployment 2018	Tech exports	-6.839	1.533	-4.461	<0.001
	Emp. in KIS	-0.422	0.165	-2.556	0.011
	Innov. SMEs	-2.723	1.020	-2.669	0.008
	Education lvl	0.126	0.037	3.438	<0.001
	NEET	0.504	0.048	10.488	<0.001
	TM'applications	0.001	0.001	2.639	0.009
II Difference between male and female unemployment 2018	Tech exports	0.376	0.129	2.921	0.004
	Emp. in KIS	-0.002	0.014	-0.107	0.915
	Innov. SMEs	-0.004	0.085	-0.480	0.632
	Education lvl	0.005	0.003	1.697	0.091
	NEET	0.001	0.004	0.152	0.879
	TM'applications	3.391E-6	0.000	0.080	0.936
III Difference between high and low education unemployment 2018	Tech exports	3.013	1.011	2.979	0.003
	Emp. in KIS	0.286	0.109	2.615	0.010
	Innov. SMEs	-1.200	0.675	-1.700	0.077
	Education lvl	-0.093	0.024	-3.862	<0.001
	NEET	-0.123	0.033	-3.750	<0.001
	TM'applications	-0.001	0.000	-3.115	0.002
IV Total unemployment evolution 2015 - 2019	Tech exports	-4.432	1.324	-3.348	<0.001
	Emp. in KIS	-1.173	.118	-9.975	<0.001
	Innov. SMEs	6.085	1.114	5.462	<0.001
	Education lvl	0.002	0.046	0.045	0.964
	NEET	0.507	0.025	0.490	<0.001
	TM'applications	0.001	0.000	0.088	<0.001
V Male unemployment evolution 2015 - 2019	Tech exports	-3.162	1.1264	-2.318	0.021
	Emp. in KIS	-0.870	0.121	-7.177	<0.001
	Innov. SMEs	3.290	1.148	2.865	0.004
	Education lvl	-0.003	0.38	-0.069	0.945
	NEET	0.486	0.056	8.650	<0.001
	TM'applications	0.001	0.000	3.986	<0.001

Model	Variable	B	SE	t	P
VI Female unemployment evolution 2015 - 2019	Tech exports	-7.190	1.174	-6.124	<0.001
	Emp. in KIS	-1.532	0.126	-12.115	<0.001
	Innov. SMEs	9.405	1.172	8.027	<0.001
	Education lvl	0.053	0.046	1.147	0.252
	NEET	0.580	0.055	10.466	<0.001
	TM'applications	0.001	0.000	3.023	0.003
VII Total low education unemployment evolution 2015 - 2019	Tech exports	-6.050	2.330	-2.596	0.010
	Emp. in KIS	-0.901	0.207	-4.335	<0.001
	Innov. SMEs	-4.979	1.961	-2.538	0.011
	Education lvl	0.168	0.065	0.214	0.009
	NEET	0.667	0.096	6.947	<0.001
	TM'applications	0.001	0.001	2.598	0.010
VIII Total high education unemployment evolution 2015 - 2019	Tech exports	-7.618	1.023	-7.449	<0.001
	Emp. in KIS	-0.908	0.094	-9.614	<0.001
	Innov. SMEs	7.952	0.892	8.912	<0.001
	Education lvl	0.002	0.028	-0.085	0.933
	NEET	0.233	0.036	6.534	<0.001
	TM'applications	0.001	0.000	4.794	<0.001
IX Difference between low and high education unemployment 2015 - 2019	Tech exports	3.269	1.006	13.203	<0.001
	Emp. in KIS	0.413	0.074	5.590	<0.001
	Innov. SMEs	-5.238	0.698	-7.505	<0.001
	Education lvl	-0.194	0.022	-8.871	<0.001
	NEET	-0.302	0.028	-10.832	<0.001
	TM'applications	0.000	0.000	-1.738	0.083
X Difference between male and female unemployment evolution 2015 - 2019	Tech exports	0.094	0.106	0.893	0.372
	Emp. in KIS	-0.057	0.011	5.028	<0.001
	Innov. SMEs	-0.548	0.106	-5.192	<0.001
	Education lvl	-0.016	0.004	-3.835	<0.001
	NEET	-0.020	0.005	-4.073	<0.001
	TM'applications	5.379E-5	0.000	2.033	0.042

Appendix 7 – Structure/questionnaire of the interviews

Interview guide

At the moment, case studies are being conducted across 3 EU regions, collecting data on innovation, human capital and unemployment
We believe that XXX region can provide interesting insights to share. Because of this I would like to ask you a few questions, given your expertise in XXX area(s). Please feel free to indicate if a specific question is difficult to answer, if it falls outside your expertise. In that case, we will skip it.
Before we start an interview, I would like to inform you that we have identified you through desk study or through other interviewees.

Overview of the labour market and vulnerable groups

- Over the last 10 years, your region/country has been improving its rates of unemployment. Specifically, XXX. However, what are the **key labour market challenges** in your region/country and why do they exist? (e.g., long-term unemployment, labour productivity, youth unemployment)

- What **population groups** are more likely to be excluded from the labour market and why?

- To what extent has technological transformation in your region/country led to changes on the labour market (eg unemployment rate – labour productivity)? Why/what factors contributed to this?

Job displacement

- What **factors, policies/instruments have been affecting unemployment**, in light of technological transformation?

- **Why** have these policies/instruments been effective?

Technological transformation & inclusive and innovative job creation

- Based on the regional innovation scoreboard, your region/country is XXX type of innovator. Over the last 10 years, your region/country has been improving XXX (Regional Innovation Scoreboard indicators). In your view, what have been the key factors, policies that **stimulate/drive** technological transformation in your region/country?

- What have been the key factors, policies that **hamper/slow down** technological transformation in your region/country?

- To what extent has innovation, technological transformation in your region/country led to **higher employment levels, creation of new & innovative jobs**? Why? What factors, policies contributed to innovative job creation?

- In your region, what factors, policies/instruments have been effective in stimulating **inclusive job creation**, in light of technological transformation (meaning, they led to creation of new jobs that benefit vulnerable groups)? For example, policies/instruments related to social entrepreneurship, social innovation, self-employment/start-up support for the unemployed?

Support for employers and employees during technological transformation

- To what extent has technological transformation been **negatively affecting working and employment conditions of employees**? What are the key challenges and why they exist?

- Could you please highlight **key policies/instruments** that aim to ensure decent working and employment conditions of employees, in light of technological transformation? To what extent have these policies/instruments been effective and why?

- Does your region/country have policies/instruments that ensure decent working and employment conditions of **employees engaged in new forms of work** (e.g., platform work)? If yes, could you please discuss these policies/instruments (what support/protection they offer, how effective they are)?

- Many employers in the EU lack knowledge/skills on how to select, adopt new technologies and ensure decent working conditions of workers. Does your region/country experience the same issues and have there been attempts to address these issues? If yes, how? How effective are these efforts?

Key question whenever an interviewee starts talking about skills, education/training:
In your view, how should the education and training systems be revised to create the opportunities to acquire skills that will be demand?

Assessment of current and future impacts of technological transformation on the labour markets

- Have the policymakers in your region/country been analysing the current and future impacts of technological transformation on the labour market?

If yes, how has it been done? What participatory and evidence-based mechanisms have been used, while identifying potential or current problems on the labour market to inform the policy design?

Follow-up question:

- How has it been assessed what population groups are more likely to be excluded from the labour market in your region/country?

If no, why not?

Employment strategy/policy design

- Has your region/country designed an employment policy that accounts for vulnerable groups and impacts of technological transformation? (note: this can also be arranged at a national level)

If yes, how has your region/country determined the goals/priorities of an employment policy, given limited resources?

- How has your region/country selected or designed policy interventions to meet these goals/priorities? For example, have you conducted an evaluation of previous policy interventions, designed a policy intervention based on international best practices?

Thank you very much for your time and for answering our questions to the best of your ability. We highly appreciate it once again!