DOI: 10.24193/tras.76E.3
Published First Online: 10/27/2025

# HARNESSING GREEN JOBS AND PERSPECTIVES ON THE LABOR MARKET IN THE EU MEMBER STATES

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**Abstract**

In the context of the EU's target to reduce carbon dioxide emissions by 55 per cent by 2030, the concern for the transition to a sustainable green economy and reduced environmental impacts has become a priority for policymakers. This paper aims to explore the impact of green jobs on the unemployment rate by analyzing how environmental protection expenditure, renewable energy consumption, R&D expenditure, economic growth, foreign direct investment, and inflation rates influence labor market dynamics for 25 EU Member States over the period 1993-2022. Following the empirical analysis and the FGLS (Feasible Generalized Least Squares) statistical model, our results indicate that an increase in R&D expenditure and environmental protection expenditure is associated with a decrease in the unemployment rate.

**Keywords:** FGLS, green jobs, unemployment, labor market, EU.

## 1. Introduction

In the European Union, the expansion of green jobs strategies is expected to involve an increase in renewable energy and manufacturing-based industries, according to the report 'Skills in transition: The way to 2035' by the European Center for the Development of Vocational Training (CEDEFOP, 2023). The conservation and thrifty use of the resources that the environment provides us do not have to be characterized by sacrifices or limitations, and they are examples of good practices that show that environmental and economic development concerns can go hand in hand (Jacob, Quitzow and Bär, 2015). In this context, one of the issues that has captured the attention of researchers interested in this field is the share of green jobs, how they change the structure of the labor market, or what skills are needed to take up a green job (Jacob, Quitzow and Bär, 2015; Söderholm, 2020).

Stanef-Puică *et al.* (2022) found that most researchers approach the concept of green jobs from the definition of an international institution. One of the definitions that best captures this concept is that of the United Nations Environment Program (UNEP). UNEP defines green jobs as being the jobs in areas such as agriculture, manufacturing, research and development, administration, and services that contribute significantly to preserving or restoring environmental quality. This includes, but is not limited to, jobs that help to protect ecosystems and biodiversity, reduce energy, material, and water consumption through high efficiency tactics, decarbonize the economy, and reduce or eliminate all forms of waste and pollution (UNEP, 2008). In a report conducted by LinkedIn Economic Graph (2023) on the transition to a green economy and green jobs, i.e., the skills needed to fill these jobs, it was jobs, it was found that between 2022 and 2023, there was an increase in green skills by 12.3% and jobs requiring these skills by 22.4%. Demand for these green skills is outstripping supply, highlighting the need for investment in the workforce. The sectors at the center of attention are energy production, transport, and finance. According to the same aforementioned report, green skills are emerging in more and more occupational categories, in professions like meteorologists, marine biologists, architectural managers, construction managers, construction administrators, plumbing engineers, utilities managers, etc.

Green jobs often require specialized training, which can lead to the creation of a skills gap between traditional and green sectors, a gap that requires targeted training programs to ensure that workers can make the transition effectively (Popp *et al.*, 2022). According to the World Bank (2023), education policies can stimulate climate action by changing the behavior of individuals, empowering them to identify answers through STEM (Science, Technology, Engineering, and Math) education and research, and retraining and upskilling employees to access new opportunities. In a study by Morgenstern, Pizer and Shih (2002) on environmental spending and green jobs, they suggest a complex relationship between environmental policies and employment. While increased environmental spending generally does not have a significant impact on employment at the industry level, some sectors show small positive effects due to labor-intensive environmental activities.

O'Callaghan, Yau and Hepburn (2022) present some key issues on the economic impact of green spending, particularly in response to the crisis caused by COVID-19. According to the authors, green investments generally generate more jobs compared to non-green investments, especially in sectors such as renewable energy and energy efficiency, which have higher fiscal multipliers, meaning that every dollar spent in these areas produces more economic activity and long-term growth. In a study investigating the link between environment-related innovation and firm-level job creation, Gagliardi, Marin and Miriello (2016) used data from 4,507 Italian manufacturing firms, linked to patent registrations, for the period 2001-2008 to test whether green innovation, as measured by environment-related patents, has a positive effect on long-term employment. The results of their study confirmed that technological innovation has a significant positive impact on job creation.

The aim of this paper is to investigate how green jobs can contribute to lowering the unemployment rate in 25 EU Member States. To achieve our objective, we have chosen to perform a Feasible Generalized Least Squares (FGLS) panel analysis, using the unemployment rate as the dependent variable. The independent variables (environmental expenditures, renewable energy consumption, and research and development expenditure) are selected due to their close association with green jobs.

## 2. Literature review

The relationship between environmental spending and unemployment is often a negative one, as countries facing higher rates of unemployment tend to allocate less funds to the environmental protection side, with governments prioritizing social programs to meet economic priorities (Le Gallo and Ndiaye, 2021; Meyer, 2016). While environmental protection regulations may lead to job losses in some regulated industries, they may also create job opportunities in less regulated sectors, leading to a change in the composition of the labor force rather than a significant net effect on overall employment levels (Hafstead and Williams, 2016). In terms of environmental spending across European countries, the study by Kuralbayeva (2018) shows that over the period 2002-2010, European countries have not shown convergence in the level of public spending on environmental protection, with spending remaining largely stable, but with small variations in the growth of spending on biodiversity protection and research and development (R&D) in countries such as Malta, the Czech Republic and Slovenia.

In terms of the relationship between renewable energy consumption and the unemployment rate, studies in the literature are divided between positive effects of consumption, negative effects or the existence of a less significant relationship (Saboori *et al.*, 2022). Stavropoulos and Burger (2020) found in a meta-analysis that there is no consensus in the literature on its effects, with controversies related to the types of renewable energy, methodologies used, sample of countries, and time intervals. Saboori *et al.* (2022) studied the relationship between renewable energy consumption, non-renewable energy consumption, economic growth, and unemployment rates in 51 US states between 1977 and

2017, and their results indicate that renewable energy consumption has a positive effect on carbon emissions and other economic factors, but on unemployment it has an ambiguous effect that varies by methodology and region. The link between renewable energy consumption and unemployment has also been studied by Apergis and Salim (2015). The two authors created a mechanism indicating that an increase in investment and capacity utilization of renewable energy positively affects labor demand. If imports of fossil fuels are replaced by renewable energy, the shift from fossil fuel investment to renewable energy investment reduces investment in the former category and places it in the latter. It follows that green jobs can change the employment structure by reducing pressures on the environment. Another study exploring the relationship between renewable energy consumption and unemployment rates in 12 OECD countries finds that, in the long run, there is a significant cointegrating relationship between renewable energy consumptions and unemployment, with both positive effects in countries such as Austria, Portugal, Spain or negative effects in countries such as Australia, Chile, France, Germany or Japan (Yilanci *et al.*, 2020). However, using a general equilibrium model with three production sectors (sector R producing energy from renewable sources, sector C producing electricity from conventional sources and sector Y producing all other goods and services in the economy) to find the effect of policies supporting renewable electricity on the unemployment rate, Rivers (2013) shows that they lead to an increase in the unemployment rate. With certain exceptions, namely when the elasticity of substitution between capital and labor is low, when capital is not internationally mobile, the unemployment rate may fall.

Research and experimental development expenditures contribute to smart and sustainable growth by bringing new ideas to the market that promote job creation, higher productivity, and the most efficient use of resources (Eurostat, 2024). Su *et al.* (2021) studied the relationship between higher education R&D expenditures and environmental sustainability with a focus on CO2 emissions in thirty-one provinces in China between 2000 and 2019. The results of the study indicate that changes in these expenditures are significantly related to changes in CO2 emissions, thus promoting environmental sustainability. Based on the relationship between economic growth, health and R&D spending and unemployment, Şenol and Onaran (2022) conducted an analysis for the period 1990-2020, which revealed that R&D spending has a positive effect on economic growth. A 1.00 unit increase in R&D expenditure leads to an increase of about 2.03 units in economic growth. Regarding the relationship between economic growth and unemployment, the results of the analysis confirmed that there is a negative relationship between the two indicators. The R&D spending is therefore vital for economic growth, which in turn is vital for lower unemployment. Another study conducted for the period 2000-2020 for Turkey indicates that a 1.00 per cent increase in R&D spending leads to a 0.72 per cent decrease in the employment rate, compared to the number of patents which indicates that a 1.00 per cent increase in the total number of patents leads to a 0.04 per cent increase in employment, i.e. a 0.04 per cent decrease in unemployment (Doğaner, 2022). The influence of university R&D spending and the unemployment rate has also been studied in terms of the output

it creates, i.e., new firms. Kirchhoff *et al.* (2007) showed in their analysis that university R&D expenditure is positively related to new firm formation. New firm formation, in turn, contributes to lower unemployment. Further, the study of Bogliacino, Piva and Vivarelli (2011) shows that R&D investment has a positive effect on job creation at the EU level, particularly in the service sector and in high-quality manufacturing sectors or through product innovation, which has a much higher potential for job creation.

As for the relationship between economic growth and the unemployment rate, the link between the two has been intensively studied in the specialized literature over the years. Building on the classical economic theories that are in fact the basis for what is being developed in today's literature, J.M. Keynes argues in his book, 'The General Theory of Employment, Interest and Money', that aggregate demand, i.e. the total expenditure in the economy on goods and services, is the main determinant of the level of output and employment. Therefore, if aggregate demand is low, the economy will operate below potential, leading to unemployment (Keynes, 1936). Another important theory on the relationship between economic growth and the unemployment rate is that of Okun (1962), who states that a 1% reduction in the unemployment rate can cause a 3% reduction in the rate of output. It follows that a 1% increase in the growth rate would lead to a 0.3% decrease in the unemployment rate. Thus, to reduce the unemployment rate, the rate of economic growth must be higher than the rate of growth of potential output (Tatom, 1978). Aghion and Howitt (1994) present some important points about the relationship between economic growth and the unemployment rate, namely that economic growth has two effects on the unemployment rate: the capitalization effect, which states that as the economy grows, firms are stimulated to create more jobs, thereby reducing unemployment rates. The creative destruction effect is when new technologies that are introduced can disrupt existing jobs, which indicates that faster growth can lead to greater job fluctuation, and consequently, a higher natural rate of unemployment.

The relationship between foreign direct investment (FDI) and the unemployment rate is one that depends on the economic context and the nature of the investment received by each country. When investments are directed towards more labor-intensive sectors, they can contribute to the creation of new jobs and thus to lower unemployment. The study by Strat, Davidescu (Alexandru) and Paul (Vass) (2015) indicates that in four of the thirteen countries analyzed, namely Hungary, Malta, Bulgaria, and Estonia, a causal relationship between the two variables was found, suggesting that FDI inflows significantly influence the unemployment rate. In three other countries, Romania, the Czech Republic, and Slovakia, the authors found that unemployment influences foreign direct investment, as foreign investors tend to be attracted to countries with an available labor supply. No causal relationship between the two variables was found for the other countries included in the analysis. The study by Zdravković *et al.* (2017) for transition countries indicates that the impact of foreign direct investment on the unemployment rate is very small or non-existent in the long run. Findings from a study conducted for developing countries in the Western Balkans indicated that FDI and GDP have a significant impact on

the unemployment rate, with a direct link, but with cross-country variations depending on the economic conditions in the host country (Kukaj, Nimani and Usaj, 2022). In line with these results, Nguyen (2022) studied the relationship between GDP growth rate, FDI inflows, and unemployment between 1998 and 2017, and the results of the study indicated that GDP growth rate and unemployment have a positive relationship with FDI.

In an analysis investigating the relationship between inflation and unemployment in seven countries (Slovenia, Croatia, Bosnia and Herzegovina, Serbia, North Macedonia, Kosovo and Montenegro) Aliu, Jahja and Lubishtani (2021) identified a negative relationship between inflation and unemployment (in Slovenia, Croatia and Montenegro) and a positive relationship between inflation and unemployment for Kosovo, North Macedonia, Serbia and Bosnia. Applying the Impulse Response Function (IRF), they confirm that a positive shock in unemployment has only a short-run effect on inflation, except for North Macedonia. Using a Granger causality test to study the relationship between the inflation rate and the unemployment rate in the G6 countries for the period 2009-2017, Korkmaz and Abdullazade (2020) state that there is a one-way causality relationship, where inflation influences the unemployment rate, and the balance between inflation and unemployment is a difficult one to manage and often macroeconomic policies aimed at reducing inflation can have negative effects on employment. The relationship between inflation and unemployment studied by means of the Phillips curve for Turkey revealed that there is a long-run relationship between the two variables, as they are correlated over time and influence each other. The results of the study indicate a significant and inverse relationship between the inflation rate and unemployment, which supports the classical Phillips curve theory that a reduction in unemployment can be achieved by accepting higher inflation and vice versa.

The development of green jobs, in particular in energy and clean technologies, can stimulate growth, but often involves considerable investment and requires additional labor training. While these jobs offer long-term opportunities, the transition may cause temporary price increases due to the costs associated with implementing new green technologies (Popp *et al*., 2022).

### 3. Data and methods

We employ our empirical analysis on 25 EU Member States, excluding Malta and Cyprus, due to the lack of data for the whole period analyzed for the variable environmental protection expenditure. Thus, the countries included in our analysis are Austria, Belgium, Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. The range for the analysis is 1993-2022, and the reason for choosing this period is the lack of data for 1990-1993 and 2023 for many of the variables in the analysis. The data were collected from international databases such as The World Bank and OECD Statistics (see Table 1).

**Table 1:** List of variables

| Variable symbol | Variable type | Variable name and description | Database |
|---|---|---|---|
| UNEMP | Dependent variable | Unemployment, total (% of total labor force) (national estimate) | The World Bank: Data (2024) |
| ln (ENV EXP) | Independent variable | Environmental protection expenditure (Annual government expenditure by function (COFOG)), National currency, Current prices, millions | OECD Statistics (2024) |
| REC | Independent variable | Renewable energy consumption (% of total final energy consumption) – log transformed | The World Bank: Data (2024) |
| RD | Independent variable | Research and development expenditure (% of GDP) | The World Bank: Data (2024) |
| GDP | Control variable | GDP growth (annual %) | The World Bank: Data (2024) |
| FDI | Control variable | Foreign direct investment, net inflows (% of GDP) | The World Bank: Data (2024) |
| CPI | Control variable | Inflation, consumer prices (annual %) | The World Bank: Data (2024) |

**Source:** Author's calculations

### *3.1. Variables*

Spending on environmental protection is mainly represented by spending on pollution abatement, water and soil, as well as spending on biodiversity protection, wastewater management or spending on environmental research and development (European Environment Agency, 2023). The reason why we chose this type of expenditure as an independent variable for our analysis is that this category of expenditure also includes operating expenditure, i.e., investment, both by the private sector (corporations) and by public administrations or non-profit institutions serving households (European Environment Agency, 2023). We consider these to be a good proxy for the green job creation part.

Closely linked to spending on environmental protection is the consumption of renewable energy, which reduces pressures on the environment (Apergis and Salim, 2015) and favors the creation of green jobs, leading to a decrease in the unemployment rate. According to the report 'Renewable energy and jobs: Annual review 2023' by the International Renewable Energy Agency (IRENA) and the International Labor Organization (ILO), the renewable energy sector employed 13.7 million people in 2022 in sectors working with solar photovoltaics, bioenergy, hydropower or wind energy (IRENA and ILO, 2023). Thus, we considered it important to include renewable energy consumption in our analysis, as it could be an important predictor for how it could contribute to lowering the unemployment rate through specific employment.

The rationale for including the independent variable of R&D expenditure in the analysis was its relationship with both the unemployment rate and the creation and sustainability of green jobs, especially in the context of advancing environmental technologies and innovations. An increase in R&D spending on environmental technologies and renewable

energy incentivizes green innovation, which is essential to be able to develop new products or processes that reduce carbon emissions (Su *et al*., 2021; Lee and Min, 2015). Thus, a robust R&D spending framework can lead to economic growth by stimulating new industries and improving existing ones. Economic growth often translates into new job creation, especially in sectors that prioritize sustainability and environmental responsibility (Su *et al.*, 2021).

As the global economy moves towards sustainability, green jobs have become increasingly recognized for their potential to boost economic growth while also addressing environmental challenges. In this context, the green economy is not only about protecting the environment, but also about reconciling economic and environmental goals by creating jobs, based on environmental industries and green technologies (Jacob, Quitzow and Bär, 2015). Thus, the decision to include economic growth as a control variable in our analysis is based on the rationale that the field of clean technologies and renewable energy has the potential to generate more jobs and drive economic growth in the medium to long term.

There is, according to the literature, a relationship between foreign direct investment and the unemployment rate, which largely depends on the economic context and the nature of the investment in each country (Strat, Davidescu (Alexandru) and Paul (Vass), 2015; Nguyen, 2022; Kukaj, Nimani and Usaj, 2022), and in most cases it is positive. Foreign direct investment can help create green jobs through technological innovation and the transfer of clean technologies that reduce the carbon footprint and improve production processes (Amendolagine, Lema and Rabellotti, 2021; Chen, Guo and Huang, 2023).

The choice of inflation as a control variable in investigating the effect on unemployment and green employment rate is justified by the complex link between inflation and unemployment highlighted in various economic studies. For example, Korkmaz and Abdullazde (2020) show that inflation unidirectionally influences unemployment, suggesting that an increase in inflation may reduce employment. In the context of green jobs, which often entail high transition costs and can lead to price increases (Popp *et al.*, 2022), controlling for inflation becomes essential to assess whether this price increase may negatively influence employment in these emerging sectors. Table 2 presents descriptive statistics of the data corresponding to our variables.

**Table 2:** Summary statistics

| Variable | Observations | Mean | Std. dev. | Min | Max |
|---|---|---|---|---|---|
| UNEMP | 742 | 8.917 | 4.390 | 1.805 | 27.686 |
| ln(ENV EXP) | 698 | 7.551 | 2.141 | 2.350 | 12.950 |
| REC | 725 | 16.887 | 11.809 | 0.9 | 57.9 |
| RD | 631 | 1.513 | 0.871 | 0.351 | 3.873 |
| GDP | 750 | 2.494 | 3.787 | -16.226 | 24.475 |
| FDI | 737 | 5.111 | 20.955 | -394.471 | 234.248 |
| CPI | 750 | 9.633 | 70.176 | -4.447 | 1500 |

**Source:** Author's calculations

According to the descriptive statistics in the table above, the unemployment rate has a mean and moderate variability, with values ranging from 1.805 to 27.686. The log mean environmental expenditure has a very high variance with a large standard deviation and a maximum value much higher than the mean, with values ranging from 2.350 to 12.950, indicating a large variation between observations. In terms of renewable energy consumption (REC) they have a lower mean and standard deviation compared to environmental expenditures, with values ranging from 0.9 to 57.9. Research and development expenditures have a low mean and standard deviation, with values ranging from 0.351 to 3.873. Economic growth has both positive and negative growth rates ranging between -16.226 and 24.475. Both foreign direct investment and the inflation rate measured by the Consumer Price Index (CPI) have large variances with both positive and negative values, respectively -394.471 and 234.248 for FDI and -4.447 and 1500 for ICC.

## 4. Methodology

For investigating the influences that our variables have on the unemployment rate at the European Union level, we have carried out a series of traditional statistical tests to legitimize our estimates (see Figure 1). Thus, we run models for the overall estimator, the intergroup and fixed effects (or intragroup) estimators, the first-differences estimator, and the random effects estimator (Ulman *et al.*, 2022; Căutișanu, 2019).

The first test carried out is the pooled OLS estimator, where the cross-sectional and longitudinal panel sizes do not play a significant role in the influence of determinants on the unemployment rate. Table 3 thus summarizes the main features of the model.

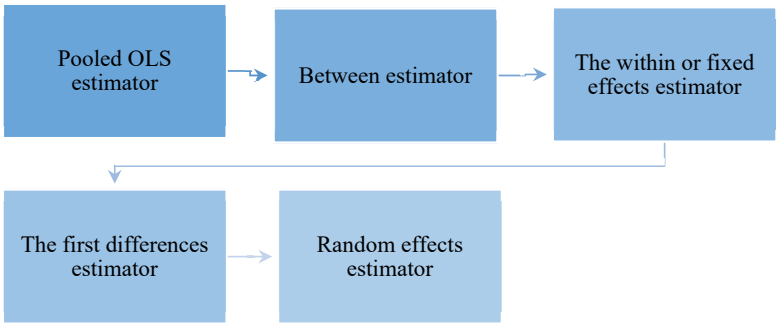


**Figure 1:** Methodological framework of panel data estimators

**Source:** Author's calculations

Given the results obtained in Table 3, following modelling with the pooled OLS estimator, assuming a risk of 10%, we have the following equation (1):

$$r\_unempl = 13.629 - 0.229 \cdot ln\ \_ENV\_EXP - 1.743 \cdot RD - 0.187 \cdot gdpgw - 0.022 \cdot FDI \quad (1)$$

The above results indicate that our model explains 16.4 per cent of the variation in the unemployment rate, with the most significant variables being environmental protection

**Table 3:** Empirical results of the pooled OLS estimator analysis

| | Coefficient | Std. err. | t | P>\| t \| |
|---|---|---|---|---|
| cons | 13.629 | 0.785 | 17.36 | 0.000 |
| ln(ENV EXP) | -0.229 | 0.089 | -2.57 | 0.011 |
| REC | 0.017 | 0.015 | 1.07 | 0.284 |
| RD | -1.743 | 0.218 | -7.98 | 0.000 |
| GDP | -0.187 | 0.043 | -4.29 | 0.000 |
| FDI | -0.022 | 0.010 | -2.19 | 0.029 |
| CPI | -0.002 | 0.003 | -0.77 | 0.442 |

**Source:** Author's calculations (Dependent variable: UNEMP)

expenditure, research and development, and economic growth, the others being statistically insignificant in our model. The negative coefficient on environmental protection expenditure tells us that an increase in environmental protection expenditure leads to a decrease in the unemployment rate, which supports our view that higher environmental policy investment and spending can lead to a decrease in the unemployment rate. The R&D expenditure also has a negative coefficient, indicating that an increase by one measure of R&D expenditure leads to a decrease by one measure of the unemployment rate. As for the results for the growth variable, it is already well known that an increase in welfare lowers the unemployment rate. The results of our analysis indicate a negative relationship between foreign direct investment and the unemployment rate, suggesting that foreign capital inflows can contribute to reducing unemployment in European Union member states. Although this coefficient is small in magnitude, it suggests that this effect is limited, depending on the economic context and the nature of investments in each country (Strat, Davidescu (Alexandru) and Paul (Vass), 2015; Nguyen, 2022; Kukaj, Nimani and Usaj, 2022).

The second estimator used in our analysis is the between estimator. In the estimation, according to Căutișanu (2019), we take into account the variations that exist from one individual to another; the results can be visualised in Table 4.

**Table 4:** Empirical results of the between estimator analysis

| | Coefficient | Std. err. | t | P>\| t \| |
|---|---|---|---|---|
| cons | 15.717 | 3.842 | 4.09 | 0.001 |
| ln(ENV EXP) | -0.184 | 0.357 | -0.52 | 0.611 |
| REC | -0.004 | 0.069 | -0.07 | 0.947 |
| RD | -2.034 | 0.881 | -2.31 | 0.033 |
| GDP | -0.293 | 0.531 | -0.55 | 0.588 |
| FDI | -0.194 | 0.107 | -1.81 | 0.087 |
| CPI | -0.051 | 0.060 | -0.85 | 0.407 |

**Source:** Author's calculations (Dependent variable: UNEMP)

According to the results obtained in Table 4, following modelling with the between estimator and assuming a 10% risk, we have the following equation (2):

$$r\_unempl = 15.717 - 2.034 \cdot RD - 0.194 \cdot FDI \quad (2)$$

The results obtained using the between estimator indicate a low ability to explain the variation in the unemployment rate across our entities. According to the F-test results, they indicate a test probability of high probability that the results are obtained randomly. Nevertheless, in contrast to the limited significance of most variables, the estimates reveal two noteworthy relationships: foreign direct investment (FDI) exhibits a statistically significant negative effect on unemployment, while research and development (R&D) expenditure also shows a significant negative association. The latter findings are particularly relevant, as they suggest that EU member states allocating more substantial resources to R&D tend to register, on average, lower levels of unemployment. This evidence supports the central hypothesis of the study, namely that innovation and sustained investment in R&D represent drivers for the creation of green jobs and for advancing the transition toward a sustainable growth model.

The next estimator, the within or fixed effects estimator, takes into account the individual effects of the panel data. The results of our modelling can be found in Table 5.

**Table 5:** Empirical results of the fixed effects estimator analysis

| | Coefficient | Std. err. | t | P>\| t \| |
|---|---|---|---|---|
| cons | 19.211 | 1.541 | 12.46 | 0.000 |
| ln(ENV EXP) | -1.184 | 0.219 | -5.39 | 0.000 |
| REC | 0.016 | 0.031 | 0.52 | 0.604 |
| RD | -0.777 | 0.512 | -1.52 | 0.130 |
| GDP | -0.155 | 0.035 | -4.41 | 0.000 |
| FDI | 0.003 | 0.008 | 0.42 | 0.675 |
| CPI | -0.002 | 0.003 | -0.76 | 0.000 |

**Source:** Author's calculations (Dependent variable: UNEMP)

Given the results obtained in Table 5, following modelling with the fixed effects estimator, assuming a risk of 10%, we have the following equation (3):

$$r\_unempl = 19.211 - 1.184 \cdot ln\ \_ENV\_EXP - 0.155 \cdot gdpgw - 0.002 \cdot CPI \quad (3)$$

As can be seen in Table 5, our model is statistically significant, confirming that at least one of the independent variables significantly influences unemployment. Thus, our fixed effects model provides us with strong empirical evidence in support of our hypothesis that environmental protection expenditure contributes significantly to lowering the unemployment rate.

The next estimator used is the first differences estimator, in which the analysis focuses on including in the statistical modelling instead of the variables Y and Xi the differences

between the values of our variables at time t and the values of the variables t-1, $\Delta Y$ and $\Delta_{X(i)}$ (Căutișanu, 2019). Table 6 summarizes the main results of the analysis.

**Table 6:** Empirical results of the first difference estimator analysis

| | Coefficient | Std. err. | t | P>\| t \| |
|---|---|---|---|---|
| cons | -0.224 | 0.068 | -3.29 | 0.001 |
| D_ln(ENV EXP) | -0.870 | 0.239 | -3.63 | 0.000 |
| D_REC | 0.204 | 0.043 | 4.67 | 0.000 |
| D_RD | 0.685 | 0.648 | 1.06 | 0.290 |
| D_GDP | -0.039 | 0.013 | -2.90 | 0.004 |
| D_FDI | 0.000 | 0.002 | 0.06 | 0.953 |
| D_CPI | 0.001 | 0.001 | 1.25 | 0.212 |

**Source:** Author's calculations (Dependent variable: UNEMP)

Given the results obtained in Table 6 from modelling with the first differences estimator, assuming a 10% risk, we have the following equation (4):

$$r\_unempl = -0.224 - 0.870 \cdot D\_ln\ \_ENV\_EXP + 0.204 \cdot D\_REC - 0.039 \cdot D\_gdpgw \quad (4)$$

According to our results, the model explains about 9 per cent of the total variation in the unemployment rate, with a Sig value, which indicates that the model is statistically significant. The results obtained with the first-differences estimator show us only two significant relationships, namely that between environmental protection expenditure and the unemployment rate, and that between economic growth and the unemployment rate; the other variables included in the analysis have a positive coefficient and therefore do not lead to a decrease in the unemployment rate.

The last estimated model is the random effects model. It includes individual errors within the idiosyncratic error (Căutișanu, 2019), and the results of the analysis are presented in Table 7.

**Table 7:** Empirical results of the random effects estimator analysis

| | Coefficient | Std. err. | z | P>\| z \| |
|---|---|---|---|---|
| cons | 17.029 | 1.33 | 12.74 | 0.000 |
| ln(ENV EXP) | -0.812 | 0.168 | -4.81 | 0.000 |
| REC | -0.006 | 0.025 | -0.24 | 0.812 |
| RD | -0.946 | 0.426 | -2.22 | 0.026 |
| GDP | -0.157 | 0.035 | -4.48 | 0.000 |
| FDI | 0.001 | 0.008 | 0.13 | 0.895 |
| CPI | -0.001 | 0.003 | -0.61 | 0.542 |

**Source:** Author's calculations (Dependent variable: UNEMP)

Given the results obtained in Table 7 as a result of modelling with the random effects estimator, assuming a risk of 10%, we have the following equation (5):

$$r\_unempl = 17.029 - 0.812 \cdot ln\ \_ENV\_EXP - 0.946 \cdot RD - 0.157 \cdot gdpgw \quad (5)$$

We observe, after modelling with the random effects estimator, that our model explains 11.2% (overall R-squared = 0.1122) of the total change in the unemployment rate, and Prob>chi2 = 0.0000, which indicates that the model is statistically significant. The results show that spending on environmental protection, R&D and economic growth are the main factors contributing to a decrease in the unemployment rate.

### *4.1. Choosing the most suitable model*

The next stage of our analysis aimed at choosing the most appropriate statistical testing model, given the results obtained in the above analyses. For this purpose, we performed a series of tests according to Căutișanu (2019) for choosing the most appropriate model (Figure 2).

The first test we performed is the Chow test (Ulman *et al.*, 2022), testing whether the general regression model and the fixed-effects model differ significantly. The working hypotheses were:

- H0: All fixed effects are null, and in this case, the general model is preferred; and
- H1: At least one fixed effect is not null, and in this case, the fixed effects model is preferred.

The results of the Chow test indicate that the null hypothesis is rejected, and the fixed effects are not significant.

The second test performed is the Breusch-Pagan Lagrange Multiplier (LM) test, by which we tested whether the general model was preferable to the random-effects model (Breusch and Pagan, 1980). The working hypotheses were:

- H0: no significant differences between individuals, and the alternative hypothesis, and
- H1: significant differences between individuals.

The result of the test indicates that the null hypothesis is rejected, the random effects model being preferred to the general model.

In order to test whether there are significant differences between the model with fixed and random effects, we performed the Hausman test (Diaconașu *et al*., 2022). The null hypothesis of the test is that the best model is the one with random effects, and the alternative hypothesis is that the model with fixed effects is the best. The obtained result indicates that the preferred model is the one with random effects, the Sig value being higher than the assumed risk of 5%.

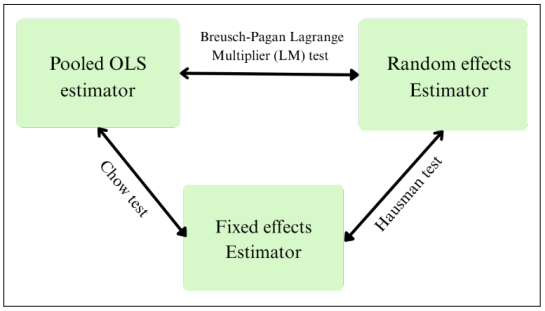


**Figure 2:** Decision flow for panel data estimation methods

**Source:** Author's calculations

### *4.2. Model validation*

Next, we applied some econometric tests in order to check the validity of the previously chosen model, following the Chow, Breusch-Pagan, and Hausman tests. Thus, we proceeded to test some hypotheses for the two components of the model, namely the stochastic and the deterministic. For the stochastic component, we tested the assumptions of independence, homoscedasticity, and autocorrelation. For the deterministic component, we analyzed the existence of multicollinearity among the independent variables (Căutișanu, 2019).

The hypothesis of independence was tested using the Pesaran, Friedman and Frees tests (Pesaran, 2021; Friedman, 1937; Frees, 1995; Frees, 2004). The hypotheses were some common ones for all tests. Thus, H0: Errors are not correlated between units (they are independent), and H1: Errors are correlated (there is dependence between units). The results of the Pesaran test suggest the rejection of the null hypothesis that errors are independent. Since the Sig value is less than the assumed risk of 5%, we can conclude that the errors are correlated and there is dependence between units. The results obtained in the Friedman and Frees tests indicate, as in the Pesaran test, the existence of dependence between units. The Friedman test has a result of 183.353 with a Sig value statistically significant, and the Frees test has a value of 5.340, well above the thresholds of the usual significance levels. Both the Pesaran, Friedman and Frees test results support the rejection of the null hypothesis of independence of errors, which leads us to invalidate the random-effects model in this respect.

The hypothesis of homoscedasticity was tested using the Wald test (Greene, 2002), with H0: The errors are homoscedastic, and H1: Heteroscedasticity exists. The results of our test indicate a Sig value less than the assumed risk of 5%, which leads us to reject the null hypothesis and accept the alternative hypothesis of heteroscedasticity.

The Wooldridge test will help us to test the hypothesis of self-correlation (Wooldridge, 2002). The null hypothesis of the test is that no correlation relationships exist, while the alternative hypothesis assumes that a correlation relationship exists between the panel units. The results of our test give us a Sig value lower than the assumed risk of 5%, which leads

us to reject the null hypothesis and accept the alternative hypothesis of the existence of autocorrelation.

The last hypothesis tested is the hypothesis of multicollinearity, and was checked by means of VIF (Variance Inflation Factor). The null hypothesis of the test was the non-existence of multicollinearity, and the alternative hypothesis assumed the presence of multicollinearity. All the values obtained are below the threshold of 2, with a mean value of 1.23, which indicates that there are no significant multicollinearity problems between the independent variables.

## 5. Results and discussions

Given that the assumptions of independence, homoscedasticity, and the autocorrelation assumption have not been met, a model to correct for them was estimated. Given that the relationship between N and T is T> N, the model we used in our analysis was FGLS (Feasible Generalized Least Squares). Our model had the form of equation (6) (Parks, 1967), and the results are presented in Table 8.

$$w_{it}Y_{it} = w\alpha + w_{k,it}\sum \beta_k X_{k,it} + w_{it}u_{it} \quad (6)$$

**Table 8:** Empirical results based on FGLSs model

| | Coefficient | Std. err. | z | P>\| z \| |
|---|---|---|---|---|
| cons | 11.478 | 1.040 | 11.03 | 0.000 |
| ln_ENV_EXP | -0.328 | 0.116 | -2.83 | 0.005 |
| REC | 0.025 | 0.018 | 1.35 | 0.175 |
| RD | -0.786 | 0.276 | -2.84 | 0.004 |
| GDP | -0.037 | 0.012 | -3.04 | 0.002 |
| FDI | -0.001 | 0.002 | -0.56 | 0.577 |
| CPI | 0.000 | 0.001 | 0.34 | 0.736 |

**Source:** Author's calculations (Dependent variable: UNEMP)

Given the results obtained in Table 8, following the model estimated using FGLS, we have the following equation (7):

$$unempl_{it} = 11.478 - 0.328 \cdot ln(ENV_{EXP})_{it} + 0.025 \cdot REC_{it} - 0.786 \cdot RD_{it} - 0.037 \cdot gdpgw_{it} - 0.001 \cdot FDI_{it} + 0.000 \cdot CPI_{it} + \varepsilon_{it} \quad (7)$$

According to the data from Table 8, the research expenditure variable has the strongest impact on unemployment, with a coefficient of -0.78 and a Sig of 0.004, being the most significant predictor in the model. Thus, a 1 percentage point increase in R&D expenditure leads to a 0.787 percentage point decrease in unemployment. These results obtained are consistent with the literature, namely Bogliacino, Piva and Vivarelli (2011), who demonstrated that R&D investment leads to a decrease in the unemployment rate, as well as with Kirchhoff *et al.* (2007), who addressed the relationship between R&D spending and the

creation of new firms, which contributes to employment growth. Thus, as demonstrated by Su *et al.* (2021), R&D expenditures in environmental technologies lead to the creation and increase in the share of green jobs, respectively, but this increase is influenced by the type of innovation, the sectors involved, and the economic context.

The second most significant variable in the model is environmental protection expenditure, with a coefficient of -0.328 and a Sig of 0.002. A 1% increase in environmental expenditure is associated with a decrease of about 0.33% in the unemployment rate. This result is consistent with previously mentioned studies such as Morgenstern, Pizer and Shih (2002) and O'Callaghan, Yau and Hepburn (2022), which show that green investment can generate more jobs, especially in labor-intensive sectors.

As for renewable energy consumption, it has a coefficient of 0.025 and a Sig of 0.175, not being statistically significant in our analysis and not having a strong direct relationship with the unemployment rate. This result confirms us that there is no clear consensus on the link between renewable energy consumption and unemployment, as emphasized by Saboori *et al.* (2022) and Apergis and Salim (2015).

Economic growth and foreign direct investment also have a negative effect on unemployment, with coefficients of -0.037 and -0.001, respectively, suggesting that both economic growth and foreign investment inflows contribute to reducing the unemployment rate. This result is supported by Okun's classical theory, which indicates a negative relationship between economic growth and the unemployment rate.

In our analysis, inflation does not have a significant impact on the unemployment rate, with a coefficient of -0.000 and a Sig of 0.736. This result is in line with that of Aliu, Jahja and Lubishtani (2021), who did not identify a relationship between inflation and unemployment and who present the relationship between the two variables as a complex one, depending on the economic context in each individual country. Given that the period under analysis was characterized by low and relatively predictable inflation, as noted by Ball and Mazumder (2020), the limited variation in prices does not provide sufficient information to identify effects on employment.

## 6. Conclusions

Our study examines the impact of green jobs on the unemployment rate, analyzing the influence of environmental protection expenditure, renewable energy consumption, R&D expenditure, economic growth, foreign direct investment, and inflation rates in 25 EU Member States over the period 1993-2022. Using the FGLS statistical model, our results show that R&D investment and environmental protection expenditure have a significant impact on reducing the unemployment rate, confirming the theoretical hypotheses formulated in the literature. A one percentage point increase in R&D expenditure leads to a 0.787 percentage point decrease in unemployment, and a 1% increase in environmental protection expenditure leads to a 0.33% decrease in the unemployment rate. The relationship between R&D and the unemployment rate indicates a strong and direct impact

of R&D expenditure on unemployment. Higher R&D spending can lead to innovations that create new jobs, improve production efficiency or open new markets, all of which contribute to reducing unemployment. In terms of the relationship between spending on environmental protection and the unemployment rate, the results indicate a much smaller impact compared to R&D, suggesting that while environmental protection spending can help reduce unemployment, its effect is relatively modest. Investment in environmental protection may create green jobs or support environment-related industries, but the overall impact on unemployment is smaller.

Our analysis shows that renewable energy consumption and inflation have no significant impact on the unemployment rate, suggesting a lack of relationship between these variables and unemployment. In contrast, economic growth and foreign direct investment have a significant negative effect on unemployment, supporting the theory that they contribute to reducing the unemployment rate.

The R&D spending had the strongest impact on the unemployment rate, reflecting the importance of technological innovations in the development of the green economy. These results are supported by previous studies that emphasize the importance of R&D investment in stimulating economic growth and creating new jobs in sustainable sectors. Alongside spending on R&D is spending on environmental protection, and our results suggest that policies that are environmentally oriented contribute not only to the goal of climate neutrality, but also to the creation of new job opportunities and economic growth. The EU and national governments can use R&D and environmental expenditure data to align the labor market policies with emerging green and digital skills needs, to take the policy decisions to link investment to workforce development and competitiveness, and to focus on innovation incentives towards sustainable technologies. Also, the governments should prioritize the public policies oriented to the budget allocation for green and digital initiatives, to design targeted training programs that will reflect the green skills acquired, and to implement structural reforms oriented to sustainable innovation and smart governance.

### *6.1. Research limitations and future research directions*

Our research provides valuable insights into the relationships between green jobs and R&D spending, environmental protection, and unemployment. However, there are limitations which are caused by not including relevant variables that may influence the unemployment rate, such as fiscal policy, labor market regulations, educational attainment of the labor force or other macroeconomic factors. Another limitation of this study is the absence of lagged variables, particularly for R&D expenditures, whose effects on employment are likely to manifest with a time delay.

Future research directions involve examining regional differences in the relationship between economic variables, unemployment, and green jobs, as well as studying the impact of structural changes on economic relationships over long periods of time that may affect the relationships between the variables analyzed. In addition, future studies will also consider the inclusion of lagged variables, particularly for R&D expenditures, to better capture delayed effects on employment outcomes.

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