Determination of Factors Affecting Wage Differentiation in EU Countries

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Abstract: - This study aims to identify the determinants of wage differentiation in European Union (EU) countries using panel data analysis. The literature review provides an overview of previous studies on wage differentiation, the current situation of wage differentiation in the EU, and the potential determinants and consequences of wage differentiation. The analysis shows that many potential variables influence wages and that direct modeling is problematic. However, the application of factor analysis led to the identification of significant factors, namely the economic strength of a country, the level of digitalization and working conditions, investment, and the unemployment rate. These findings are consistent with the existing literature. The robustness analysis of the results is provided. The conclusion offers recommendations for increasing wages based on the research results.

Key-Words: - EU countries, factor analysis, panel data, principal component analysis, regression analysis, wage differentiation.

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1 Introduction

Wage differentiation, often perceived as wage inequality, is a phenomenon that occurs in many contexts. There can be two research interests in regional wage differentials: cross-country wage differentials and wage differentials within a country or region. Wage differentials between individuals or groups have interested economists and policymakers for many years. According to [1], wage differentiation is the main source of inequality in the European Union (EU). Even after adjusting for price level differences, wages are much higher in Western Europe than in Central and Eastern Europe.

The standard indicator used is annual net earnings. Towards the end of 2022, Eurostat published a new wage-related indicator, the average annual full-time adjusted salary. Figure 1 presents the values of both indicators for the 27 EU countries in 2021. Based on the second indicator, the average in the EU for 2021 was 33,511 EUR, while Luxembourg had the highest average salary of 72,247 EUR and Bulgaria had the lowest with 10,345 EUR. This specific indicator does not adjust for the purchasing power parity (PPP), but the wage differences are apparent and will not disappear after doing so. In the past three available years (2019–2021), the countries with the highest average wages were Luxembourg, Denmark, and Ireland, while the countries with the lowest average wages were Bulgaria, Hungary, and Romania. For the annual net earnings indicator, the earnings of a single person without children earning 100% of average earnings were used. The differences in the values of the indicators shown are due to the use of different units (PPS vs. EUR) and the inclusion of gross and net salaries in each indicator. Nevertheless, both indicators effectively highlight the wage differences among the countries.

Explaining wage levels has been a research goal for a long time. The fundamental work building on individual employee characteristics [2] studied the correlation between years of schooling and earnings. The presented model was augmented by the number of years of experience, and the resulting function can be described as earnings depending on the net investment in oneself (years of education and years of potential experience). Other researchers have built on this work, e.g. in [3], authors adjusted the original equation by replacing years of experience with age and job tenure due to a lack of data. They also added additional employee characteristics (gender, type of contract), job and enterprise description, and considered the regional aspect. The main aim of their analysis was to understand the functioning of labor markets in Europe.

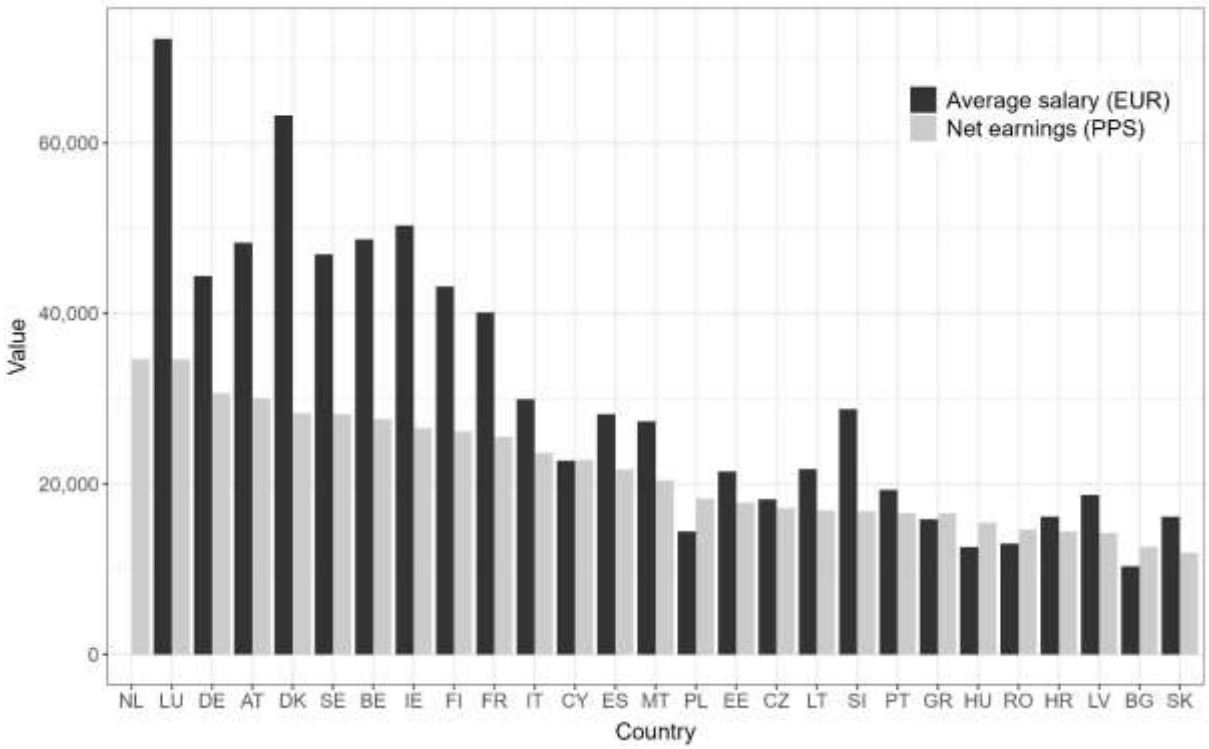

Fig. 1: Average full-time adjusted salary per employee and annual net earnings for the 27 EU countries in 2021. Data on average salary per employee in the Netherlands are not available
Source: Own processing, data source is [4]

The coefficient of determination explaining the wages varies from 41% to 85% in different countries. The most important factors were indicated age, level of education, and occupation. Employer characteristics such as size and sector also make a difference. In addition, regional differences within a country also play a role in intra-country differentiation.

Using similar variables, the work [5] tested the factors affecting wages on data from the 2016 Annual Survey of Hours and Earnings (UK). The work results show that job tenure seems to have the largest impact, part-time workers earn less than full-time workers, and employees in enterprises with more than 500 workers generally earn more than employees in smaller enterprises. The paper [6] states that in theory, a worker's wage depends on productivity, which depends on personal skills (influenced by education, experience, etc.) but also on job characteristics (such as management, technology used, etc.). Authors of [6], compared wage differentials between nine European countries, using data on male workers (to avoid the gender pay gap effect), whereby they decomposed them into the wage structure and the composition effect. As explanatory variables, a set of individual characteristics such as worker's experience, education, occupation, industry, and marital status were used, most of which are statistically significant in the model. It is concluded that the wage level seems to depend more on productivity determinants than on human capital characteristics. Additionally, the results show that institutional interventions such as the minimum wage are not likely to play a role. The impact of the minimum wage on various economic characteristics depends on the minimum wage level, as assessed, for example, by the Kaitz index. In certain periods the minimum wage can positively affect labor productivity, [7].

According to [8], wage inequality is mainly caused by skill-based technological change and, therefore, by an increasing gap between skilled and unskilled workers. The work also mentioned the effect of wage-setting institutions on wage inequality within a community or country. However, this is not necessarily true for cross-country wage differences. Based on this research, globalization has a smaller effect than technological advancement, but it is also a cause of income inequality as it increases the wages of earners at the top of the income distribution.

Authors of [9], constructed a model using twelve EU countries and the United Kingdom, which considers the following as sources of wage determination: personal and job characteristics (education, tenure, general working experience), weights of these characteristics (forming a skill index), and returns-to-skills function (skills pricing

function). According to their findings, the latter is the main source of wage differentiation across the countries. This also supports the finding that individual characteristics explain only a small part of the difference. Therefore, skill level differences contribute the most to the wage difference.

In general, it can be summarized that data on specific employees collected typically utilizing a questionnaire survey will make it possible to explain differences in wages within a company or country, practically allowing, for example, to optimize the wage spectrum of a firm and to estimate the cost of production, [10], but it is not sufficient to determine wage differences between countries.

2 Potential Factors Affecting Wage Differentiation on Country Level

The set of discussed factors is based on up-to-date research as well as on economic theories. Firstly, inequalities of different kinds can be assumed, [11]. Gender inequality can mean, for instance, having unequal access to education, employment, healthcare, or political representation. The most discussed form of gender inequality is the gender pay gap, and equally important is the examination of the gender employment gap.

Income inequality refers to the unequal distribution of income among individuals in a society. One way of measuring income inequality is the Gini coefficient which shows how much a country deviates from having an equal income distribution. An overview and further analysis of income inequality measures are provided in [12]. Analyzing the impact of inequality on economic growth on data from OECD countries, the author of [13] concluded that income inequality has a statistically significant negative impact on growth. Moreover, the inequality at the bottom of the income distribution is what limits growth. In [14] is concluded that some degree of equal income distribution is one of the determinants of sustainable growth. The effect of income inequality on economic growth, and potentially wages, therefore, seems to be negative.

Gross fixed capital formation (GFCF) is an economic indicator that refers to the total amount of investments made in fixed assets. This includes land improvements, purchases of plants, machinery, and equipment, as well as construction of roads, schools, hospitals, commercial buildings, etc. Higher levels of GFCF (which can be measured either as a percentage of the gross domestic product or in absolute terms) indicate that a country or region is investing in its future and has the potential for long-term growth. Based on the research using data on enterprises in Serbia, authors of [15] concluded that increasing investment in permanent assets by the enterprise is positively correlated with higher salaries of employees. While the relationship between GFCF and wages is complex and can vary based on other factors present, investment in capital in various forms is generally considered a positive driver of economic growth and higher wages.

The share of part-time workers can also be identified as an important factor. Part-time work was originally intended to integrate those who would otherwise be excluded from the workforce and can serve as a starting point for younger or inexperienced workers. However, part-time work can also present several challenges, such as unpredictable work schedules that limit the ability to plan other activities. Another disadvantage of part-time work may lie in lower wages and benefits, as well as fewer opportunities for career advancement. As noted in [16], part-time workers earn 29.3% less per hour than full-time workers with similar demographic characteristics and education. Moreover, part-time workers have limited opportunities for career progression and, therefore, less chance to develop leadership skills to take up positions of greater responsibility. This is also why part-time workers are underrepresented in most managerial and senior positions, [17].

Productivity is considered to be a major determinant of wages by many researchers. The economic theory attributes this correlation to the impact of productivity on wages; a summary of the known economic theory is given in [18]. The author of [19] finds that internationally, wages move in line with productivity. He argues that the gross output used should be replaced by net domestic product and suggests using full-time equivalent employment (taking into account full-time and part-time workers) as a measure of labor input.

Monitoring the share of employees with a tertiary education is also suggested, as the attainment of a higher education is generally believed to have a positive impact on future earnings. In addition to the wage premium, these workers are also less likely to be unemployed, see [20]. Using data from Australia, in the study [21] there is evidence that higher levels of education are associated with significantly higher wages. Some of the current research focuses on the fact that there has been a rapid increase in the supply of tertiary graduates. This in turn could hurt the wage difference compared to people without a tertiary education. In [22] we read about evidence that there

is no oversupply of tertiary graduates, as the wage gap between those with and without tertiary education remains substantial. This is because the demand for graduates has shifted as a result of the need for skilled labor. Furthermore, the wage premium in most countries has either remained stable or is still increasing.

The number of hours worked per week can have an impact on the employee's wage. Authors of [23] worked with data from Portugal to see how the reduction of working hours required by law affects wages. The compulsory reduction from 44 to 40 hours per week, which directly affected about half of all workers, was introduced unexpectedly. Initially, employers compensated for the loss of labor by using overtime. However, this increased hourly wages, so that the monthly wage fell only slightly. Using data on countries of all income levels, we can read in [24] that workers from developing countries work about 50% more hours per week than workers from rich developed countries. In terms of differences across countries, the number of hours decreases on average as income increases, especially in the poorest countries. In contrast, the work [25] adds that as incomes rise, people can afford more of the things they enjoy, including spending less time working and more time on leisure. The effect of minimum wage increases on consumption in EU countries is modeled in [26], the effect is negative in the long run and the mechanism of the effect involves movements in the price level, unemployment, and total household income.

The rate of income tax has a direct impact on people, but it is also closely linked to the economic growth and development of a country. The author of [27], who focuses on the impact of income tax changes on economic growth, reports that research shows a negative relationship between income tax rates and GDP, as investment and consumption increase as tax levels fall. Another finding is that the current open economy counteracts income redistribution (through progressive taxation) due to the high mobility of higher-skilled and higher-income workers. Higher trade openness can contribute to the increase in wage inequalities within the country, [28]. Conversely, a reduction in the progressivity of the tax system is associated with an increase in real wages.

Most researchers who study the relationship between the unemployment rate and wages build on the “wage curve” introduced in [29]. The main conclusion is that the employees who work in areas of high unemployment (regional unemployment), or industries with high unemployment rates, receive lower wages. The study [30] examines the employment-wage relationship using panel data from ten OECD countries (between 1950 and 2005) and finds statistical evidence in support of it, highlighting the direction in which wages are affected by changes in employment.

The level of digitization in the economy is a complex issue that can affect wages in various ways. Some studies suggest that digitization can increase productivity and create new jobs, leading to higher wages for workers. For example, the work [31] conducted a study on European data, using several information and communication technology (ICT) indicators to show that the use of ICT has positive economic effects, particularly on the increase of the employment rate of women, reducing long-term unemployment and productivity growth. It emphasizes that the potential positive effects are not simply due to the increased use of ICT, but rather to the exploitation of the full range of opportunities offered by digital technologies. The authors of [32] find evidence that in Germany firms' investments in new digital technologies have a positive effect on their employees' wages. Authors of [33] show that wage growth is only associated with new technologies for middle-skilled workers.

Gross domestic product (GDP) per capita is a measure of a country’s economic output that accounts for its population and is often used as an indicator of a country’s economic well-being and standard of living. In work [34] is reported that there is a positive correlation between GDP per capita and real wages, with data showing that a 1% change in GDP per capita is associated with a 0.6% to 1% change in wages. Furthermore, it is indicated that as GDP increases, the wage gap between countries decreases. Interestingly, the study [35] notes that workers' wages in Sweden grew with GDP per capita until the 1880s. After that, they even grew faster than the economy.

The sectoral composition of an economy refers to the distribution of economic activity across different sectors, such as agriculture, industry, and services. This composition can be measured in various ways, including gross value added (GVA) or the number of employees. The sectoral composition of the economy has an impact on average wages, with some sectors tending to have higher wages than others. Higher-paid sectors tend to be those that require more skilled workers and have greater bargaining power. Authors of [36] highlight the significant impact of sectoral differences on wages, alongside productivity. In particular, they note that wages vary according to the sector of employment, with the industrial sector generally offering higher

wages than the services sector. The study [37] finds that there are wage differentials across sectors, with the agricultural sector being associated with lower wages and lower levels of capital intensity, while the non-agricultural sector shows the opposite pattern. Authors of [38] argue that changes in the composition of the workforce in an economy can have a large impact on wages in all sectors.

Capital flow is measured by the capital account of the balance of payments, which measures all transactions related to the receipt or payment of capital transfers such as debt forgiveness, investment grants, capital taxes, and other capital transfers. It also includes the acquisition or disposal of non-produced and non-financial assets, such as land, subsoil assets, patents, trademarks, copyrights, and franchises. Wages in the economy can be affected both positively and negatively by capital flows. Inflows of capital may stimulate economic growth, driving up labor demand and leading to higher wages, while outflows of capital may reduce investment and slow down economic growth, potentially leading to lower wages. According to research [39], relaxing restrictions on capital inflows in developing countries can lead to higher real wages in the manufacturing sector, thereby improving living standards. However, it is important to note that this conclusion is specific to the industrial sector and may not hold for the whole economy. Authors of [40] report that restricting capital inflows in Australia would lead to lower incomes and wages in the long run. According to the study [41], which analyses data mainly from European countries, the opening of the capital account can lead to an increase in wage inequality. The reason for this is that when capital complements skilled labor, the increase in capital from abroad can also increase the demand for skilled workers, leading to a widening gap between skilled and unskilled workers.

To summarize the above results of research, there are many possible determinants of wages. However, as argued by [6], the actual determinants of the wage gap in the EU are not well known due to a lack of data and empirical studies. Many determinants also affect wages indirectly through the influence of other determinants such as the tertiary education share of the population. It is therefore not easy to disentangle their individual influence and the presence of many variables in the model will raise multicollinearity and follow-up problems. The aim of this study is to find significant determinants of wage differentiation in EU countries using appropriate multivariate methods.

3 Materials and Methods

For this research, panel data from the 27 Member States of the EU between 2009 and 2021 are processed. The dependent variable is the annual net earnings (in Purchasing Power Standards) of a full-time single worker without children earning an average wage. The indicator was not available for Croatia in the years 2009–2012 and for Cyprus in 2009–2013 and 2015–2016. These two countries were excluded from some of the analyses during these years. Independent variables are described in Table 1. Due to the missing data, the 2021 Gini coefficient for Slovakia has been replaced by the 2020 figure, the value of *tertiary_education* for Ireland in 2009 by the 2010 figure, and the value of *tertiary_education* for Portugal between 2009 and 2010 by the 2011 figure. As with the dependent variable, missing data on the income tax rate for Croatia between 2009 and 2012 and for Cyprus between 2009 and 2013, as well as 2015 and 2016, led to exclusion from some of the analyses. Missing data on the level of digitization from between 2009 and 2014 have been replaced with data from 2015.

While most of the variables are explained in the above section, the measurement of the level of digitization deserves more attention. The Digital Economy and Society Index (DESI) and two of its components were selected for this purpose. The DESI is a composite index published annually since 2014. Until 2021, the index consisted of five components, and the DESI was calculated as a weighted average of these as follows: Connectivity (25%), Human Capital (25%), Use of the Internet (15%), Integration of Digital Technology (20%), and Digital Public Services (15%). However, since 2021, the DESI consisted of four main areas, with the Use of Internet components removed to align with the Digital Compass. Each of the four components now accounts for 25% of the DESI. As the available data for this indicator is usually for the previous five years, data for 2015 and 2016 were obtained using the previous methodology. Data for the period between 2017 and 2021 were available using the new methodology. As no data were available for the period between 2009 and 2014, these years were replaced by data from 2015. Panel data are analyzed using regression analysis. The F test of equality of all intercepts for individual and/or time effects and the Hausman test were applied to select either the pooled model, the fixed effects model, or the random effects model. The variable for gross value added for the industry sector is not included in the model since it is redundant.

Table 1. Independent variables

Factor affecting wage differences	Description	Variable
Gender employment gap	The difference between the employment rates of men and women in the age group between 20 and 64 years	*gender_gap* [%]
GFCF	A percentage of GDP	*gfcf* [%]
	The absolute value based on purchasing power adjusted GDP per capita	*gfcf_abs* [EUR]
Income inequality	Gini coefficient	*gini*
Share of part-time workers	A percentage of the total employment in the age group between 20 and 64 years	*part_time* [%]
Productivity	Output per hour worked based on GDP at a purchasing power parity	*productivity* [2017 Int$ /hours]
Share of employees with obtained tertiary education	A percentage of the total employment in the age group between 20 and 64 years	*tertiary_education* [%]
Weekly working hours	The average number of usual working hours in a full-time job in the age group between 20 and 64 years	*hours_worked* [hours]
Income tax rate	A percentage of gross wage earnings for a single person without children earning 100% of the average earnings	*tax_rate* [%]
Unemployment rate	The proportion of unemployed individuals within the labor force in the age group between 15 and 74 years	*unemployment_rate* [%]
Level of digitization	The digital economy and society index (DESI)	*desi*
	The connectivity component of the DESI index	*connectivity*
	The human capital component of the DESI index	*human_capital*
GDP	GDP per capita in PPS	*gdppc*
The sectoral composition of an economy	The gross value added for agriculture	*GVA_agriculture* [%]
	The gross value added for the services sector	*GVA_services* [%]
	The gross value added for the industry	*GVA_industry* [%]
Capital flow	The capital account of the balance of payments, which tracks all transactions related to the receipt or payment of capital transfers	*capital_account* [million EUR]

Source: Own construction

After conducting a regression analysis on the initial variables, principal component analysis (PCA) and factor analysis (FA) were employed to reduce the number of predictors. This procedure was repeated for the entire panel of data and each year separately. The final model was then reconstructed with the use of other types of earnings concerning the family situation (one-earner couple with two children, two-earner couple with two children, and two-earner couple with no children) to check their robustness.

Data were retrieved from the Eurostat and ILOSTAT databases. All the analyses were performed in the computing system MATLAB R2024a and using the R software (ver. 4.3.0) The significance level was set to 0.05.

4 Results

This chapter aims to develop a model that can identify the factors contributing to wage differentials in EU countries using panel data. The primary dependent variable for the models is the annual net earnings of a single person without children earning 100% of the average earnings. The values are displayed in Figure 2 for the three key years (first, middle, and last) of the dataset. The plot provides an overview of the earnings trend over time, with most countries showing an upward trend. However, Greece shows the opposite trend. In Ireland, earnings initially declined but started to increase after reaching a low point in 2014. In Spain, earnings increased until 2019, experienced a significant decline, and then rose again in 2021, likely due to the COVID-19 pandemic. Slovakia shows a slight increase over the 13 years, with earnings in 2015 being the second-highest after 2021. The other three types of earnings (based on family situation) follow the same trend.

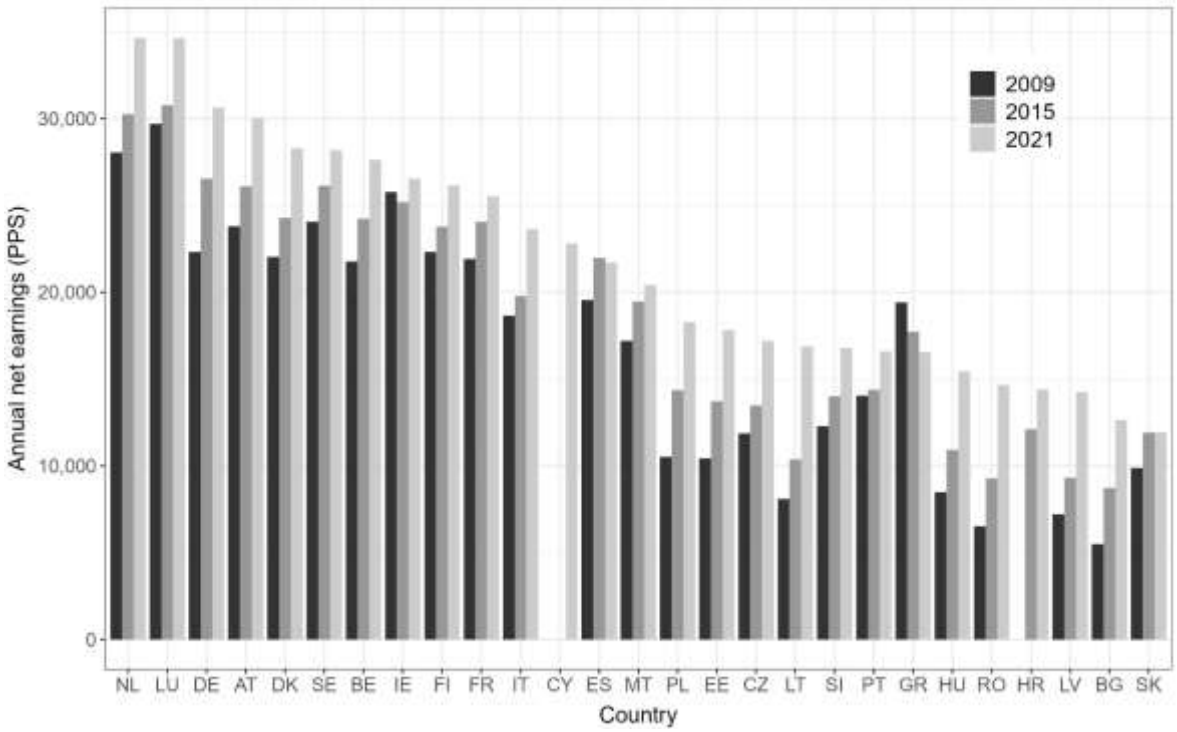

Fig. 2: Annual net earnings for the 27 EU countries in 2009, 2015 and 2021
Source: Own processing, data source is [2]. *Data is missing for Cyprus (in 2009 and 2015) and Croatia (2015)*

Table 2. Random effects model with initial variables after backward selection

	Estimate	**Std. Error**	**z-value**	**p-value**
intercept	6 031.41	6 607.81	0.91	0.361
gender_gap	197.41	24.08	8.20	<0.001
gfcf	−903.39	179.63	−5.03	<0.001
gfcf_abs	4.49	0.75	6.00	<0.001
gini	92.45	36.74	2.52	0.012
part_time	343.05	28.41	12.07	<0.001
productivity	−88.89	20.94	−4.25	<0.001
tertiary_education	83.51	20.08	4.16	<0.001
hours_worked	−382.43	143.20	−2.67	0.008
tax_rate	61.69	22.32	2.76	0.006
desi	394.82	66.71	5.92	<0.001
human_capital	−166.83	74.92	−2.23	0.026
gdppc	0.17	0.04	4.41	<0.001
GVA_agriculture	−422.33	153.23	−2.76	0.006
GVA_services	170.00	28.06	6.06	<0.001

Source: Own calculation

4.1 Model with Initial Variables

Firstly, a regression analysis was performed using the backward selection method to determine the most significant explanatory variables. Based on a Hausman test, the random effects model was deemed more appropriate. The variables removed in this model are *unemployment_rate*, *capital_account*, and *connectivity* and are a subset of the variables removed in the fixed effects model. There are many significant variables in the resulting model, see Table 2. However, some of their coefficients have unexpected signs. For example, *productivity* is not expected to hurt wages, and the same applies to *human_capital*.

4.2 Model with Factors based on Panel Data

To obtain clearer results from the regression analysis, PCA was applied, followed by FA. The reduced number of predictors, as a result of the factor analysis, was then used to construct the model. For PCA, all independent variables were used, except for *GVA_industry* and *GVA_agriculture*. This is because it was not possible to include all three variables in the FA, and

therefore *GVA_services* was chosen as the service economy is a growing sector. Standardizing the data was necessary since some of the variables had values in tens of thousands while others had values smaller than ten.

A scree plot was constructed using the explained variance of the principal components. The most apparent breaking point suggests using two components. However, these components only explain 48.3% of the total variance. The next bend in the line indicates retaining five components. Still, since four components explain 67.7% of the variance, this option was also considered. Therefore, FA was applied using both four and five factors.

In the case of four factors, the resulting factor identification is shown in Table 3. There, the specific assignment of variables to each factor in terms of their correlation can also be seen. Using five factors instead of four resulted in very similar factors: Economic strength of a country (Factor 1), Level of digitization and working conditions (Factor 2), Investment (Factor 3), Digital skills and income inequality (Factor 4), and Unemployment rate (Factor 5).

Firstly, four-factor models were built and then compared with five-factor models. For the four factors, significance testing of the effects and the Hausman test led to the fixed effects model being the most appropriate. The fixed effects model also shows that all four factors are significant, Table 4.

In the case of the five factors, the Hausman test favored the random effects model, but it was necessary to remove Factor 4 (Digital skills and income inequality) due to its high p-value. The model was then augmented with the variables *gini* and *human_capital*. However, neither proved to be significant, and both were sequentially eliminated from the model. The resulting random effects model is shown in Table 5.

When comparing the models, it is important to consider the variables that strongly correlate to the significant factors. In the case of five starting factors, Factor 4 is not significant, and therefore, the *gini* and *human_capital* variables may not be determinants. However, *human_capital* still correlated to Factor 2, although the coefficient value is relatively low (0.49). In the model with four starting factors, *gini* only correlated at −0.37, which also does not show the significance of this variable. The results demonstrate that both models lead to the same conclusion, with the same variables (*gdppc*, *gfcf_abs*, *productivity*, *connectivity*, *human_capital*, *unemployment_rate*, *desi*, *gfcf*) proving to be significant in explaining wages.

Table 3. Factor identification for four factors (all years)

Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
Economic strength of a country	Human capital and its technological endowment (digital)	Investment	Unemployment rate
productivity (0.89)	*desi* (0.91)	*gfcf* (−0.92)	*unemployment_rate* (−0.98)
gdppc (0.88)	*human_capital* (0.71)	*part_time* (0.48)	*gini* (−0.37)
gfcf_abs (0.86)	*connectivity* (0.64)	*capital_account* (−0.37)	*tax_rate* (0.29)
GVA_services (0.47)	*tertiary_education* (0.49)		
	hours_worked (−0.43)		
	gender_gap (−0.41)		

Source: Own construction

Table 4. Fixed effects model with four starting factors based on panel data

	Estimate	**Std. Error**	**t-value**	**p-value**
Factor 1	2 389.93	284.13	8.41	<0.001
Factor 2	1 606.63	120.22	13.37	<0.001
Factor 3	645.86	123.78	5.22	<0.001
Factor 4	1 284.04	117.20	10.96	<0.001

Source: Own calculation

Table 5. Random effects model with five starting factors based on panel data

	Estimate	Std. Error	z-value	p-value
Intercept	18 943.04	867.51	21.84	<0.001
Factor 1	2 105.51	243.60	8.64	<0.001
Factor 2	1 362.09	99.44	13.70	<0.001
Factor 3	317.48	114.21	2.78	<0.001
Factor 5	−1 015.80	106.79	−9.51	<0.001

Source: Own calculation

Table 6. Characteristics of Potential Final Models

Model	Type	RMSE	Number of predictors
with initial variables	random effects	777.34	14
with four starting factors	fixed effects	1 094.59	4
with five starting factors	random effects	1 061.47	4

Source: Own calculation

4.3 Model Comparison

The models selected from each method were compared. Table 6 summarizes the model characteristics. Based on the root mean squared error, the model with initial variables seems to be describing the earnings the best. However, due to the high number of regressors and the potential presence of a counteracting effect, the decision falls between the model with four starting factors and the model with five starting factors. As the model with five starting factors has a slightly lower RMSE, it was considered as the final model. Additionally, the variables included in the model are very similar to the one with four starting factors.

It was not possible to conduct the Im-Pesaran-Shin test to reject a spurious regression due to an insufficient number of degrees of freedom for the auxiliary regression model of the test. However, a spurious regression was ruled out by estimating the model using the first differences of dependent and independent variables, which resulted in the same factors being significant with the same signs as in the final model.

4.4 Robustness Check

An alternative method for creating a model explaining earnings is to generate factors based on an analysis conducted for each year. The validation of the resulting model in the previous section is also discussed by analyzing the other three types of earnings as the dependent variable.

4.4.1 Model with Factors based on Individual Years

For consistency and interpretability, four factors were applied. The resulting factors could then be compared across years to identify similarities and create a new panel dataset. This panel dataset can be subsequently used for regression analysis and model construction.

The first step after obtaining the factor output was to assign the individual variables to each factor based on their correlation coefficients. However, it was challenging to consistently group the factors across the years since the correlations of the variables changed over time.

One group of variables that remains consistent over time includes *gdppc*, *gfcf_abs,* and *productivity*. *GVA_services* is also part of this group in most years. Next, the variables related to the level of digitization were grouped. These also include *gender_gap* and *hours_worked* in most cases, and *tertiary_education* is part of this factor in over half of the cases. Another factor group is based on the high correlation of the *gfcf* variable, which had a correlation coefficient of 0.9 in ten out of the thirteen years (with the smallest value of 0.83). The fourth factor contains the *unemployment_rate* variable (with relatively high correlation coefficients) in most years, while *gini* was present in seven years.

In some cases, certain variables had the same correlation coefficient values associated with two factors. In such cases, the variable was assigned to the factor that was more typical across all years. For example, in 2009, the variable *gender_gap* had the same correlation coefficient values with both Factor 2 and Factor 4. It was ultimately assigned to Factor 2. Similarly, in 2015, productivity was assigned to Factor 1 despite the alternative option of assigning it to Factor 3. However, the most difficult decision was regarding the variable *part_time*, which had the same correlation coefficient values with both Factor 1 and Factor 2 since the occurrence of this variable is not as stable. It was ultimately assigned to Factor 2, where it belonged more often.

Table 7. Absolute frequencies of variables related to the factors (FA based on four factors) in particular years between 2009 and 2021

Variable	Factor 1	Factor 2	Factor 3	Factor 4
gender_gap	0	11	0	2
gfcf	0	0	13	0
gfcf_abs	13	0	0	0
gini	0	6	0	7
part_time	2	4	5	2
productivity	13	0	0	0
tertiary_education	4	7	1	1
hours_worked	0	10	0	3
tax_rate	3	0	4	6
unemployment_rate	0	1	2	10
desi	0	13	0	0
connectivity	0	12	0	1
human_capital	0	11	0	2
gdppc	13	0	0	0
GVA_services	10	0	0	3
capital_account	3	1	3	6

Source: Own construction

Table 8. Fixed effects model with four starting factors based on individual years

	Estimate	Std. Error	t-value	p-value
Factor 1	423.22	329.19	1.29	0.200
Factor 2	−98.20	298.50	−0.33	0.742
Factor 3	228.99	103.30	2.22	0.027
Factor 4	−53.98	`127.049	−0.43	0.671

Source: Own calculation

The absolute frequencies of the variables identifying a given factor in a given year are shown in Table 7.

Finally, a panel dataset composed of the individual year factors was used in the panel regression. In the fixed effects model, Factor 3 was the only significant factor (with a p-value of 0.029), while all other factors were insignificant, even after sequential elimination. The model with all factors can be seen in Table 8. It can be concluded that this approach did not succeed in the regression, but it confirmed the stability of the important variables for factor identification.

4.4.2 Model with Different Types of Earning as the Dependent Variable

In this section, three other earnings types are discussed, namely the earnings of a one-earner couple with two children, a two-earner couple with two children, and a two-earner couple with no children. The same independent variables in the form of factors used for the final model were employed. Three models were constructed for each type of earnings, and based on tests, one was chosen for comparison with the final model.

Based on the random effects models using other types of earnings, it can be concluded that the final model is robust. This is because the significant factors remain the same in each case, and the signs of all estimated coefficients are consistent (with Factor 5 being the only one with a negative effect) and have corresponding values. Additionally, the coefficients for the earnings of two-earner couples are approximately double that of the earnings of a single-earner, providing further evidence of stability in the model. A comparison of the estimated coefficients can be found in Table 9.

Factor 1 (Economic strength of a country) has the highest weight in terms of affecting earnings. It also follows expectations since the corresponding variables (*gdppc*, *gfcf_abs*, and *productivity*) are positively correlated with the factor. This is followed by Factor 2 (Level of digitisation and working conditions), with *desi*, *connectivity*, and *tertiary_education* positively correlated, as expected. However, *hours_worked* and *gender_gap* are negatively correlated with this factor. The next factor is Factor 5 (Unemployment rate), which has a negative effect on earnings. This is as expected since the *unemployment_rate* variable is positively correlated. Lastly, Factor 3 (Investment) has a positive effect, while *gfcf* is associated negatively with this factor, which is the opposite of what was expected. However, taken in absolute terms, the *gfcf_abs* variable (included in Factor 1) is positively and strongly correlated.

Table 9. Estimates of coefficients for the final model using four different types of earnings

Earnings specification/Variable	Intercept	Factor 1	Factor 2	Factor 3	Factor 5
Single person without children	18 943	2 106	1 362	317	−1 016
One-earner couple with two children	22 513	2 679	1 553	436	−1 333
Two-earner couple with two children	40 414	4 403	2 857	624	−2 475
Two-earner couple with no children	38 052	4 231	2 709	635	−2 052

Source: Own calculation

5 Discussion

This paper has taken a comprehensive approach to identifying the determinants of wage inequality, using a wide range of indicators from different perspectives. Factor analysis was considered to be an appropriate approach, in which a large number of potential wage determinants are grouped into factors. This approach has been tested for the panel as a whole as well as for individual years and with different dependent variables. The chosen approach was successful in producing an appropriate and robust model.

The variables associated with the "Economic strength of a country" factor demonstrated an effect in line with existing studies. The study [34] concluded that GDP has a positive effect on wages and the paper [19] found the same for productivity, both of which are supported by our study. However, the results for gross fixed capital formation (GFCF) are less clear. While it is expected to have a positive effect as an indicator of capital investment, as concluded in [15], the final model shows a positive impact when measuring GFCF in absolute numbers (per capita), and a negative impact when using GFCF as a percentage of GDP. One possible explanation for this discrepancy is that measuring in absolute numbers may reflect a higher level of capital per worker, such as through the adoption of more advanced technologies, which can lead to higher productivity and wages. However, when considering values as a percentage of GDP, higher values could potentially indicate a weaker overall economy, which may be associated with lower wages. Another explanation for this effect could be that a higher share of a country's output is invested in physical capital at the expense of other sectors that have a positive impact on wages, such as human capital development. This naturally leads to the results of the variables indicating the level of digitalization (DESI and human capital), which has a positive effect on wages. This conclusion is consistent with the findings of the work [32]. Similarly, the share of employees with tertiary education was found to have a positive effect on wages, which is in line with the idea that employees with higher education tend to earn higher wages, see [20].

With regards to the average number of hours worked authors of [42] suggest a non-monotonic relationship with wages, with a turning point at 40 hours per week (which may be at a lower value for European countries). Although this value is very close to the number of hours worked in EU countries, a majority of observations are (slightly) above this value, which validates the conclusion based on the final model; weekly hours harm wages. However, it is important to note that this relationship could potentially be reversed if policies lead to shorter working hours, although the 40-hour threshold could still change in that case. Additionally, the effect of the average number of working hours may differ if countries with more varied average hours were included in the analysis.

The gender employment gap is shown to hurt wages in the final model. This result is also in line with the findings of the study [43], which indicate that most enterprises see women's participation as a key aspect of their future strategies. The model shows that the unemployment rate hurts wages, which is consistent with the findings of many other studies. This further confirms the nature of the "wage curve" introduced in [29].

There are many other factors, not included in this analysis, that could explain the wage differentiation, for example, access to education, talent outflow abroad, law enforcement, bureaucracy, regulation, large and strong government, the ownership structure of the economy, and lack of interconnectedness of key sectors of the economy. Although measuring some of these factors may be challenging, it would be worth expanding the analysis to include them. On the other hand, the variables used in this study were able to estimate the earnings quite well, as demonstrated by the predicted decreasing trend (for the first few years) in earnings in Greece. This shows that the prediction is not based on a spurious regression. The reason for this unusual trend in Greece may lie in the Great Recession, which had significant consequences for this country.

Another interesting aspect is the fluctuation in 2020 due to the COVID-19 pandemic. The model correctly predicted the impact of the pandemic in some countries, but in others (Austria, Croatia,

Cyprus, Italy, Lithuania, Slovenia, and Sweden), where the pandemic did not affect wages, the model predicted a decrease. In the study [44] we can read that in the case of Austria, a new model was developed, allowing for a reduction of working hours by up to 90% while maintaining the employment relationship. The state compensated for the wages almost to the full extent, which prevented an increase in unemployment rates, and probably also contributed to the continued growth of wages during the pandemic. Slovenia also passed laws during the pandemic, that covered 80% of the salaries of workers who were on hold, while also paying for all contributions to health and pension funds, [45].

From an economic perspective, wage differences between countries can cause labor market imbalances, with some countries facing labor shortages in certain sectors while others experience high unemployment rates. Authors of [46], found that the wage gaps between rich and poorer countries can often be attributed to a "place premium". These wage gaps, which do not stem from inherent differences in worker productivity, but rather from an inefficient distribution of labor, create a strong incentive for workers to migrate to wealthier countries. This leads to one of the most frequently mentioned consequences of wage differences – brain drain, [47].

Another frequently discussed issue related to the consequence of wage differences is that multinational corporations take advantage of the wage gaps between countries and exploit workers by forcing them to work long hours in poor conditions. However, the study [48] shows that the opposite is true. The authors conclude that there is no systematic evidence that multinationals harm their employees, promote worse working conditions, offer lower wages than other jobs, or suppress workers' rights. Instead, foreign ownership was found to have a positive impact on wages by increasing labor productivity and the scale of production, which in turn leads to better working conditions. From this perspective, therefore, wage differentials have a positive impact on workers in poorer countries.

6 Conclusions

Based on the results obtained, there is potential for some measures that could be implemented by the state or government that could lead to higher wages. Concerning the education system, the government should use various methods to make the teaching profession more attractive, to attract better quality teachers, and to encourage young people to enter the profession. One of the fundamental measures is to increase salaries, especially for teachers in primary and secondary schools. In addition, social recognition is also important, and long-term efforts are needed in this regard. In addition to the salary, the introduction of other benefits could be effective in attracting more people to the field. One example could be a housing allowance (especially for young teachers in expensive cities).

In terms of pupils and students, there could be a change in the supporting scholarships. One type could be focused on providing sufficient motivation to achieve better results. On the other hand, social scholarships are also important to support students from families with worse economic conditions. It is also important to have a sophisticated education system that uses modern scientific knowledge and methods and focuses on creativity and critical thinking as well as STEM competencies.

This topic is also related to the motivation of young and educated people to stay in the country. In this regard, adjusting the social security system to support young people and young families could help. This could include policies for more affordable housing and certain tax incentives. Additionally, making the country generally more attractive for a living (the so-called good place to live) could also help. This can be achieved through the enforceability of the law, guaranteed human rights (including minority rights), social responsibility policies, and sustainability.

Regarding the development of digitization, it is possible to pursue this topic in several ways. Firstly, within the services provided by the state to its citizens. Smooth communication between government institutions, authorities, and citizens is particularly helpful in this respect. An important part of this is also the availability of high-quality internet connectivity (especially in remote areas) and technology. In this respect, it would be appropriate to adopt legislation to ensure this, and also to encourage citizens to use digital services. An example could be Estonia, where the level of digital public services is particularly high, facilitating many processes and eliminating unnecessary bureaucracy. Other areas where digitization could be improved are the (aforementioned) education system and the healthcare system.

Various measures can also be taken to increase productivity. One way could be to create a favorable business environment that attracts investors in areas with high value-added. Specifically, this could involve improving the enforceability of laws, improving infrastructure, and taking steps to

minimize bureaucracy. This is also associated with setting up appropriate protection for employees while giving employers the ability to lay off unproductive employees. Another measure related to productivity is the efficiency of public administration, which involves optimizing the number of employees and processes, including digitalization. The funds saved through these methods could be used to make necessary investments by the state.

From the perspective of the impact of the number of working hours, policies could be adopted to support maintaining a 40-hour work week. Alternatively, it is possible to try reducing working hours by a few hours, which may lead to increased employee productivity.

Another main point is reducing the unemployment rate. In this regard, governments can support the establishment of sheltered workshops for people with disabilities or provide supportive programs to reintegrate long-term unemployed individuals into the workforce. Another way could be investing in retraining programs for people in less attractive industries and supporting job opportunities in rural areas. The possibility of declaring personal bankruptcy may also be a possible way to motivate people to take up employment. Furthermore, it may be helpful to direct young people towards industries that appear to be promising in terms of labor market development as part of the educational process. In addition to these measures, governments can also support employment rates during crisis periods, such as the COVID-19 pandemic. This worked well in several countries where the state provided sufficient financial support to employers, which led to the retention of many employees who would otherwise have lost their jobs.

To reduce the gender employment gap (which also promotes employment rates), supportive measures are needed to enable women to perform paid work. This can be supported, for example, by improving the availability of nurseries and kindergartens for children. Another way is to work on eliminating prejudices and stereotypes arising from the potential patriarchal nature of society and promote a fair working environment in the workplace.

Overall, the complex model was found to be correctly developed, and robust to changes in the dependent variable, and the variables included through the significant factors are consistent with other papers. Based on the model, recommendations can be made towards reducing the wage differentials. Another direction of research in this area could be, for example, the prediction of the evolution of wage differentials in light of the emerging robotization and automation.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the authors used Grammarly for language editing. After using this service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Tamara Kocurová realized the majority of the underlying literature review and prepared the first draft of the paper. The authors equally contributed to the research process, at all stages from the formulation of the problem to the final findings and conclusions.

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Conflict of Interest

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