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**Assessment Cover Page**

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| *Assessment Title* | Capstone Project Proposal |
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I further confirm that this work has not previously been submitted for assessment by myself or someone else in CCT College Dublin or any other higher education institution.

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**Gender Workforce Participation**

## Project proposal

### Introduction

This report focuses on analyzing participation in the workforce, with the aim of checking if there are gender disparities. We will look at the challenges and opportunities that people face based on their gender in different roles and job positions.

Women face persistent gender barriers, a lack of role models, and stereotypes that continue gender inequality. As civil rights activist Marian Wright Edelman said: "You cannot be what you cannot see."

### Objectives

#### General Objective:

Explore and analyze the gender gap in the workforce using the Eurostat dataset, starting with an exploratory data analysis (EDA), then develop and optimize a classification model to identify key patterns and predict gender disparity in employment accurately. Machine learning techniques and data visualization will be applied to interpret results and find the best solution, giving a clear understanding of the problem.

#### Specific Objectives:

* Perform exploratory data analysis (EDA) to explore gender gap characteristics in the workforce and understand the Eurostat data structure.
* Apply machine learning techniques and data visualization to find relevant patterns explaining the gender gap in employment.
* Develop a classification model to predict gender disparity in employment accurately, using Eurostat data.
* Compare and adjust at least three machine learning algorithms to choose the best-performing model.
* Optimize selected algorithms by tuning hyperparameters and using cross-validation to improve model accuracy.
* Visualize the final model results to make interpretation and understanding of the gender gap impact easier.

### Problem definition

The existence of gender disparities in the workforce can affect equity and equal opportunities. It is important to identify and understand these disparities to implement measures that promote gender equality and inclusion in the workplace.

#### Why fight the gender pay gap?

* Respect for rights: Respect for women's work rights is essential.
* Productivity: A competitive market needs motivated people who are paid fairly.
* Reducing poverty and inequality: Lower incomes for women affect their pensions and the economic situation of their children, especially single mothers.
* Social harmony: Equal pay encourages a fair division of care work, strengthening personal and work life and contributing to a more just society

## Scope and Methodology

### Scope

This project will analyze data related to job roles, gender, age, workforce performance, education, and other relevant factors. We will investigate patterns and trends in gender distribution across different job roles and departments, as well as their relationship with age, workforce performance, and educational level.

### Methodology

For this project, we will use the CRISP-DM methodology (Cross-Industry Standard Process for Data Mining):

Business Understanding:

* Identify business objectives.
* Determine data mining goals aligned with business objectives.
* Define success criteria.
* Develop a preliminary plan to achieve objectives.

Data Understanding:

* Gather relevant data sources.
* Explore data to understand its quality, content, and structure.
* Identify data issues, anomalies, and potential biases.
* Determine data requirements for modeling.

Data Preparation:

* Clean and preprocess data to handle missing values, outliers, and inconsistencies.
* Select relevant features for analysis.
* Transform and engineer features as needed for modeling.
* Split data into training and testing sets.

Modeling:

* Select appropriate modeling techniques based on data characteristics and objectives.
* Build initial models using selected techniques.
* Evaluate model performance using relevant metrics.
* Fine-tune models by adjusting parameters and algorithms.

Evaluation:

* Assess model performance against success criteria and business objectives.
* Validate models using cross-validation or holdout datasets.
* Interpret model results and identify areas for improvement.
* Document findings and recommendations for stakeholders.

### Ethical considerations

Identifying potential biases:

* Examine the data and models to identify any inherent biases.

Assessing potential impact:

* Evaluate how potential biases could affect different user groups or individuals impacted by the decisions made by the model. Consider whether bias could result in discrimination or injustice towards certain groups.

Mitigating identified biases:

* Implement strategies to mitigate the identified biases. This could include gathering more representative data, designing more equitable algorithms, and incorporating checks and procedures to prevent biased decisions.

## Project management and planning

### Data Source Overview

The dataset was obtained from Eurostat, specifically the data is broken down by demographic and social characteristics. The link to access the dataset is included below.

<https://ec.europa.eu/eurostat/databrowser/view/LFSI_EMP_A/default/table?lang=en>

### Project Plan

Business Understanding:

* Identify project objectives and key research questions.
* Establish success criteria and define the project scope.

Data Understanding:

* Select and acquire the dataset on women in the technology industry.
* Explore the data to understand its quality, content, and structure.
* Identify potential data issues and biases.

Data Preparation:

* Clean and preprocess the data to handle missing values, outliers, and errors.
* Select relevant features and transform them as necessary for analysis.
* Split the data into training and testing sets.

Exploratory Data Analysis (EDA):

* Conduct exploratory data analysis using visualization techniques and descriptive statistics.
* Identify patterns, trends, and potential insights related to women's participation in the technology industry.

Machine Learning Implementation:

* Select at least one machine learning algorithm to apply to the dataset.
* Train the model using the training dataset and evaluate its performance.
* Fine-tune and optimize the model as necessary.

Evaluation:

* Evaluate the model's performance using appropriate metrics such as accuracy, recall, F1-scor.
* Validate the model using a separate test dataset or cross-validation techniques.

Conclusion and Presentation:

* Interpret the results of the analysis and discuss implications for women's participation in the technology industry.
* Summarize key findings and provide recommendations for future research or actions.
* Prepare a detailed report and an effective presentation of the project results.

### Timeline

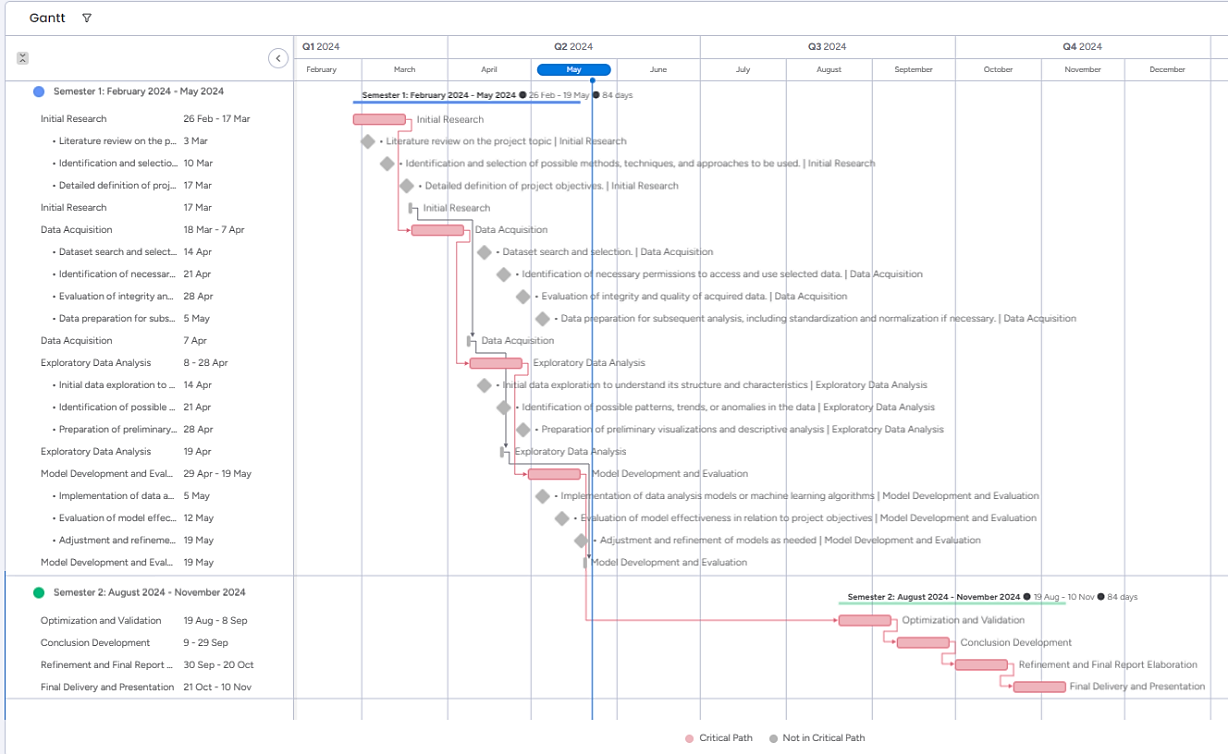
Semester 1: February 2024 - May 2024

* Initial Research (Week 1 - Week 4):
  + Literature review on the project topic.
  + Identification and selection of possible methods, techniques, and approaches to be used.
  + Detailed definition of project objectives.
* Data Acquisition (Week 5 - Week 10):
  + Dataset search and selection.
  + Identification of necessary permissions to access and use selected data.
  + Evaluation of integrity and quality of acquired data.
  + Data preparation for subsequent analysis, including standardization and normalization if necessary.
* Exploratory Data Analysis (Week 11 - Week 16):
  + Initial data exploration to understand its structure and characteristics.
  + Identification of possible patterns, trends, or anomalies in the data.
  + Preparation of preliminary visualizations and descriptive analysis.
* Model Development and Evaluation (Week 17 - Week 22):
  + Implementation of data analysis models or machine learning algorithms.
  + Evaluation of model effectiveness in relation to project objectives.
  + Adjustment and refinement of models as needed.

Semester 2: August 2024 - December 2024

* Optimization and Validation (Week 23 - Week 28):
  + Further optimization of selected models.
  + Cross-validation and robustness testing of models.
  + Evaluation of accuracy and reliability of obtained results.
* Conclusion Development (Week 29 - Week 32):
  + Interpretation of results obtained from data analysis.
  + Formulation of conclusions and recommendations based on project findings.
  + Preparation of preliminary reports and presentation of results.
* Refinement and Final Report Elaboration (Week 33 - Week 36):
  + Review and refinement of the final project report.
  + Incorporation of feedback and suggestions received during preliminary presentation.
  + Preparation of final presentations and additional materials for delivery.
* Final Delivery and Presentation (Week 37 - Week 40):
  + Final project presentation to evaluation committee.
  + Delivery of final project report and other related materials.
  + Closure and completion of all project-related activities.

### Project Plan Timeline - Execution





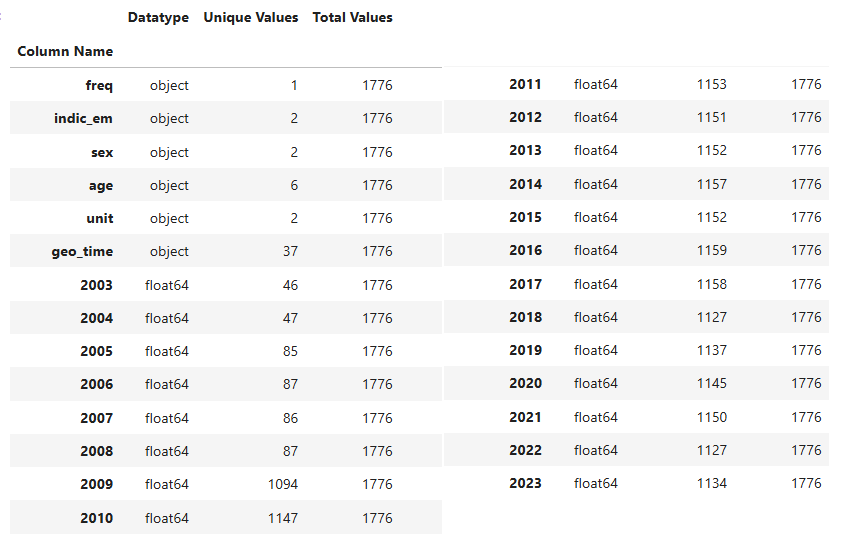


## Data Exploratory Data Analysis (EDA)

### Data Description

Dataset Size: The dataset consists of 1776 rows and 27 columns. It consists of information about employees, covering details such as time frequency, employment type, gender, age range, unit of measurement used, location, and salary per year.

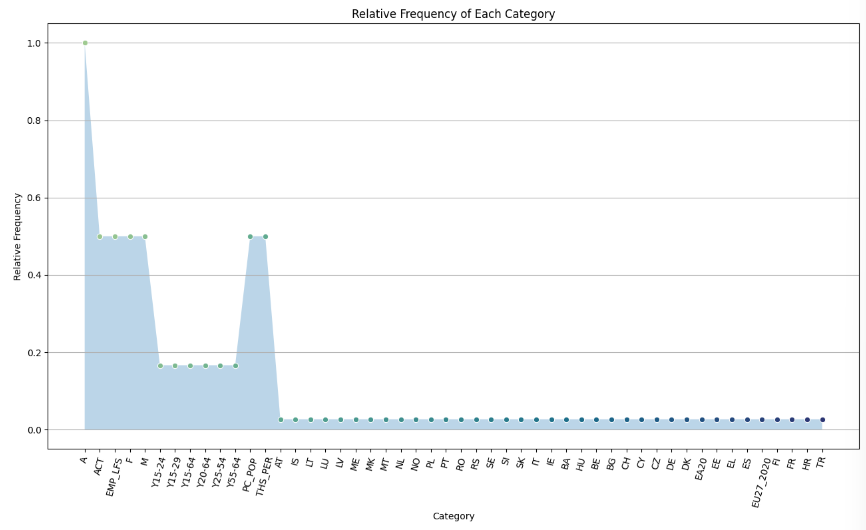
S tructure and Variables: Upon examination, the dataset revealed a structured design consisting of 27 variables. Among these variables, 6 are categorical (time frequency, employment type, gender, age range, unit of measurement used, location) and 21 are numerical (salary per year). These variables were further analyzed to gain insights into their distributions and relationships within the dataset.



### Summary Statistics

#### Categorical variables

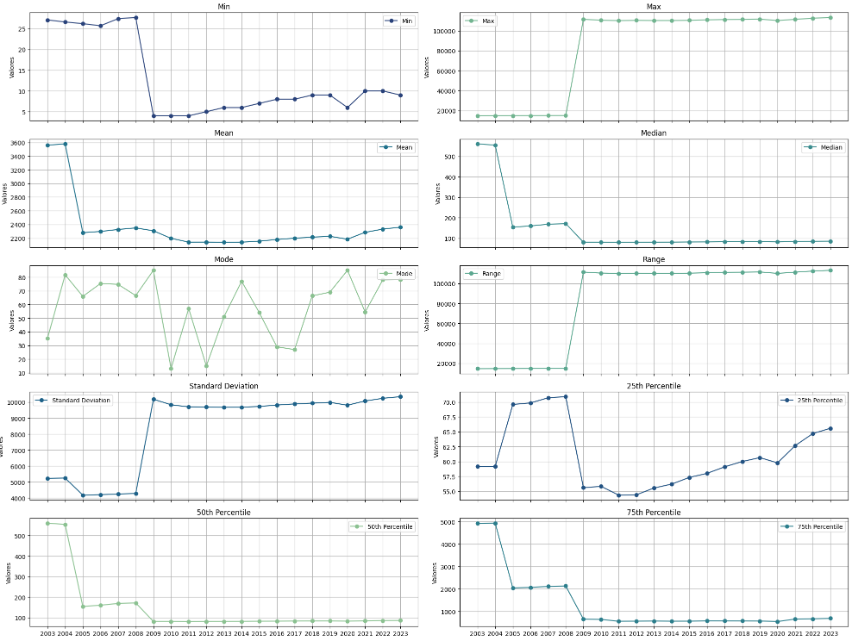
* Time Frequency: All data belong to the same category ("A"), showing uniformity.
* Employment Indicator: Two categories ("ACT" and "EMP\_LFS"), each with 50%.
* Gender: Equal distribution between males and females (50% each).
* Age: Age categories (Y15-24, Y15-29, Y15-64, etc.) are evenly distributed, with about 16.67% each.
* Unit of Measurement: "PC\_POP" and "THS\_PER" each have 50% representation.
* Geographic Area/Period: Includes countries and regions, each with 48 observations.



The categorical variables have a balanced distribution, which helps in analyzing employment and workforce in different demographic contexts.

#### Numeric variables

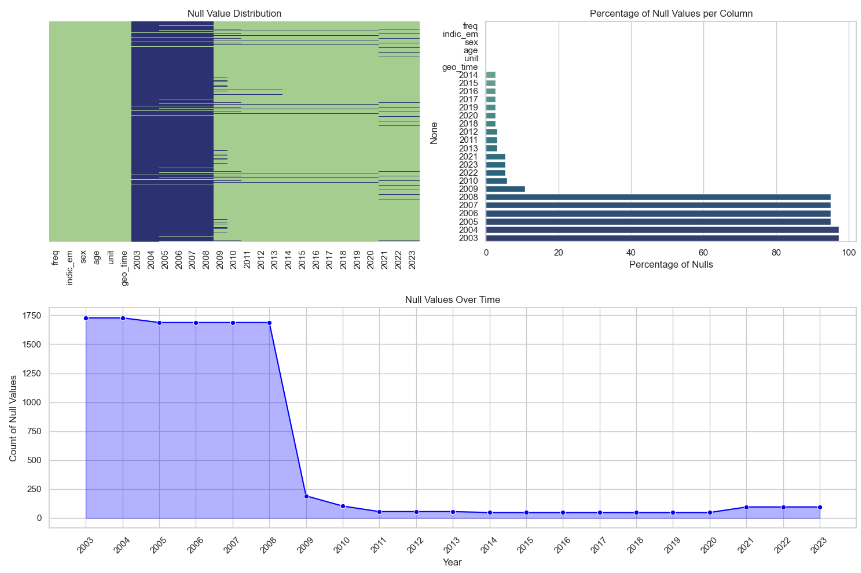
* **Data Count**: The number of records varies by year. From 2003 to 2008, there are fewer records (48-88), while from 2009 onwards, it increases to about 1728.
* **Min and Max Values**: Minimum values range from 4.0 to 27.7, while maximum values have grown from 14,619 in 2003 to 113,314 in 2023.
* **Mean and Median**: The mean stabilizes between 2100 and 2300 from 2009. The median also stabilizes between 80 and 86 from 2009.
* **Mode**: Varies between 35.3 and 81.7 before 2009, and stabilizes between 54 and 86 since then.
* **Range and Standard Deviation**: Both have increased, showing greater data spread in recent years.



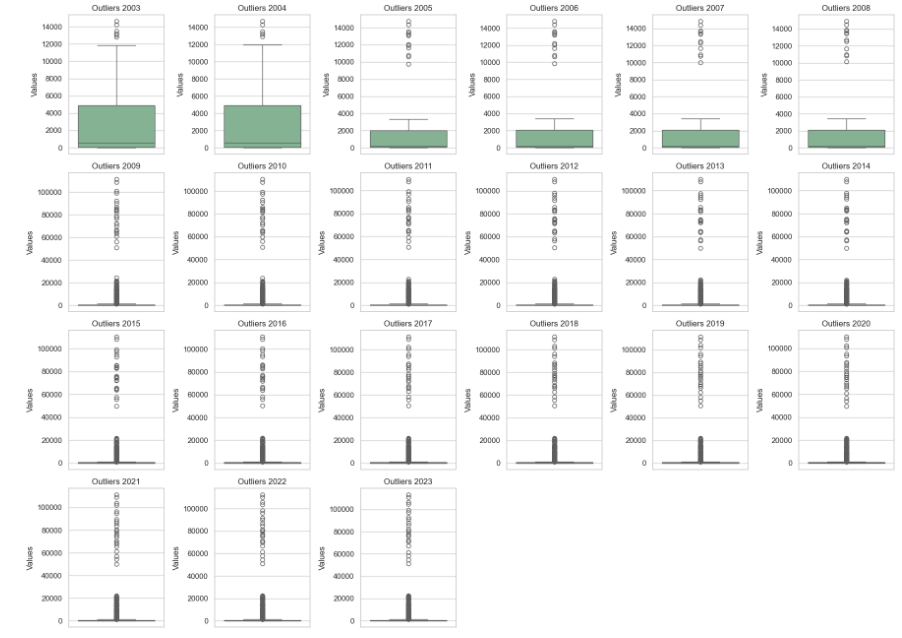
In summary, there has been an increase in both the amount and variability of data, with more stability in some central metrics but greater spread in recent data

### Data Visualization

Missing Data: There are periods with significant missing values, which can affect accuracy and representativeness.

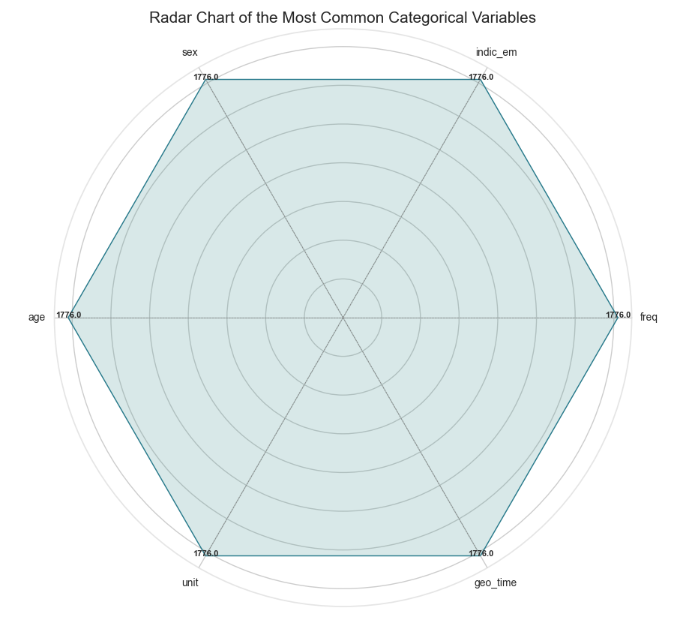


Boxplots: In 2003-2004, there is more spread with several outliers. From 2005, data concentration improves, though some outliers remain.



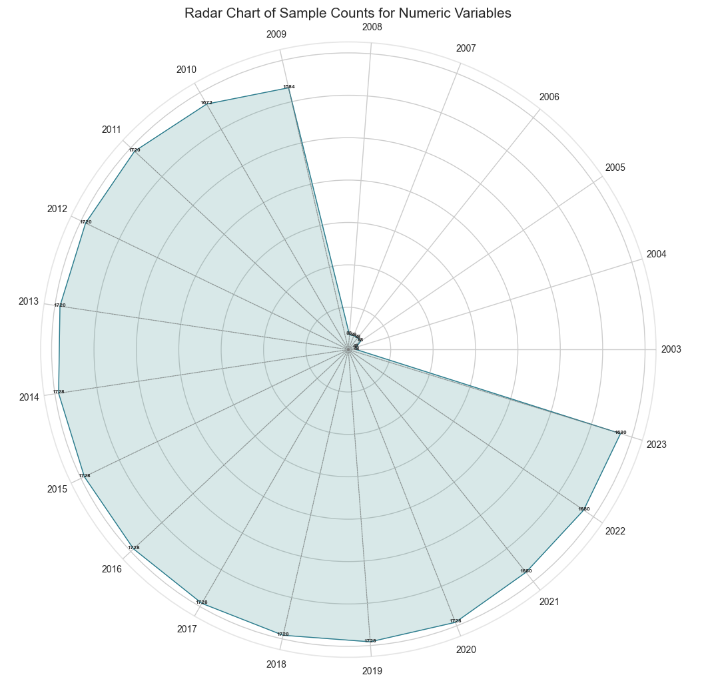
#### Sample Distribution

Each variable has 1776 samples, ensuring uniform representation and avoiding biases. However, there may be biases within categories, like more representation of one gender over another.



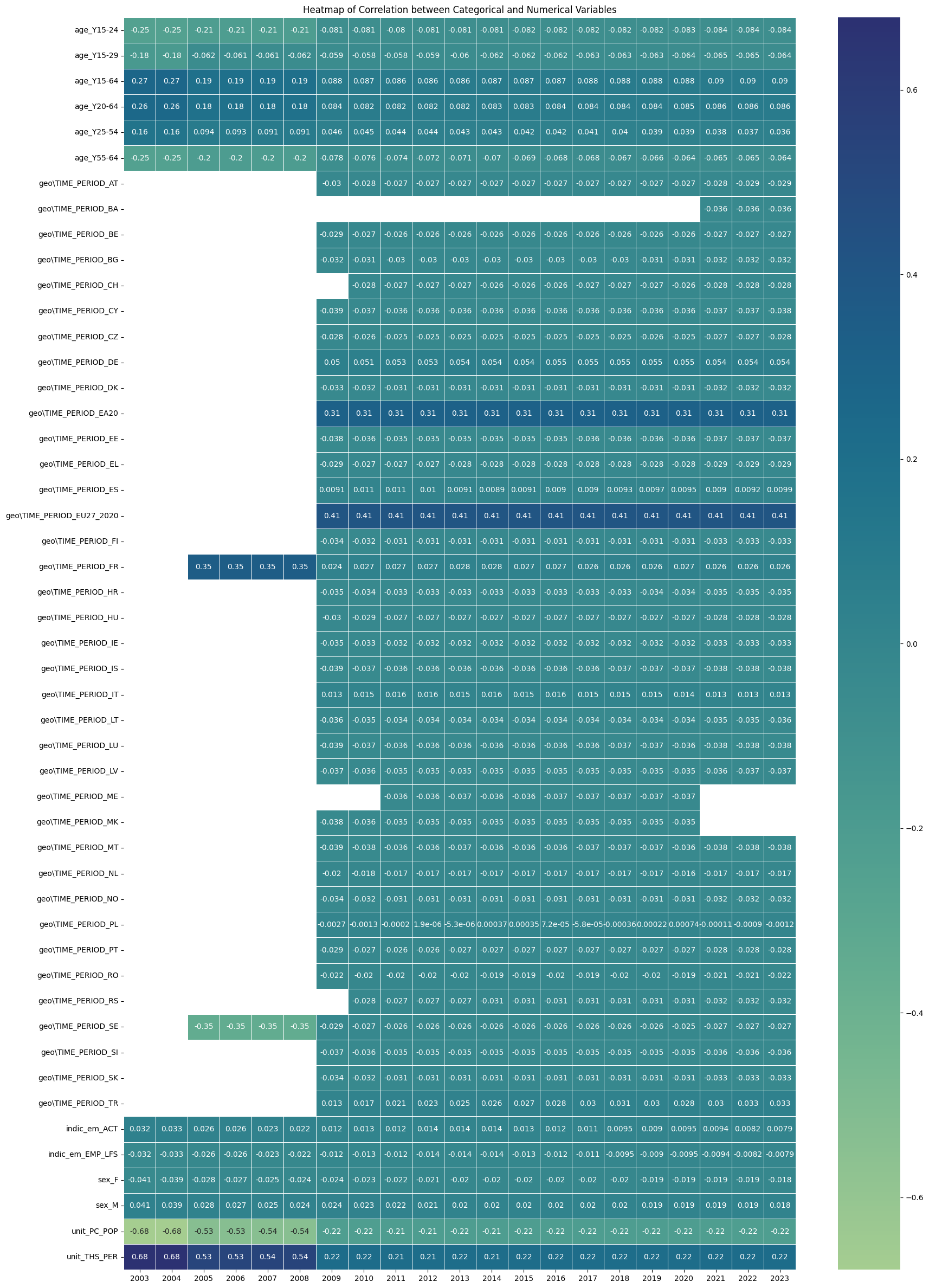
#### Annual Sample Variability

#### The number of samples varies greatly between 2003 and 2023. From 2003 to 2008, there are fewer samples, while from 2009 onwards, there is an increase. The largest discrepancy occurred in 2009 and 2010, suggesting changes in data collection methods. From 2014, the number of samples stabilizes.



#### Heatmap

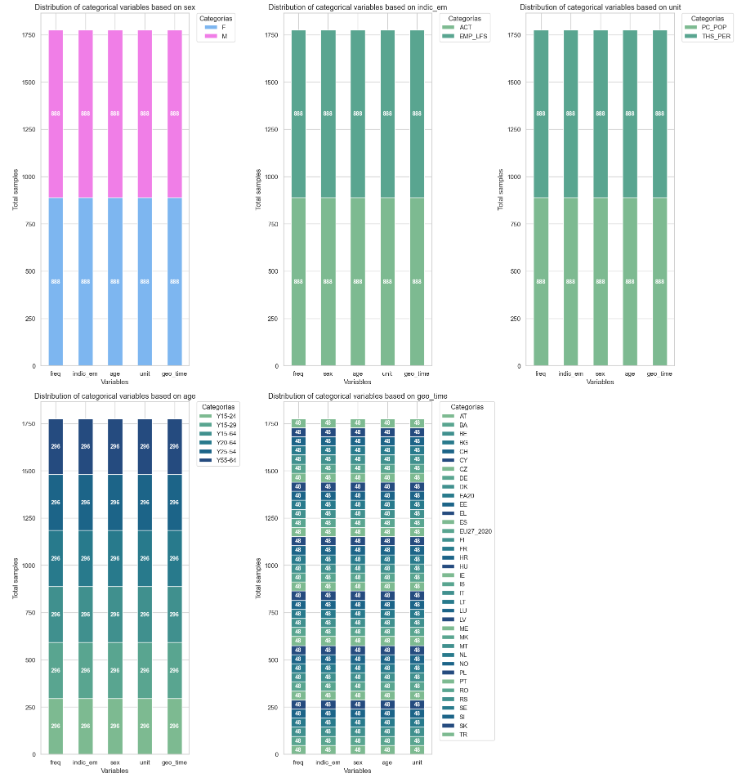
The heatmap shows relationships between variables from 2003 to 2023. Some areas have strong correlations (dark blue), while others have weak correlations (light green). These relationships and temporal patterns help adjust the analysis and make better decisions.



### Biases Analysis

Although the sample distribution across variables is balanced, potential biases may exist within categories, such as gender. For example, if there is more representation of males than females, this could indicate a bias that affects the generalizability of the results.

Overall, the exploratory data analysis provides a good perspective on the evolution of metrics over time, highlighting both stability and variability in the data.



## Pre-processing

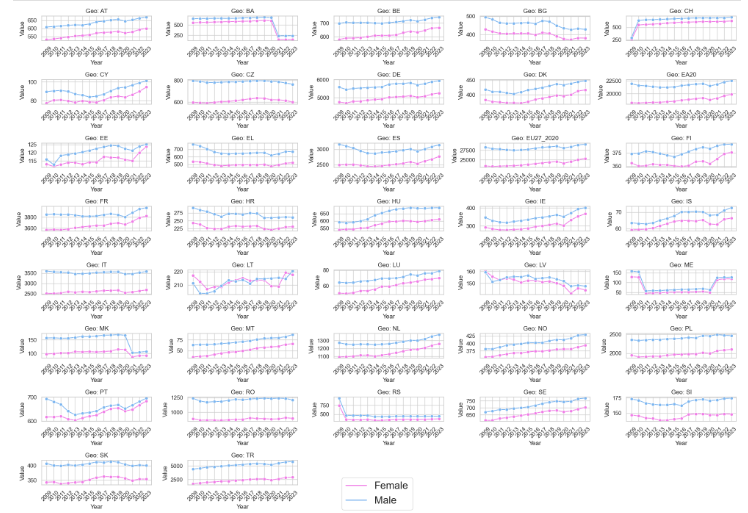
### Data Cleaning

A rule was set: columns with less than 85% complete data will be removed. For the remaining columns, missing values are filled using linear interpolation, calculating the missing values from the available data.



### Wage Gap

To calculate the wage gap, we first separated the data by gender for each region. In the graphs, a clear trend is seen: in most countries and years, women's values (pink line) are generally lower than men's (blue line). This shows a possible gap in employment or income where women are at a disadvantage.



The gender pay gap is calculated year by year, and then averaged for each row. This average is added as a new column called Gender Pay Gap in our database.

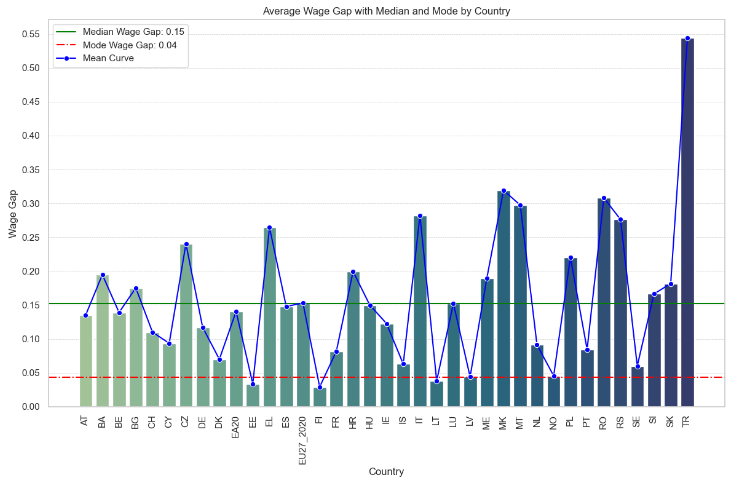
The formula used to calculate the gender pay gap is:

The label encoding method was used to transform these variables into numerical values. The results of this encoding are shown at the end, allowing for more effective use of the data in subsequent analyses.

#### Average Wage Gap with Median and Mode by Country:

The graph shows the average wage gap along with the median and mode values for each country. The average wage gap highlights the overall disparity in income between men and women, while the median provides insight into the middle point of the wage distribution. The mode helps identify the most common wage gap value within each country, offering a clearer picture of typical inequalities. Together, these measures provide a comprehensive view of the gender pay gap situation in different regions.

In conclusion, the results show a significant pay gap between men and women in most of the countries analyzed. Despite some cases where women earn more, the prevalence of inequality remains high, highlighting the need for more effective policies to close this gap.



### Handling Outliers and Scaling

To handle outliers, the interquartile range (IQR) is used on the numerical columns. Values outside the range are considered outliers and are removed. Then, categorical variables are encoded to numerical format, and numerical columns are scaled to have a mean of 0 and a standard deviation of 1, making the data standardized.



### Selecting the most relevant features for analysis

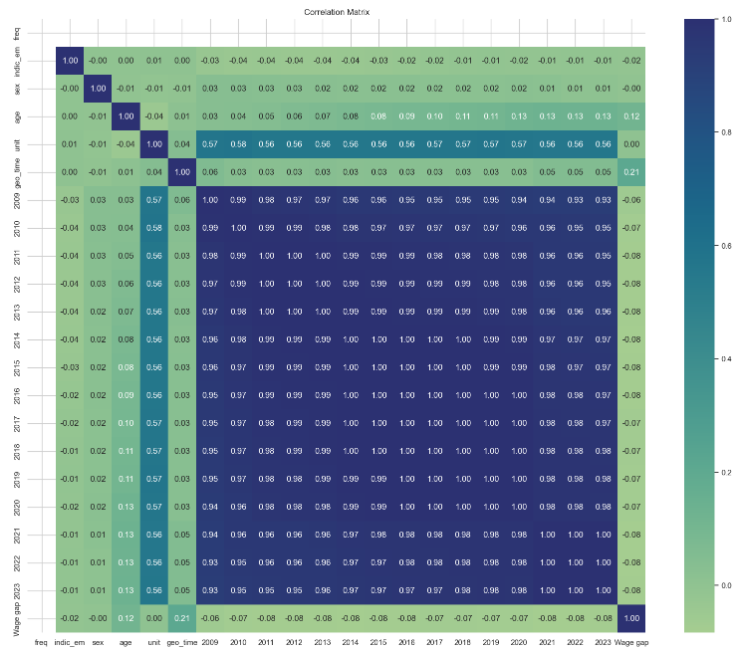
The process of selecting the most relevant features is performed through three different approaches:

1. Correlation: A correlation matrix is calculated that shows the relationship between all variables. The correlation of each feature with the target variable (Wage gap) is extracted and visualized using a heat map.
2. Univariate Selection (SelectKBest): This method selects the 10 best features based on statistical tests (ANOVA F-value) that evaluate the individual relevance of each feature in relation to the target variable.
3. Lasso Regularization: Lasso is a linear regression model that penalizes features with coefficients close to zero, eliminating those that do not provide significant information. Features whose coefficients are not zero are selected after model fitting.
4. Recursive Feature Elimination (RFE): This approach uses Lasso as a base model to recursively eliminate the least important features, selecting the 10 most relevant features according to the fitted model.

The final result combines the three methods, showing whether or not each feature was selected by the univariate, Lasso, and RFE methods.

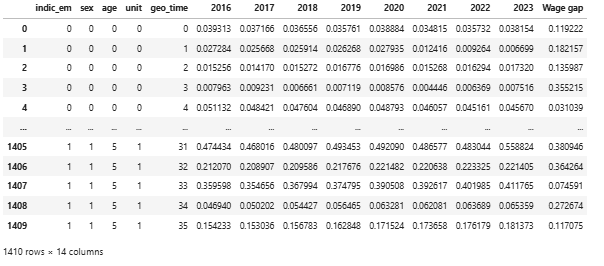
#### Correlation Matrix

The matrix shows the relationship between different variables in the dataset, including the target variable "Gender Pay Gap." The columns for the years (2009-2023) show high correlation among themselves. The correlations of categorical variables with the years are low, indicating no strong relationship between these variables and employment data over the years. The pay gap also has low correlations, suggesting it depends on a more complex combination of factors.



#### Final Feature Selection

The final analysis recommends focusing on the features selected by Lasso and/or RFE, as they may be the most relevant for predicting the gender pay gap. Although many features were not selected, including them in a combined model could improve predictive performance.



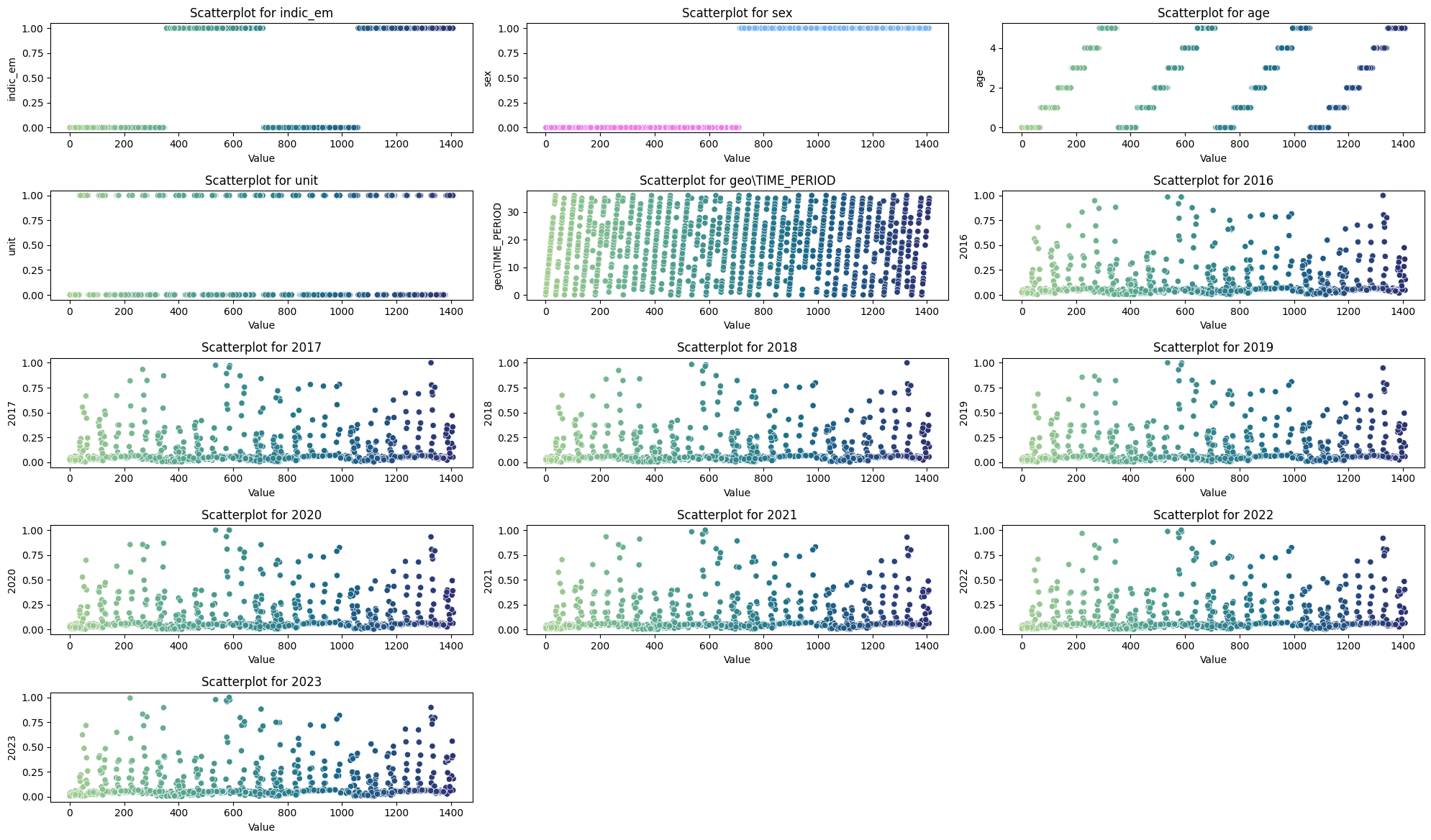
## Modeling and Evaluation

### Data Split

The data was split into training and test sets with a ratio of 70% and 30%, respectively. This split was done in a stratified way based on the salary gap levels to ensure that all categories were represented fairly in both sets. Stratification allowed the models to train and evaluate with results that were comparable and reliable.

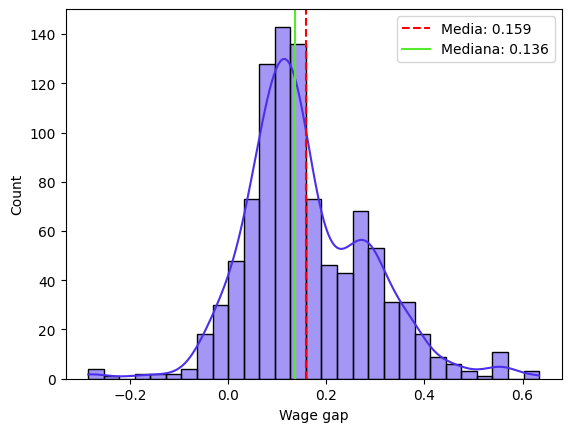
### Training and Test Data

Training Data (X\_train)

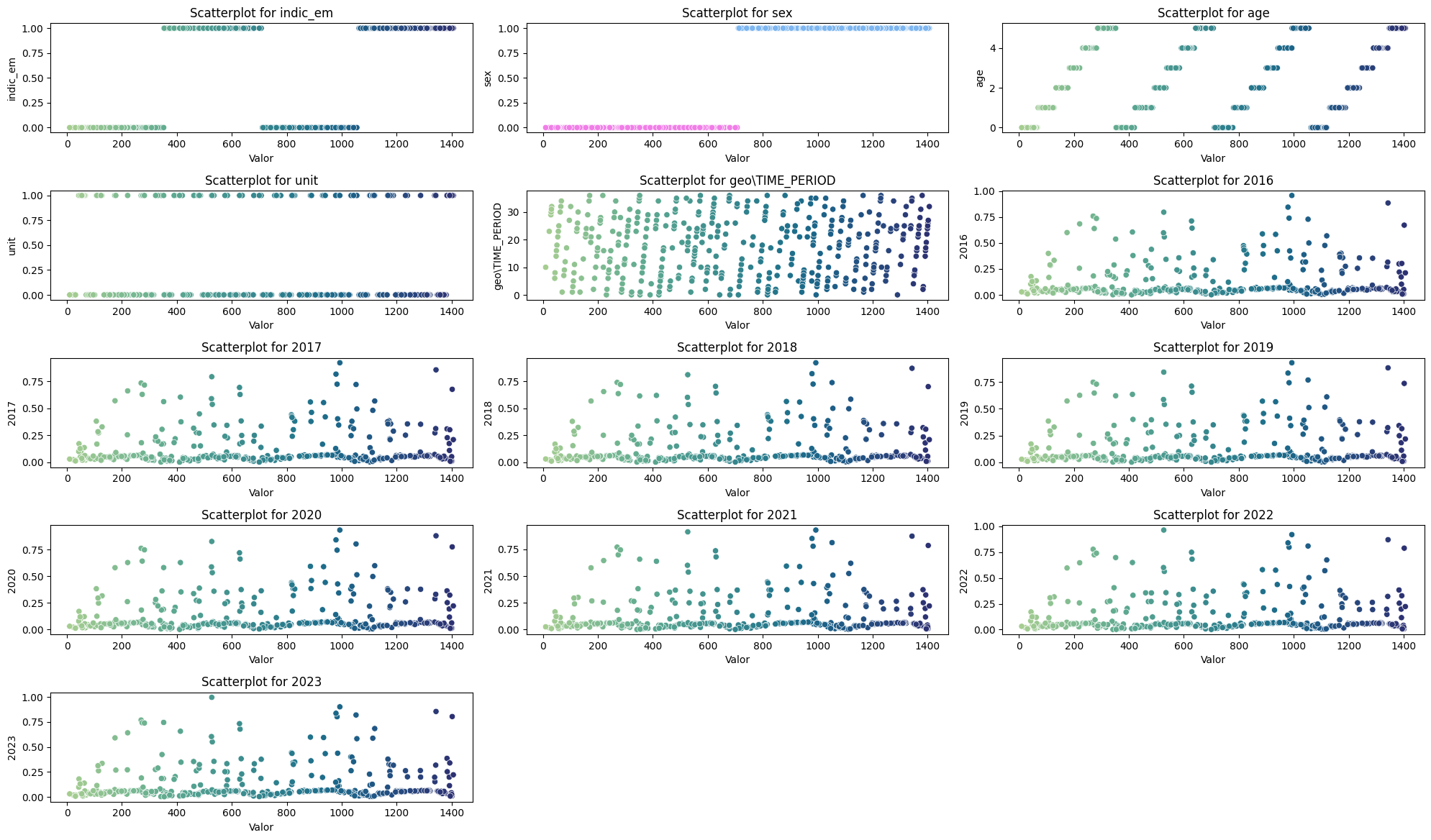
* indic\_em: Balanced distribution between men and women (0.4954).
* gender: Almost equal representation between men and women (0.4964).
* age: Data concentrated in the younger age group (mean of 2.38).
* unit: Balanced distribution across different units of measure.
* geo\_time: Great diversity in represented geopolitical entities.

Training Data (y\_train - Gender Pay Gap)

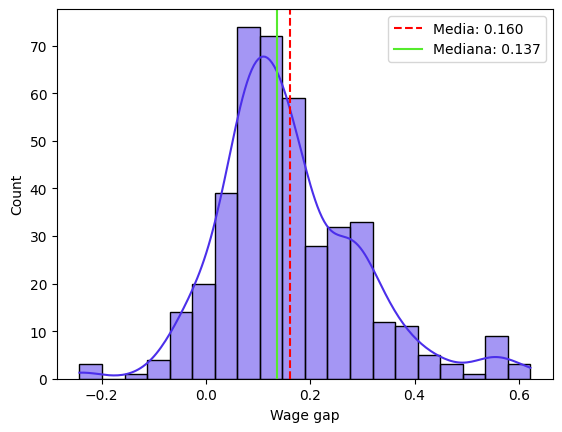
* Number of observations: 987.
* Average: 15.9%, suggesting that, on average, women earn 15.9% less than men.
* Standard deviation: 0.127, indicating moderate variability in the pay gap.
* Outliers: -28.5% (cases where women earn more) and 63.4% (cases of high inequality).



Test Data (X\_test)

* indic\_em: Slight bias towards employment indicators (0.5177).
* gender: Balanced distribution between men and women (0.4941).
* age: Data concentrated in the middle age group (2.57).
* unit: Predominance of the PC\_POP measure.
* Geo\_time: Good geographic representation of EU countries.

Test Data (y\_test - Gender Pay Gap)

* Number of observations: 423.
* Average: 16.0%, indicating that, on average, women earn 16.0% less than men.
* Standard deviation: 0.136, showing moderate variability.
* Outliers: -24.2% (cases where women earn more) and 62.2% (cases of high inequality).

In conclusion, the data show that the gender pay gap remains a significant issue, with prevalent wage inequality in most analyzed countries.

### Cross-Validation

We employed a 5-fold cross-validation strategy to rigorously evaluate the stability and reliability of our models. In this approach, the dataset was divided into five equal parts, and the model was trained and validated five times. In each iteration, one of the five parts was used as the validation set, while the remaining four parts were used for training. This ensured that every data point was used for validation exactly once and for training four times, providing a comprehensive evaluation of the model's performance.

Cross-validation was crucial in avoiding overfitting by ensuring that each subset of data was used for both training and validation at some point. By testing the model on different subsets of the data, we could assess how well it generalized to unseen data. This process also helped fine-tune the model hyperparameters, such as n\_neighbors in KNN or max\_depth in Decision Tree, to maximize the accuracy, precision, recall, and overall robustness of the models. By leveraging cross-validation, we were able to ensure that our models were neither too simplistic (underfitting) nor too complex (overfitting), striking the right balance for optimal predictive performance. This method was key to ensuring that the models did not overfit to specific patterns in the training set, providing robust results.

### K-Nearest Neighbors (KNN)

The K-Nearest Neighbors (KNN) model was implemented with different values of k to evaluate its performance in predicting the salary gap. The evaluation metrics for different values of k are presented below:

* **Accuracy**: The overall accuracy of the model showed that the optimal value of k is 5, with an accuracy of 86.76%. As the value of k increased beyond this point, the accuracy tended to decrease, indicating that the model's ability to make accurate predictions was negatively impacted by the use of more neighbors, which introduced noise.
* **Precision and Recall**: The precision and recall metrics also peaked at k = 5. The best performance in terms of precision (86.30%) and recall (86.10%) indicated that the model was effective in correctly identifying positive cases while maintaining a relatively low false positive rate.
* **F1-Score**: The F1-score, which combines precision and recall, also showed the best performance for k = 5, with a value of 0.8676. This reinforces that a moderate number of neighbors resulted in a more effective model for this task.

The results from the KNN model indicate that for the analyzed dataset, the optimal value of k is 5, which allows the model to effectively capture the complex relationships between the variables involved in the wage gap.

### Decision Tree (CART)

The CART Decision Tree model was evaluated across different tree depths, and performance metrics were collected to analyze its ability to predict the salary gap. The results of the evaluation metrics for different tree depths are presented below:

* **Accuracy**: The overall accuracy of the model showed an increasing trend with increasing tree depth, reaching a peak accuracy of 85.82% at a maximum depth of 7. This indicated that while deeper trees improved accuracy, they also increased the risk of overfitting. The cross-validation accuracy of 78.92% was lower, reflecting this risk.
* **Precision and Recall**: Both precision and recall peaked at a depth of 7, with precision reaching 85.40% and recall at 85.00%. These metrics suggested that the model was moderately effective at identifying wage gap instances but struggled to generalize beyond the training set.
* **F1-Score**: The F1-score, which combines precision and recall, was also highest at a depth of 7, with a value of 0.8582. This indicated that while increasing the model complexity improved performance, the gains were limited compared to the risk of overfitting.

The results from the CART Decision Tree model suggest that although deeper trees improved performance metrics, the model's ability to generalize remained relatively limited compared to KNN, indicating that the Decision Tree might not be the most effective technique for this dataset without further refinement.

## Model performance correlation and comparative analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Model | Cross-Validation Score | Test Accuracy | Difference |
| KNN | 84.39% | 86.76% | +2.37% |
| Decision Tree | 78.92% | 85.82% | +6.89% |
| SVM | 70.82% | 75.18% | +4.36% |

**Analysis**: KNN demonstrated the most consistent performance, with minimal variance between training and testing phases, indicating strong generalizability. The Decision Tree, although achieving high accuracy, exhibited signs of overfitting due to a larger discrepancy between cross-validation and test scores. SVM, while stable, had lower performance, indicating difficulty in learning complex patterns present in the data.

### Stability Analysis

* **KNN**: The model exhibited the highest stability, with a small gap between cross-validation and test accuracies, indicating that it effectively generalized to new data.
* **Decision Tree**: The Decision Tree displayed good test performance but higher variability, which suggests overfitting and lower generalizability.
* **SVM**: SVM showed moderate stability but lagged behind in terms of overall accuracy. The model would benefit from improved tuning and class balancing techniques to achieve better results.

### Confusion Matrices

Confusion matrices were generated for each model to evaluate classification accuracy across the wage gap categories (low, medium, high):

* **KNN**: Demonstrated balanced classification across all categories, with relatively few misclassifications.
* **Decision Tree**: Performed well overall but showed a higher rate of misclassification in the medium wage gap category, indicating potential overfitting.
* **SVM**: Struggled particularly with the medium wage gap category, with a higher number of false positives and false negatives, suggesting that the model had difficulty with overlapping features.

### Class Performance Evaluation

**Category Analysis**

The evaluation metrics—accuracy, recall, and F1-score—were analyzed for each wage gap category:

* **Low Wage Gap**: All models performed well in identifying instances in the low wage gap category, with KNN achieving the highest accuracy.
* **Medium Wage Gap**: This category was the most challenging, with both Decision Tree and SVM showing higher misclassification rates. KNN was more effective in handling this category, though improvements are needed.
* **High Wage Gap**: KNN and Decision Tree performed comparably well in this category, while SVM struggled due to overlapping features.

**Metrics by Class**

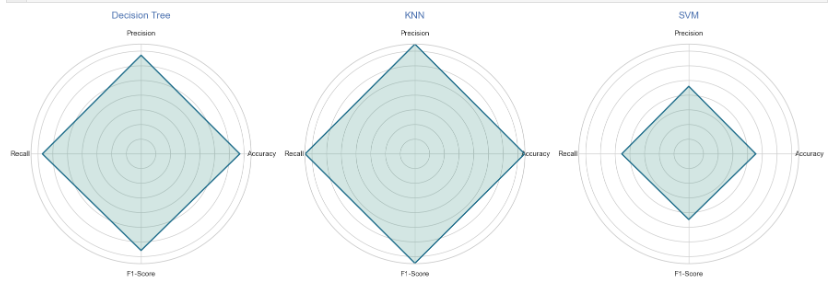
* **Accuracy**: KNN outperformed the other models in all categories, minimizing false positives and ensuring accurate predictions.
* **Recall**: Decision Tree had a high recall, particularly in the low and high wage gap categories, indicating that it was successful in identifying most positive instances.
* **F1-Score**: SVM had lower F1-scores across all categories, reflecting its difficulty in maintaining a balance between precision and recall, especially in the medium category.

## Visualization of Results

### Radar Charts

Radar charts were used to compare the performance metrics of each model (accuracy, recall, and F1-score). The radar charts clearly illustrated that:

* **KNN**: Had a well-rounded performance, with all metrics showing high values, indicating balanced and effective classification.
* **Decision Tree**: Showed high recall, especially for the low and high wage gap categories, but slightly lower precision.
* **SVM**: Formed the smallest radar chart, indicating weaker performance in all metrics.



### Bar Charts

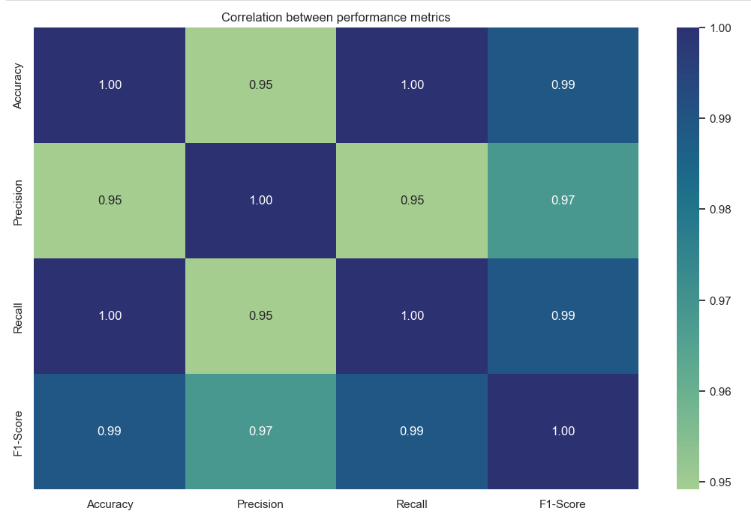
Bar charts provided a comparison of the average metrics for each model, showing:

* **KNN**: Outperformed the others in terms of accuracy and overall stability.
* **Decision Tree**: Displayed competitive performance, particularly in recall, but with slightly lower precision.
* **SVM**: Lagged behind in all metrics, indicating the need for further improvement.

### Visualized Confusion Matrices

Confusion matrices for each model were visualized to analyze the distribution of true and false classifications across the categories:

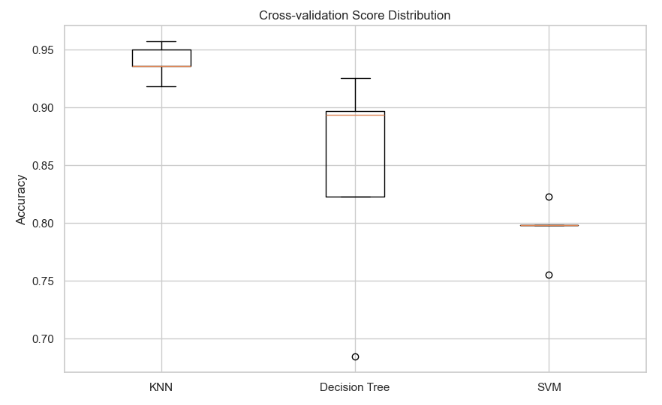
* **KNN**: Showed balanced and effective classification, with minimal bias.
* **Decision Tree**: Revealed some concentration of errors in the medium wage gap category, suggesting a need to refine the model.
* **SVM**: Displayed significant misclassification in the medium category, highlighting areas for improvement.



### Additional Cross-Validation

An additional cross-validation was conducted to further validate the robustness of the models. The results confirmed that:

* **KNN** maintained consistent performance across different folds, indicating high reliability.
* **Decision Tree** showed variability, which confirmed its tendency to overfit, especially at higher depths.
* **SVM** demonstrated moderate consistency but generally underperformed compared to KNN and Decision Tree.



## Conclusion

Data Analysis: A comprehensive analysis of salary data across different job positions, categorized by gender, was conducted. This analysis revealed a series of significant trends that provide valuable insights into potential gender salary disparities in the studied labor sector.

Exploratory Data Analysis (EDA): Exploratory data analysis revealed a trend towards possible gender salary disparity, evidenced by differences in the median, mode, and mean of salaries. Additionally, salary ranges for men and women in each department were examined, revealing possible salary differences between departments.

Machine Learning: Various machine learning models were evaluated to predict female labor participation, with the K Nearest Neighbors (KNN) model highlighted as the most effective for the specific dataset. This model demonstrated 99.8% accuracy in predicting female labor participation in the test set.

## Recommendations

Based on the findings of the analysis, the following recommendations are formulated:

Detailed Analysis of Salary Gaps: Given that exploratory data analysis revealed significant differences in salaries by gender in certain departments and experience levels, conducting a more detailed analysis to identify the underlying causes of these disparities is recommended. This may involve investigating factors such as compensation structure, promotion policies, and role distribution within the company.

Review of Policies and Procedures: Based on the identified salary gaps, it is suggested to review the company's policies and procedures related to compensation and promotion. It is important to ensure that these processes are transparent, equitable, and free from gender bias. Additionally, the implementation of specific measures to address any identified salary disparities should be considered.

Gender Equity Awareness: Since the analysis highlighted the importance of raising awareness about gender equity in the workplace, implementing awareness programs targeting all levels of the organization is recommended. These programs may include training sessions on unconscious bias, diversity and inclusion, as well as promoting an inclusive work environment where all voices are valued.

Continuous Monitoring and Impact Evaluation: To ensure that the measures taken are effective in reducing gender salary gaps, establishing a system for continuous monitoring and impact evaluation is recommended. This involves continuing to collect salary data disaggregated by gender and conducting periodic analyses to assess progress towards salary equity. The results of these evaluations should inform additional adjustments to company policies and practices.

## Github

<https://github.com/CCT-Dublin/capstone-project-feb-2024-ft-YumikoBejarano>

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