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Graduate Business School

# Analysis of Irish population

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## 1. Execute Summary:

This analysis, which is devoted to researching the Irish population and demographics, sheds light on understanding the past and the future of the population of Ireland. Our team analyzed the dispersion and central tendency of the total population of Ireland between 1841 and 2022. In addition, the dynamics of the main populous counties were also analyzed, using sampling by factor. Furthermore, our team analyzed the central tendencies in birth and death rates per 1000 people as well. In the inferential statistics part, we proved the hypothesis that the Irish annual total population growth is greater than the EU using three types of tests. In addition, using the One t-test our team found evidence that the most populous regions in Ireland are doing better than the nation on average in terms of annual population growth. In investigating the correlation between population natural growth and various factors, our team conducted three correlation tests (Multi correlation analysis) and found the female unemployment-to-population ratio data describing natural growth the best. Taking this into consideration, we forecasted the population's life expectancy with a 95% confidence displayed as upper and lower confidence intervals. Finally, we also proved the life expectancy and the percentage of the population receiving higher education datasets have a tight correlation. To sum up, the research concludes that the Irish total population has a greater substantial annual growth than in the EU, with the three most populous counties surpassing the national level. The national growth, which is tightened by the female unemployment-to-population ratio upward dynamics, is defined by the future working conditions for women and health services for the people. The life expectancy at birth in Ireland, which has the best correlation with time and the female unemployment-to-population ratio, is set to continue linear growth.

## 2. Introduction:

After many decades, the population and demographic data still plays the role of important indicator in evaluating current social conditions and conclusions about the good and bad time in Ireland. As the country is gaining popularity as the “next global finance/IT hub” among professionals, it is crucial to make the statistics analysis of data at different intervals to understand the past and the future in terms of population and the people of Ireland. By conducting the analysis our team wants to answer these groups of questions:

a) What are the historical tendencies in the total population over a long time? How significantly greater is the annual total population growth in Ireland than in EU, and is there sufficient data to conclude?

b) What are the historical dynamics of the most populous counties in Ireland? Does the greater population in key driving counties mean that the population growth is greater than national as well?

c) What do the births and deaths data together and individually indicate in recent decades? Which independent data could describe (have a better correlation with) the natural growth dynamics the best?

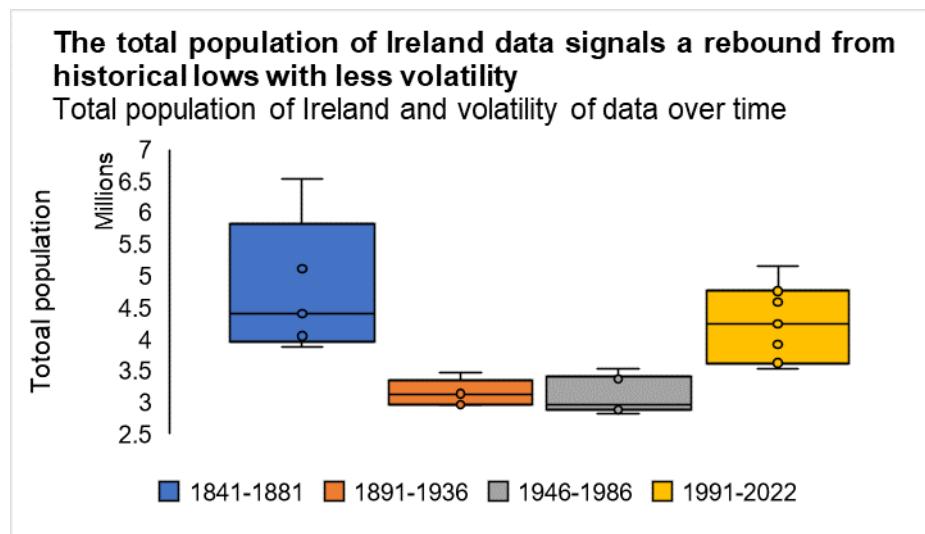
d) What do the life expectancy data show with subjects to different age groups? What is the forecasted life expectancy in the upcoming decades? Which data better describes the life expectancy and has a non-zero  $\beta_1$  regression coefficient?

The total population, life expectancy, birth and death rates data are taken from the “Central Statistics Office of Ireland” website as well as GDP per capita, female employment-to-population, and unemployment rate among women from the “Our World in Data” website.

### 3. Statistics analysis

#### 3.1 Descriptive statistics:

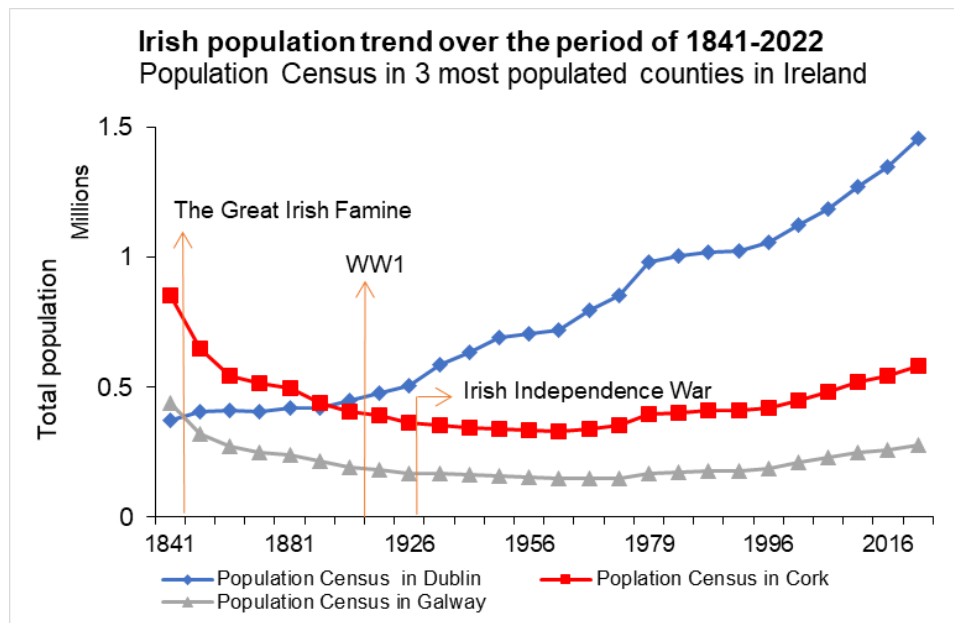
To present the general trends in the total population of Ireland, we processed the data set consisting of 26 observations between 1841 and 2022 and visualized it using the box plots. The data presented in Graph 1 below was grouped into four groups equal by time but not the number of observations, which better describe both the main central tendency and dispersion.



**Graph 1: The dispersion and central tendency of the Irish total population**

The Irish population has been unstable for the last 180 years, particularly due to the Great Famine which led to numerous deaths and emigrations, resulting in a halving of the population from 6.52 million in 1841 to 2.96 million in 1936. However, since the establishment of a new economic world order, the population stabilized at 2.96 million by 1986 and has experienced significant growth, reaching 5.1 million people over the last 30 years. Once shocked by the Great Famine and its consequences, the Irish population not only surpassed the population wows of the late 19th century but has all chances to reach all-time high levels as well.

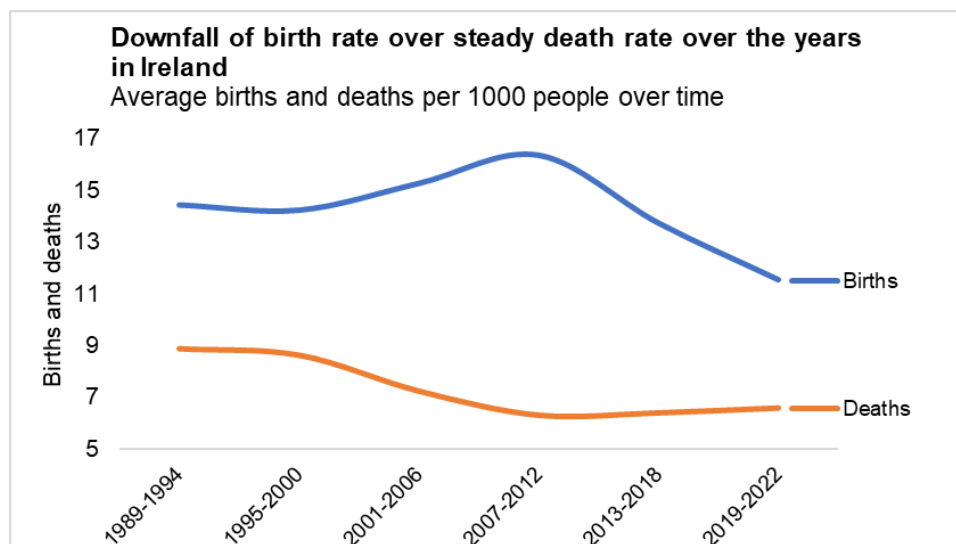
To understand the tendencies within the country, the presented above data was subjected to the county filter. This sorting allowed sampling of the population data of the leading ones. As a result, Cork, Dublin, and Galway were selected as the most populous and relevant and visualized in Graph 2 for further analysis.



**Graph 2: Population in Dublin, Cork, and Galway**

The graph depicts the population growth trends of Irish counties, with Dublin emerging as the most populous, trailed by Cork and Galway. Over time, Dublin has consistently been at the forefront of urbanization and economic development as the nation's capital. Its population has experienced substantial growth, namely, nearly increased in 5 folds. In contrast, Galway witnessed a pronounced decline, reaching its lowest point in 1966, followed by a gradual but steady increase from 440'198 to 277'737. A comparable pattern is evident in Cork, where a notable population decline during and after the Great Irish Famine led to its lowest point in 1961. Nevertheless, as the total population in Ireland bounced off in the second half of the 20th century, the other cities began to embrace this trend. This graph underlines the main beneficiary city of the domestic migration as well as average contributing cities.

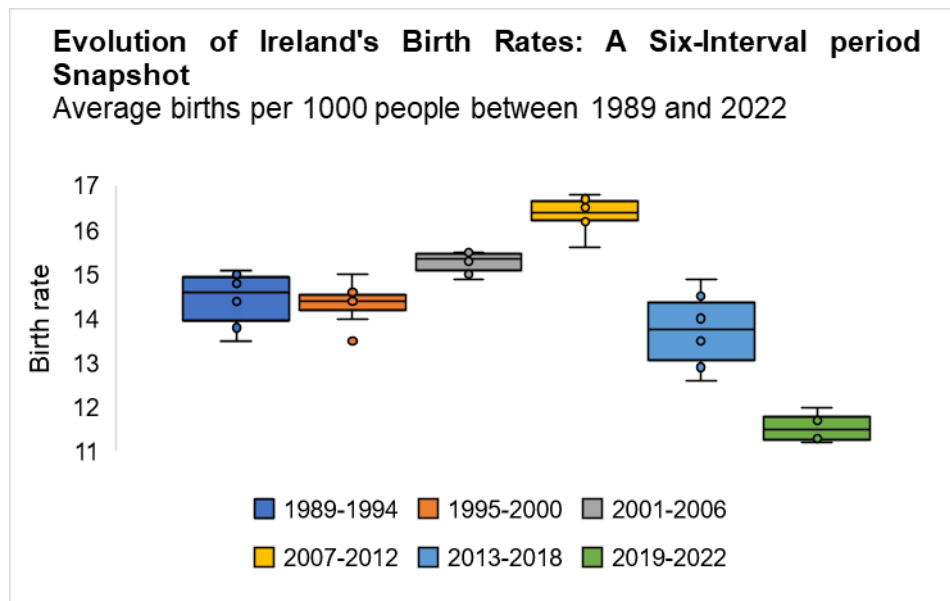
Along with the data presented above, we also analyzed central tendencies in birth and death rates more closely as this data sheds light on understanding the actual demographic situation in Ireland. Each data set consisted of 34 observations and was split equally into six intervals to adequately reflect the average trends of the last 33 years, Graph 3 below.



### Graph 3: Average births and deaths per 1000 people

According to the graph, Ireland has encountered drastic changes in its birth rate but seems to have stability in its population's death rate over the years. After joining the EU, Ireland has seen good development in its multiple sectors and administration, and the birth rate of its citizens has flourished. From 2001 to 2012, a massive rise in the birth rate was seen at a mean rate of 16.35. The death rate, in contrast, has been stable with minor fluctuations, indicating that this country has a significant life expectancy.

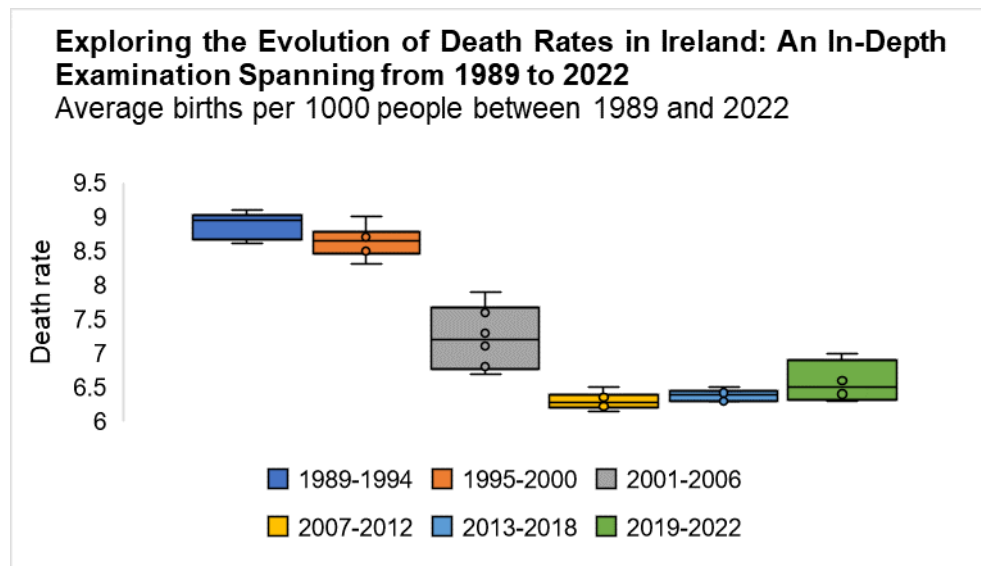
To make better conclusions the presented data was processed and visualized in box plots, so the central tendency and dispersion would be displayed. In Graph 4 below, the births per 1000 people were exposed.



**Graph 4: The dispersion and central tendency of births per 1000 people**

Ireland has seen a good rise in the birth rate, with 14.95 being the highest between 1989 and 1994. McGreevy (2023) reported that “due to the Celtic Tiger baby boom, which peaked in 2009, a decade ago, in 2012, 71,674 children were born from a smaller population base with almost 500,000 fewer people living in the State at the time.” Between 2007 and 2012, the highest birth rate was 16.65, the lowest was 16.25, and the median death rate was 16.4. Post 2012, the birth rate experienced a downfall, with the average birth rate hitting 13.75 between 2012 -2018 and 11.5 between 2019-2022. This indicates that the senior group will play a significant role in the future. The report (McGreevy, 2023) also confirms that “This will have consequences down the line for school enrolments and for the tax base to fund the State’s increasingly elderly population.”

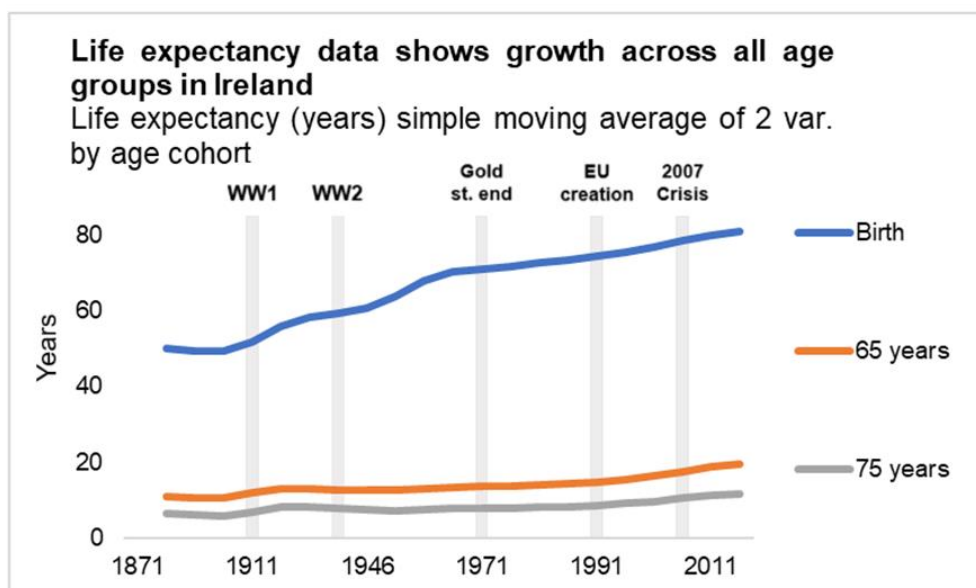
In Graph 5 provided below the death data was also exposed.



**Graph 5: The dispersion and central tendency of deaths per 1000 people**

The mortality rate in Ireland was in a state of downfall between 1989 and 2012. The death rate was plummeting with the increase in life expectancy and decent improvements in the Irish health system. The median death rate was 8.95 between 1989 and 1994 and was going down. So, in 2007-2012, it saw the lowest death rate, 6.2, with a median of 6.28 and the highest of 6.36. Due to increasing intake of tobacco, alcohol and drugs, the population suffered from numerous health diseases. As a result, a gradual rise in the death rate can be observed from 2013- 2022, where the median death rate was 6.4 and between 2019-2022, it was 6.5.

Finally, the life expectancy data set was used by our team of analysts to research the demographic situation in Ireland, which also best describes historical social conditions in the country. In Graph 6 presented below, this data set was presented using three simple moving averages of 2 var. for three key cohorts, for example, “at birth”, “65 years”, and “75”. All these age groups are exclusively important in displaying the general existing social conditions in the country, as these polar age groups, namely, the young (“at birth”) and the elders/seniors (“65-75 years”) are independent and can’t overlap each other.



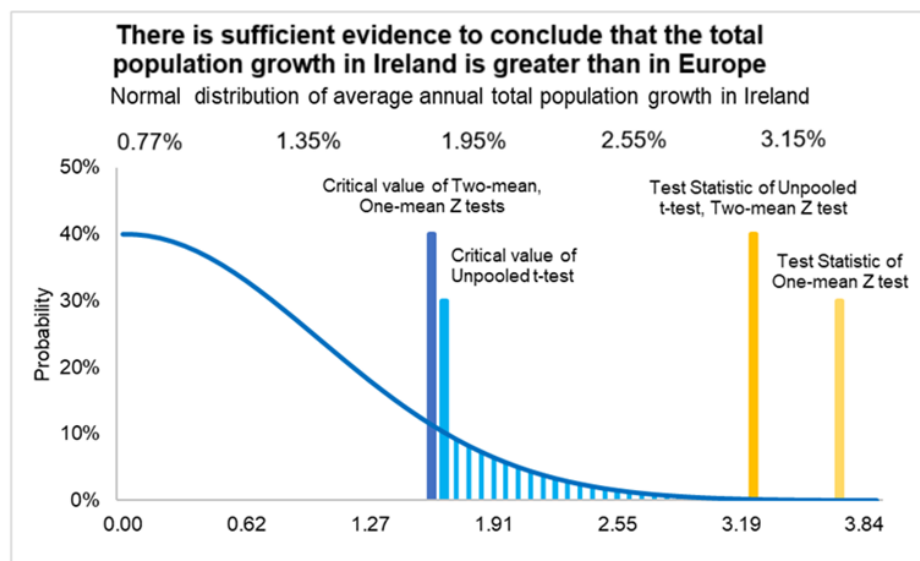
**Graph 6: Life expectancy simple average of 2 var. by age cohort**

Over the last 150 years, life expectancy in Ireland increased significantly. The simple moving average of life expectancy at birth had substantial growth at around 62% during the observed period, showing no signs of cooling down despite numerous events on the global stage. In contrast, the life expectancy in 65+ age groups was impersistent. Considerable growth of 35% has been shown during the 1991–2022 interval, whereas in the 1871–1991 time frame, it was only the prolonged accumulation. One of the key reasons for this historical tendency could be the economic development of Ireland after joining the EU. In general, Ireland has an upward trend in Life expectancy at any age, reflecting both the economic and social evolvement in the country after long years of total population stagnation.

### 3.2 Inferential statistics:

In our pursuit to examine the assumption that the population growth in Ireland is extensive, we compare its annual growth to that of Europe through three tests: two mean Z tests, an unpooled t-test, and a one-mean z test. The stated tests were conducted based on 71 observations.

The null hypothesis ( $H_0$ ) suggests equal population growth between Ireland and Europe, while the alternate hypothesis ( $H_a$ ) posits Ireland's annual growth exceeds Europe's. The hypothesis is tested using the critical value approach based on the value of test statistics and the critical value which are denoted by 'z' and ' $\alpha$ ' respectively, Graph 7.



**Graph 7: One, two-mean Z tests, and unpooled t-test with Irish total population growth**

The one-mean z test, performed to check whether the difference between the mean of a sample mean and the mean of a population is statistically significant and is unlikely to have occurred by chance, we compare sample means ( $\mu_1 = 0.77\%$ ,  $\mu_2 = 0.43\%$ ) with known population standard deviations ( $\sigma_1 = 0.007777757$ ,  $\sigma_2 = 0.003462294$ ), we reject  $H_0$  as the test statistic exceeds the critical value.

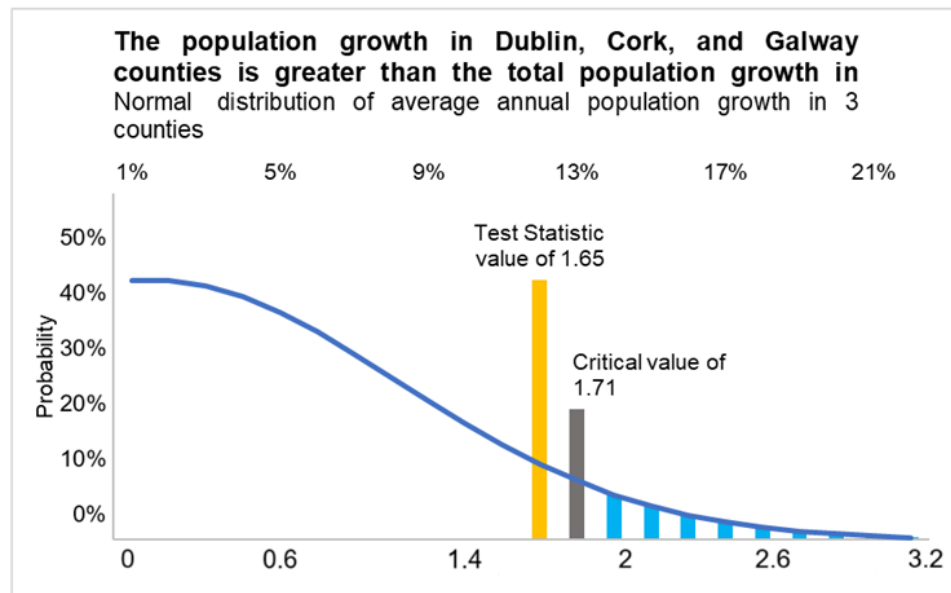
The unpooled t-test, assuming equal population variances, supports  $H_a$  ( $\sigma_1 = 0.007833116$ ,  $\sigma_2 = 0.003462294$ ). With a calculated z value surpassing  $\alpha$ , we reject  $H_0$ .

In the third test, considering a benchmark population mean of 0.43%,  $H_0$  posits equality, while  $H_a$  contends a greater mean. As the z value surpasses  $\alpha$ , we reject  $H_0$  in favour of  $H_a$ .

Hence, we can conclude that the annual population growth in Ireland is greater than the annual population growth in Europe. Mccarthaigh Sean (2018) Irish Examiner confirms that Ireland had the highest rate of natural increase (an excess of births over deaths) in its population in the EU in 2017.

To exercise the hypothesis related to the counties, we compared the yearly population growth in Ireland's three most populous counties – Dublin, Galway, and Cork – with the overall annual population growth in Ireland, Graph 8. The set null hypothesis ( $H_0$ ) suggests that the annual population growth in these three counties equals the overall growth in Ireland, while the alternative hypothesis ( $H_a$ ) posits that the annual population growth in these counties surpasses the overall growth in Ireland. Employing a right-tailed test to assess these hypotheses:

The sample mean ( $\mu$ ) is identified as 1.55%, with a sample standard deviation ( $\sigma_1$ ) of 0.066467104 and a standard error (SE) of 0.0132.



**Graph 8: One t-test with Dublin, Cork, and Galway county's population growth**

After employing calculations, although the test statistic value (1.65) leans towards accepting the null hypothesis (falling below the critical value of 1.71), the p-value (0.056) exceeds our typical threshold of 0.05. Consequently, we reject the null hypothesis, suggesting some evidence supporting  $H_a$ . Therefore, we can conclude that the annual population growth in Cork, Galway, and Dublin might indeed be greater than the overall growth in Ireland. The Central Statistics Office (2022) authenticates that all counties have shown population growth since 2016.

In investigating the correlation between population natural growth and various factors, three correlation tests were conducted, Table 1. For this purpose, the most relevant and adjacent datasets, namely, GDP per capita, female employment-to-population, and unemployment rate women were selected.



<i>Name of data</i>	Natural growth per 1000 people	GDP per capita change	Female employment-to-population ratio	Unemployment rate women, %
Natural growth per 1000 people	100%	-30.8%	52.7%	-17.3%
GDP per capita change	-30.8%	100%	-0.9%	-30.5%
Female employment-to-population ratio	52.7%	-0.9%	100%	-68.9%
Unemployment rate women, %	-17.3%	-30.5%	-68.9%	100%

**Table 1: Multiple correlation of the Natural growth and GDP per capita, Female employment-to-population, Unemployment rate of women**

For the impact of GDP per capita change (1), the null hypothesis ( $H_0: \beta_0 = 0, \beta_1 = 0$ ) was rejected for the intercept( $\beta_0$ ) but not for the coefficient ( $\beta_1$ ), indicating a weak negative correlation with natural population growth. The model fit was deemed poor, with a negative R.

For the analysis of the unemployment rate of women and its impact on natural population growth, the null hypothesis ( $H_0: \beta_0 = 0, \beta_1 = 0$ ) was rejected for the intercept( $\beta_0$ ) but not for the coefficient ( $\beta_1$ ). A weak negative linear relationship was found, indicating a slight change in natural population growth as the unemployment rate for women varies in the opposite direction.

Examining the relationship between the female unemployment-to-population ratio and life expectancy, the null hypothesis ( $H_0: \beta_0 = 0, \beta_1 = 0$ ) was rejected for the intercept( $\beta_0$ ) but not for the coefficient ( $\beta_1$ ). A moderate positive linear relationship was observed, signifying that as the female employment-to-population ratio increases, so does life expectancy. With this information in consideration, we can conclude that the female unemployment-to-population ratio data describes natural growth the best.

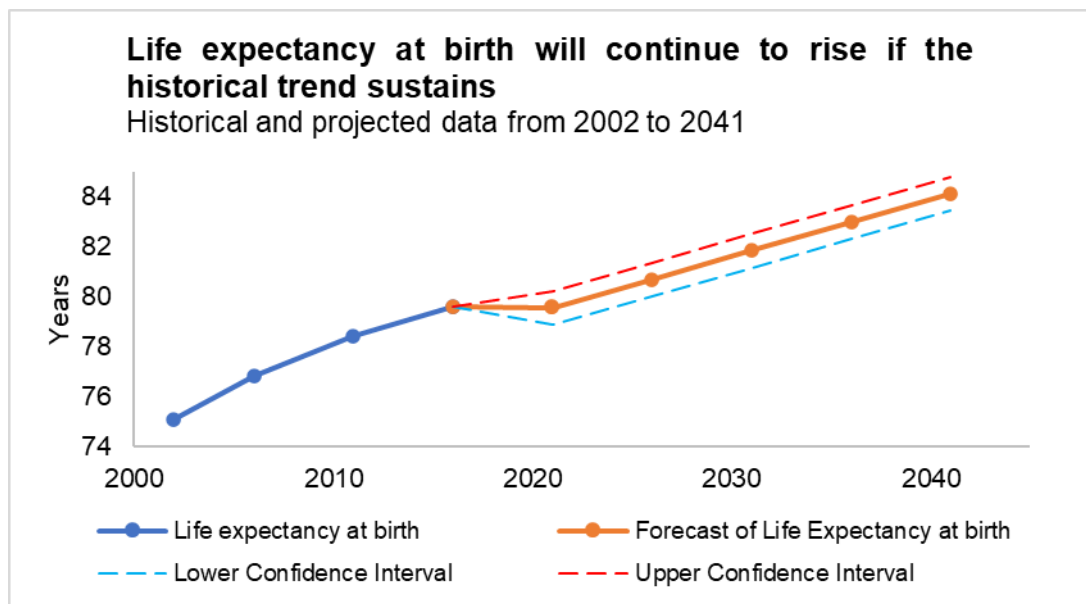
Over the years, Ireland has witnessed a consistent rise in life expectancy. Through regression analysis, we examined the time factor as a possible best-describing data of life expectancy. The null hypothesis ( $H_0$ ) suggests no significant relationship between the years and life expectancy, while the alternative hypothesis ( $H_a$ ) posits a significant association.

Regression Statistics	
R coefficient	98.66%
F	Significance F
731.17	3.19E-17
Coefficients	
$\beta_0$	-380.889
$\beta_1$	0.228

**Table 2: Life expectancy at birth and time regression statistics: R, F,  $\beta_0$ , and  $\beta_1$  coefficients**

The beta coefficient in Table 2 indicates a positive correlation, with a small p-value (0.0000000000000000671666731947644), leading to the rejection of the null hypothesis. Notably, Healthy life expectancy in Ireland, as reported by Johns (2023), surpasses EU averages.

As the regression statistics indicate the significance of the observed correlation, our team modulated the projection for the life expectancy regarding time data, Graph 9 below.



**Graph 9: The life expectancy at birth data forecast with upper and lower intervals**

The forecasting provides the population's life expectancy with a 95% confidence and values under a particular confidence interval ex: - A forecast of the life expectancy of people in Ireland for the year 2021 is expected to fall within the range of 78.8 to 80.21, and reach 84.1 by 2041 with a 95% confidence.

Additionally, a new association explores the impact of the "Percentage of The Population Receiving Higher Education" on life expectancy through regression, Table 3. The null hypothesis (H0) asserts no significant impact, while the alternative hypothesis (Ha) suggests a significant influence.

Regression Statistics	
R coefficient	89.97%
F	Significance F
84.92	1.23E-08
Coefficients	
$\beta_0$	39.197
$\beta_1$	0.322

**Table 3: Life expectancy at birth and the percentage of the population receiving higher education regression statistics: R, F,  $\beta_0$ , and  $\beta_1$  coefficients**

The positive  $\beta_1$  value (0.322324801) and small p-values for both intercept and slope support the rejection of the null hypothesis. The high R-value (0.81) indicates substantial variability in life expectancy. In her report, Duffy (2023) mentioned that 'Ireland had the second-highest percentage of people aged 25-34 with a third-level qualification in 2021 at 61.7 per cent.' Therefore, an association between life expectancy and people receiving education is very tight. It

would be worth noting that correlation and regression do not imply causation, and other factors not included in these statistics may also contribute to changes in life expectancy.

## Conclusions:

a) Ireland's population faced notable fluctuations, notably during the Great Famine and post-1980s globalization. Despite a decline from 1841 to 1936, recent decades witnessed a rebound, reaching 5.1 million. Statistical tests consistently reject the null hypothesis in comparisons with the EU, affirming Ireland's growth surpasses that of the EU. This provides ample evidence for a significant disparity in population growth between Ireland and the EU. This conclusion aligns with McCarthaigh Sean's (2018) observation that Ireland had the highest rate of natural increase in the EU in 2017.

b) Examining Dublin, Cork, and Galway as the most populous counties, the analysis affirms Dublin's consistent population growth, while Cork and Galway experienced fluctuations. Despite the compliance of the Test Statistic being lesser than the Critical value, the test proves the hypothesis that the annual population growth in these counties surpasses the overall growth in Ireland.

c) Births in Ireland surged, notably during the Celtic Tiger baby boom, while death rates remained stable over the last 30 years. In spite of this, the mortality rate rose post-2012, potentially influenced by lifestyle factors, the analysis suggests a significant life expectancy during this time. Out of the three most relevant data sets, the analysis of the female employment-to-population ratio suggests a strong positive linear relationship with natural growth and thus explains its dynamics the best.

d) Life expectancy at birth in Ireland showed consistent growth over 150 years, with a significant increase in the "65+" and "75+" age groups since 1991. The regression analysis indicates a positive association between life expectancy and the variable "Years." The forecasting predicts an upward trend for life expectancy within the confidence intervals for each year. The association with the percentage of the population receiving higher education is also robust, suggesting a strong positive linear relationship with a non-zero  $\beta_1$ .

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## Summary:

Team members	Summary of work	Percentage to the total work
Fedor Sharonov (23205178)	<ul style="list-style-type: none"> <li>Engaged in data collection efforts</li> <li>Conducted data processing activities</li> <li>Contributed to both Descriptive and Inferential statistics tasks</li> <li>Documented process</li> </ul>	33.33%
Shreyas Lengade (23200486)	<ul style="list-style-type: none"> <li>Colleceted the data</li> <li>Assisted in data processing activities</li> <li>Contributed to both Descriptive and Inferential statistics tasks</li> <li>Helped in documenting process</li> </ul>	33.33%
Megha Dewangan (23200042)	<ul style="list-style-type: none"> <li>Engaged in data collection efforts</li> <li>Helped in conducting data processing activities</li> <li>Contributed to both Descriptive and Inferential statistics tasks</li> <li>Assisted in documenting</li> </ul>	33.33%