**Population in Ireland: Where are we heading to?**

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*\* Excluding diagrams, code, references and titles.*

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# **Introduction**

Data is a collection of facts. When data is summarised, it gives us information about the context within which it was collected, and with the use of analytical tools we can produce evidence of the information, and with the evidence we have today, we can attempt to predict future occurrences.

We would be producing a capstone project on an interesting and relevant subject ‘population-growth rates’. We would be conducting an in-depth analysis of population decline in Ireland as many of today’s largest economies are reported to be experiencing decline in population growth rate (World101, 2022).

(Honohan, 2021) reported Ireland as one of the largest GDP in Europe, as a result, its economic stability is imperative, if the European Union (EU) will retain its economic viability on the world stage.

The Organisation for Economic Co-operation and Development (OECD, 2023) and the United Nations (UN, 2023) reported that a country requires a fertility rate of 2.1 children per woman to ensure a stable population. For several decades, the EU are below this fertility rate and for most case, this decline has been below replacement level (UN, 2023). Many factors influence a countries population like birth rate, death rate and migration been key determining factors of population growth or decline (World101, 2022).

Through exploratory data analysis, we aim to find if there is any correlation between this 3 major factors and population decline / growth in Ireland. Our project aims to predict Ireland’s population in the near future, furthermore, we will forecast Ireland’s population until the year 2100, which is the year that global population is expected to peak as stated by (Wilmoth, Menozzi and Bassarsky, 2022) at a level of almost 11 billion.

**Objective**

* Observe through exploratory analysis of our data, the population growth/decline trend in Ireland from 1960 to 2022.
* Check for correlation between the number of births, deaths, and marriages, been determining factors of population growth and population decline in Ireland.
* Find an optimal machine learning model that makes projections into the future regarding Ireland’s population.
* Analyse our results to make conclusions concerning Ireland’s population stability.

# **Problem definition**

Human capital is an important bed rock of any stable economy, a large population means more workers and customers which ultimately boosts a country’s GDP (World101, 2022).

As previously mentioned, stated by (Wilmoth, Menozzi and Bassarsky, 2022) world population is expected to peak around 2100 at a level of almost 11 billion. (OECD and UN, 2023) both reported a country requires a birth rate of 2.1 children per woman to maintain a healthy population growth. However as shown in *fig.1,* Ireland has recorded a progressive decline in its birth rate since 1970 but were still within a healthy birth rate.

Gráfico

Descripción generada automáticamente

Figure 1: Fertility rate, children per woman 1970-2022 (OECD 2023)

Since 1991, Ireland has declined below a healthy population birth rate, and trend suggests that this decline may continue unless objective measures are implemented to prevent it.

We believe Ireland is facing a significant challenge in its birth rate which is a major driver of population growth or decline. This challenge could potentially impact Ireland’s economic and societal stability.

# **Scope**

In this capstone project we will analyse the current trend of the population in Ireland with public data collected by the Central Statistics Office (CSO) and the United Nations (UN) from 1960 to 2022. With this data we seek to explore the correlation between the number of births, deaths and marriages in Ireland to provide a better understanding of its population trend. With this data we aim to predict Ireland’s population for the next few years until 2030, and until the year 2100, which is the year that the global population is expected to peak, furthermore, we will be developing any relevant finding throughout the analysis.

**Project phases:**

**Data preparation,** where we will perform an Exploratory Data Analysis (EDA) to get a better understanding of our dataset, this involves cleaning, sorting, describing and shaping the dataset and sourcing more data if needed. Using a Jupyter Notebook and python language, this task will represent around 65% of the workload and time during project implementation due to the importance of high-quality data going into a machine learning model to be able to obtain reliable results.

**Machine Learning,** we will train multiple machine learning models and observe which model optimal for our dataset. Through metrics that measures regression models, we will ensure machine learning model makes accurate and reliable predictions. This task will represent around 15% of the workload and time during project implementation.

**Visualization,** we will get a better visual understanding of relationships and trends in our dataset using tools such as Seaborn and Matplotlib.pyplot which will help us draw our conclusions and provide visual evidence to stakeholders during presentation. This task will represent around 5% of the workload and time during the project.

**Machine Learning model evaluation,** we will use different evaluation metrics to understand each model’s performance, such as the r2 score, Akaike Information Criterion and Mean absolute Error. This task will represent around 5% of the workload and time during project implementation.

**Forecasting,** we will be making a forecast with our best model or models, this involves making predictions about future to estimate possible scenarios, in this case, about the future of Ireland’s population and its stability. This task will represent around 5% of the workload and time during project implementation.

**Conclusions,** we will summarise our findings, understanding, scenarios and our overall opinion regarding this analysis, we, by any means, consider ourselves as experts on this field, our assumptions and conclusions cannot be considered as an expert’s advice.

Our conclusions must be red with educational proposes only.

This task will represent around 5% of the workload and time during project.

# **Data source**

The dataset we intend to use for our independent features of this analysis is going to be gotten from the CSO Ireland office. The CSO is responsible for collection, compilation, extraction and dissemination of high-quality data used for analysis of economic and social important topics in Ireland.

Additionally, for our dependent feature we intend to use a dataset gathered by the United Nations. The United Nations (UN) is an international organization founded in 1945 and it remains the one place on Earth where all the world’s nations can gather together, discuss common problems, and find shared solutions that benefit all of humanity (United Nations, 2023a).

We believe they would be able to provide accurate and reliable data for our project, we got data on the quarterly birth rate, death rate, marriage rate, migration rate population trend of Ireland from year 1960 to 2022 by the CSO and the population per year of Ireland from the UN. With this data we seek to accomplish our project scope.

# **Ethical considerations**

We considered the socioeconomic importance of this project topic, as this can influence public action or inactions, for example people deciding to have more children because of fear of decline, but we established after consideration that we do not seek to make any conclusions on the population stability of Ireland but just to analyse and report our findings for capstone research purpose only.

Also, to prevent breach of anonymity of population from which the data was gathered, the CSO anonymised all the dataset.

We rang CSO office Dublin to advise us on permission we might require to use their data, On the phone CSO confirmed we do not require any permission to use data available on open source as shown in *fig.2* and [here](https://www.cso.ie/en/aboutus/whoweare/copyrightpolicy/%20) .

A diagram of a pyramid

Description automatically generated

Figure 2: Central statistics office on data usage

As well as the data from the CSO, the data from the UN is available in electronic format, for this data is important to mention the following disclaimer:

These documents do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries (United Nations, 2022b).

# **Approach and data exploration**

At this first stage we will approach the case aiming to fit a Random Forest Regressor Machine Learning model, due to its multiple benefits like low risk of overfitting, easy to determine feature importance and not needing considerable pre-processing work, to name a few, this model will help us understand the data that we have and give us a good insight about Ireland’s population.

Let’s have a first look at our data:

Texto

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Figure 3: Dataset 1, independent features.

Aplicación

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Figure 4: Dataset 2, dependent feature (target).

As we can see, we will need to perform data cleaning, manipulation and feature engineering to be able to analyse our data.

First, we need to understand our features:

***Dataset 1***

Statistic Label

- Marriages Registered

- Marriage Rate Registered per 1000 Estimated Population

- Deaths Registered

- Death Rate Registered per 1000 Estimated Population

- Deaths of Infants under 1 Year Registered per 1000 Births

- Births Registered

- Birth Rate Registered per 1000 Estimated Population

- Opposite sex marriages

- Same sex marriages

- Civil partnerships

- Births registered that were first births

- Births registered outside marriage

- Opposite sex marriage rate

- Same sex marriage rate

- Civil partnership marriage rate

- Percentage of first births registered

- Percentage of births registered outside marriage

- Average age of mothers giving birth

Quarter

Years from 1960 (Q1) to 2023 (Q1); each year has 4 quarters (Q1, Q2, Q3 and Q4).

State

- State

UNIT

These represents the metric of the next feature (VALUE).

- Number

- %

VALUE

Values regarding the Statistic Label feature.

***Dataset 2***

Entity

Countries.

Code

Abbreviation of the countries.

Year

Years of the values.

Population - Sex: all - Age: all - Variant: estimates

Values of the population.

Population - Sex: all - Age: all - Variant: medium

Projections values of the population.

Subsequently, and knowing that we require to analyse values per year and that we are not analysing rates and groups of population (male, female or infants), we are in a position to perform our cleaning, manipulation and feature engineering to end up with the following dataset:

Tabla

Descripción generada automáticamente

Figure 5: Dataset after pre-processing the data.

# **Findings**

Population in Ireland throughout 1960 to 2022:

Gráfico

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Figure 6: Population in Ireland from 1960 to 2022.

Births, deaths and marriages in Ireland throughout 1960 to 2022 (0 to 62):

Gráfico, Gráfico de líneas, Gráfico de dispersión

Descripción generada automáticamente

Figure 7: Independent features behaviour from 1960 to 2022.

Relationship between births and deaths in Ireland throughout 1960 to 2022 (0 to 62):

Gráfico, Gráfico de dispersión

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Figure 8: Relationship between births and deaths.

Relationship between births and marriages in Ireland throughout 1960 to 2022 (0 to 62):

Gráfico, Gráfico de líneas, Gráfico de dispersión

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Figure 9: Relationship between births and marriages.

Succeeding the observation of relationships between births, deaths and marriages, let’s have a closer look at births and deaths due to the declining and rising respectively.

Births in Ireland throughout 1960 to 2022 (0 to 62):

Gráfico, Gráfico de dispersión

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Figure 10: Births in Ireland from 1960 to 2022.

As shown in *fig.10*, we can observe a clear pattern declining births in Ireland every 15 years and it seems that a rising pattern lasting 15 years its developing, therefore, we can expect 3 more years (from 2022) of further declining of births in Ireland reaching its lower value in 2025.

Deaths in Ireland throughout 1960 to 2022 (0 to 62):

Gráfico, Gráfico de dispersión

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Figure 11: Deaths in Ireland from 1960 to 2022.

As shown in *fig.11*, we can observe that Ireland had a clear declining pattern from 1970 to 2005, however, since then, Ireland’s population deaths has been dramatically rising.

# **Machine Learning model**

As previously mentioned in our approach, we will use Random Forest Regressor from sklearn as our Machine Learning model for this first stage of the analysis.

To be able to obtain the best results possible for our dataset, we will use a tool called Grid Search CV from sklearn as well, this tool will help us to iterate multiple values of hyperparameters of our model searching for the best combination to get the highest R2 score attainable, being R2 score our metric to measure our model.

The R2 score, also known as the coefficient of determination, is a metric that measures how well a regression model fits the actual data, it gives us a value on a scale of 0 to 1, a value of 1 indicates that the model perfectly predicts values in the target field (our dependent variable) and a value of 0 indicates that the model has no predictive value (IBM, n.d.).

Moreover, we will be using cross validation for time series data, this cross validation technique starts with a small set of data for training, makes a forecast and then use the same forecasted data as part of the next training set and so on and so forth.

For the sake of science, we will train our model in 3 different proportions of our data to compare them, the results were the following:

r2\_score result (**training**)(90% training): 0.996

r2\_score result (**testing**)(90% training): 0.991

r2\_score result (**training**)(80% training): 0.996

r2\_score result (**testing**)(80% training): 0.994

r2\_score result (**training**)(70% training): 0.996

r2\_score result (**testing**)(70% training): 0.982

By only looking at our R2 scores, it would seem that our model with 80% of training data is the one that will perform the best in regards to predicting the population in Ireland, however, lets explore the features importance of our model:

90% training:

Year: 0.979

Births: 0.00826

Deaths: 0.00820

Marriages: 0.00378

80% training

Year: 0.954

Births: 0.00961

Deaths: 0.0320

Marriages: 0.00346

70% training

Year: 0.953

Births: 0.00851

Deaths: 0.0347

Marriages: 0.00345

We can observe that our ‘year’ feature is the main determining factor in our data, nevertheless, knowing the rapid rising of deaths in Ireland, we can understand why our model is taking ‘deaths’ feature as the second more important feature to predict the population in Ireland, in future years we can anticipate that this feature will gain more relevance.

Gráfico

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Figure 12: Feature importance from our Random Forest Regressor model.

After seeing our r2 scores, we are concerned about a possible data leakage from our ‘births’ and ‘deaths’ features, therefore, we will only keep our ‘year’ feature and re-train our Random Forest Regressor model to see how it performs, using the r2 score and the Mean Absolute Error.

Results of our Random Forest Regressor model with only our ‘year’ feature as independent variable:

r2\_score result (**training**)(80% training): 0.996

r2\_score result (**testing**)(80% training): 0.997

Mean Absolute Error result (**training**)(80% training): 31691.124

Mean Absolute Error result (**testing**)(80% training): 20442.245

Even after removing all our features but ‘year’ to prevent any data leakage, our model keeps performing well, this could be due to the most important feature by far is our ‘year’ feature.

# **Second approach**

Following our initial understanding of our data and feature importances using the Random Forest Algorithm, we will now compare how well ARIMA and SARIMA models perform in our data.

**ARIMA**: Autoregressive Integrated Moving Average, takes into account the past values and predicts future values based on that (Bajaj, 2023).

**SARIMA**: Seasonal – ARIMA, similarly to ARIMA, uses past values but also takes into account any seasonality patterns (Bajaj, 2023).

In this new approach, considering that our data is based on time, we will treat it as a time series, using our target feature (population) we will make sure that our data is stationary before training our models.

Making our data stationary is a relevant step since non-stationary data can lead to unreliable model outputs and inaccurate predictions, a stationary time series data typically results in a better model performance.

Time Series is a way of studying the characteristics of the response variable concerning time as the independent variable. To estimate the target variable in forecasting, we use the time variable as the reference point (Pandian, 2021).

In order to confirm if our data is stationary or not, we will use the Dickey Fuller test, through which we find if the time series is having any unit root.

Unit root is a feature of time series that indicates if there is any stochastic trend in the time series that drives it away from its mean value, the presence of unit root makes a time series non stationary (Santra, 2023).

Interfaz de usuario gráfica, Texto, Aplicación

Descripción generada automáticamente

Figure 13: Dickey Fuller test.

Since we got a p – value of almost 1, we can say that our data is not stationary, hence, we will use the differencing method to make it stationary.

Differencing: Method of transforming a time series dataset, it can be used to remove the series dependence on time, this includes structures like trends and seasonality (ProjectPro, 2023).

Interfaz de usuario gráfica, Texto

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Figure 14: First order differencing.

As we can see, our p – value is more than 0.05, therefore, our data still non stationary, we will need to perform the second order differencing method.

Interfaz de usuario gráfica, Texto, Aplicación

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Figure 15: Second order differencing.

After performing the second order differencing method, we got a p – value of 0.0034, with that we can conclude that our data is stationary, let’s visualise our data after this method.

Gráfico, Gráfico de líneas

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Figure 16: Data comparison after second order differencing method.

# **ARIMA**

Firstly, we will use the ARIMA algorithm, as previously mentioned, this algorithm is used understand past data or predict into the future. To find the best values for our ARIMA algorithm, we will create a function to iterate multiple values through the algorithm, we are looking for the lowest Akaike’s Information Criterion (AIC).

**Akaike’s Information Criterion:** Evaluates the trade-off between goodness of fit and complexity (KALRA, 2023).

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Figure 17: AIC values.

Now that we have our AIC values (1, 2, 0) we can construct our ARIMA model.

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Figure 18: ARIMA model.

Now that we have our ARIMA model, we can compare the actual population vs the ARIMA model forecast.

Gráfico, Gráfico de líneas

Descripción generada automáticamente

Figure 19: Actual population vs ARIMA forecast.

# **SARIMA**

After constructing our ARIMA model, we will now analyse the SARIMA algorithm.

In order to find the seasonal order for our SARIMA model, we will use the ‘pmdarima’ library as follows.

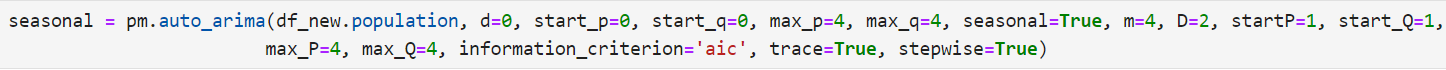


Figure 20: Searching for seasonal order for the SARIMA model.

Texto

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Figure 21: Best seasonal order.

Now that we have our best values, we can construct our SARIMA model.

Interfaz de usuario gráfica, Texto, Aplicación

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Figure 22: SARIMA model.

As we did with our ARIMA model, let’s now compare the actual population vs the SARIMA model forecast.

Gráfico, Gráfico de líneas

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Figure 23: Actual population vs SARIMA forecast.

Let’s compare the ARIMA and SARIMA models against the actual population.

Gráfico, Gráfico de líneas

Descripción generada automáticamente

Figure 24: ARIMA and SARIMA models vs actual population.

Even though our ARIMA model seems to fit better than our SARIMA model, we already know that seasonality its being created as time goes on from our EDA, therefore, we can say that our SARIMA model performs better than our ARIMA model for forecasting population based on the data that we have.

Since we got good results from our Random Forest Regressor and our SARIMA models, we can make a forecast of population for the next 8 years (until the year 2030).

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Figure 25: SARIMA forecast.

Interfaz de usuario gráfica, Texto, Aplicación

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Figure 26: RF regressor forecast.

As we can see, when we try to make a forecast using our Random Forest Regressor, it is not able to perform even though it got quite good scores while training and testing.

This problem can be explained, Random Forest Regressor will always predict an average of the values seen previously, therefore, is unable to discover trends that would enable it to perform in this type of scenarios (Mwiti, 2020).

Lastly, we can now visualise our population forecast for the years 2023 to 2030 using our SARIMA model.

Gráfico, Gráfico de líneas

Descripción generada automáticamente

Figure 27: SARIMA forecast for the year 2030.

According to our SARIMA model, Ireland would have a population of 5.368 million by the year 2030.

Now that we have our forecast visualisation, we can make a forecast until the year 2100 and compare it with the projections from the United Nations World Population data, if we recall, as stated by (Wilmoth, Menozzi and Bassarsky, 2022) world population is expected to peak around 2100 at a level of almost 11 billion.

Gráfico, Gráfico de líneas

Descripción generada automáticamente

Figure 28: SARIMA forecast until the year 2100.

Gráfico, Gráfico de líneas

Descripción generada automáticamente

Figure 29: UN projections for Ireland's population in a high fertility scenario.

Gráfico, Gráfico de líneas

Descripción generada automáticamente

Figure 30: UN projections for Ireland's population in a low fertility scenario.

Source: <https://ourworldindata.org/population-growth#explore-data-poverty>

From the above comparison, we can confirm that our SARIMA model is performing well, our projections are quite similar to the UN high fertility projections and our bottom line of our confidence interval (yellow shadow) follows the UN low fertility projections.

# **Conclusions**

**Ireland’s population stability:** The results of this analysis suggest that Ireland have and will have a stable population growth in the coming years, however, we cannot leave out the fact that there is a pattern of declining births every 15 years as the data showed us, following this pattern, by the year 2025 we can expect a new record low in births per year.

If this trend does not change, Ireland will have more people dying than being born at some point.

**Worst case scenario for Ireland:** The real problem comes when the fertility rate has been consistently low for decades, normally, a country can recover if the fertility rate only falls from 2.1 for a few years.

In a low fertility case scenario (a possible one), Ireland’s population will start to decline around the year 2045, just 21 years from now, this scenario will directly affect Ireland’s workforce, economy, welfare systems, housing, social fabric, etc., from those reasons the demographic topic is so important, we can get valuable information and understanding of a country’s current and future stability.

The impact in the previously mentioned areas would be felt as labour shortages, jobs difficult to fill, fewer and fewer young adults entering the workforce, rural communities dying out; all of these issues would be translated into a country’s infrastructure hard to maintain with a shrinking workforce.

According to the CSO, we can already see these issues happening:

* People aged 65 and over showed an increase in population share between 2017 and 2023, increasing from 13.6% to 15.3%.
* People aged 45 – 64 showed an increase in population share between 2107 and 2023, increasing from 24.1% to 25.3%.
* Population living in Dublin increased from 27.6% in 2011 to 28.4% in 2023 (population concentrating in a ‘big city’ may mean people leaving rural communities).

Population change closely coincides with the trend in net migration between the years 1988 and 2023, the natural increase without immigration in Ireland’s population is of only 20,000 in 2023, this represents a drop of 23% from the natural increase in 2022 (Central Statistics Office, 2023) as shown in *fig. 31.*

Gráfico, Gráfico de líneas

Descripción generada automáticamente

Figure 31: Population change 1988 - 2023 (CSO).

With this information from the CSO and from our analysis, we can confidently say that Ireland is at a stage that it cannot stop bringing foreigners to permanently live in Ireland since the births pattern suggest that we will have a decline as soon as the year 2025 and the population growth is highly dependent on immigrants as well as the workforce, hence, the economy of the country.

**Consequences of population decline:** The consequences of global population decline are around half a century away, but for some countries declines are already underway. As stated by Charles Jones, an economist at Standford, in his paper ‘The End of Economic Growth?’, fertility rates in high income countries have fallen from five children per women to four, three, two and now even fewer.

From a family point of view, there is not much of a difference between 2 or 1 children, however, this decision between having 2 (or more) children versus 1, is of critical importance, it is the difference between an Expanding Cosmos of exponential growth in both population and living standards and an Empty Planet, in which incomes stagnate and the population vanishes.

Nevertheless, the emergence of declining population in many countries and the possible consequences for the future of economic growth, make this topic worthy of further exploration (Jones et al., 2020).

As proposed in 1937 by John Maynard Keynes, an economist and philosopher, a too rapidly declining population would involve many severe problems, but a stationary or slowly declining population may, if we address the situation in a proper manner and wisdom, enable us to rise the standard of life to what it should be, whilst retaining those parts of our traditional scheme of life. Yet there will be many social and political forces to oppose the necessary change (Keynes, 1937).

As we can see, there is a relevant concern surrounding this topic from nearly 90 years, and the expected repercussions in Keynes and Jones papers are highly similar, even with decades apart.

Despite decades of exploration regarding the global population, at present times, we can take a look to the demographic crisis in Japan to get an idea of what could happen to Ireland if this topic is not addressed on time.

**Current situation of Japan’s population**: Japan is currently in a population crisis that they knew it was coming nearly 8 years back, the number of new births fell for an eighth consecutive year in 2023, reaching a new record low and representing a 5.1% decline from the previous year.

The demographic crisis has become one of Japan´s most pressing issues, more people are dying than being born each year, causing the population to fall rapidly and as a consequence you get a population with much, much fewer young people than older adults, that at the same time it translates to a skewed ratio.

Even if Japan manages to boost its fertility rate dramatically and immediately (an unrealistic scenario), it would take several decades until the skewed ratio balances out and the babies being born right now reach childbearing age themselves.

Japan’s government is trying to stabilise this crisis with immigration, they are creating new visa categories and considering proposals to allow certain types of skilled workers to stay indefinitely, a 2022 report by a Tokyo – based research organization found that Japan need about four times as many foreign workers by 2040 to achieve the government’s economic goals (Yeung, 2024).

Moreover, we can take a quick look at John Calhoun famous mouse - behaviour experiment, the Universe 25 experiment.

**Universe 25 experiment, 1968 – 1973:** Biologist John Calhoun built a mouse colony at the National Institute of Mental Health in Maryland in 1968, the colony had everything a mouse could desire, plenty of food and water, a perfect climate, reams of paper to make cozy nests and 256 separate apartments. Free from predators and other worries, a mouse could theoretically live to an extraordinarily old age.

Following an adjustment period, the first pups were born 3.5 months later, and the population doubled every 55 days afterward. Eventually this growth slowed, but the population continued to climb, peaking at 2,200 mice during the 19th month.

Between the lack of sex, which lowered the birth rate, and inability to raise pups properly, which sharply increased infant mortality, the population of the colony began to plummet. By the 21st month, newborn pups rarely survived more than a few days. Soon, new births stopped altogether, older mice lingered for a while, hiding like hermits or grooming all day. By the spring of 1973, less than five years after the experiment started, the population crashed from 2,200 to 0 (Kean, 2022).

After more than four decades from the Universe 25 experiment, it can still give us an ‘insight’ of what could happen to the human population, which could top by the year 2100 as stated by (Wilmoth, Menozzi and Bassarsky, 2022).

If we delve into the Universe 25 experiment, at the very least, mice and men seem rather similar when we compare the experiment and modern civilization, for instance, a person’s financial status can be compared to the hierarchical status of mice, the more money you have (human) / the more fights you win (mice), the higher the status among society. To conclude the present analysis, and since the further we go the more questions we have, here are a few to think about.

* - How will humanity interact in the future in a world where more land/space cannot be created?
* - If we think about the amount of time that society spends on social media platforms, are we really interacting with one another at all?
* - If we are not interacting like in the past, how can we expect a stable world population? since we need that human interaction to procreate and have a healthy fertility rate.
* - If the world population starts to decline, technology will take over jobs more and more often, by that time, how will the economy of the world work?

# **Github**

<https://github.com/LeopoldoCCT/Strategic_Thinking_>

# **References**

Bajaj, A. (2023). *ARIMA & SARIMA: Real-World Time Series Forecasting*. [online] neptune.ai. Available at: https://neptune.ai/blog/arima-sarima-real-world-time-series-forecasting-guide.

Central Statistics Office (n.d.). *Copyright Policy - CSO - Central Statistics Office*. [online] www.cso.ie. Available at: https://www.cso.ie/en/aboutus/whoweare/copyrightpolicy/ [Accessed 27 Oct. 2023].

Central Statistics Office (2023). *Key Findings - CSO - Central Statistics Office*. [online] www.cso.ie. Available at: https://www.cso.ie/en/releasesandpublications/ep/p-pme/populationandmigrationestimatesapril2023/keyfindings/.

Central Statistics Office, Ireland (2023). *Total Births, Deaths and Marriages Registered*. [online] Data.cso.ie. Available at: https://data.cso.ie/table/VSQ04 [Accessed 12 Oct. 2023].

Honohan, P. (2021). Is Ireland really the most prosperous country in Europe? *Central Bank of Ireland*, [online] 2021(1). Available at: https://www.centralbank.ie/docs/default-source/publications/economic-letters/vol-2021-no-1-is-ireland-really-the-most-prosperous-country-in-europe.pdf [Accessed 24 Oct. 2023].

IBM (n.d.). *R2*. [online] www.ibm.com. Available at: https://www.ibm.com/docs/en/cognos-analytics/11.1.0?topic=terms-r2 [Accessed 17 Dec. 2023].

IBM (n.d.). *What is Random Forest? | IBM*. [online] www.ibm.com. Available at: https://www.ibm.com/topics/random-forest [Accessed 16 Dec. 2023].

Jones, C., Gsb, S., Di Tella, S., Doepke, M., Fernandez-Villaverde, J., Galor, O., Greenwood, J., Klenow, P., Tonetti, C. and Weil, D. (2020). *The End of Economic Growth? Unintended Consequences of a Declining Population*. [online] Available at: https://web.stanford.edu/~chadj/emptyplanet.pdf.

KALRA, K. (2023). *Cross-Validation and Information Criteria*. [online] Medium. Available at: https://medium.com/@khwabkalra1/cross-validation-and-information-criteria-4ff1074509cc [Accessed 7 May 2024].

Kean, S. (2022). *Mouse Heaven or Mouse Hell?* [online] Science History Institute. Available at: https://www.sciencehistory.org/stories/magazine/mouse-heaven-or-mouse-hell/.

Keynes, J.M. (1937). Some economic consequences of a declining population. *The Eugenics review*, [online] 29(1), pp.13–7. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2985686/?page=1 [Accessed 10 May 2024].

Mwiti, D. (2020). *Random Forest Regression: When Does It Fail and Why?* [online] neptune.ai. Available at: https://neptune.ai/blog/random-forest-regression-when-does-it-fail-and-why [Accessed 8 May 2024].

Organisation for Economic Co-operation and Development (2023). *Fertility rates - OECD data*. [online] OECD. Available at: https://data.oecd.org/pop/fertility-rates.htm [Accessed 13 Oct. 2023].

ProjectPro. (2023). *What is differencing in timeseries and why do we do it? -*. [online] Available at: https://www.projectpro.io/recipes/what-is-differencing-timeseries-and-why-do-we-do-it.

Ritchie, H., Rodés-Guirao, L., Mathieu, E., Gerber, M., Ortiz-Ospina, E., Hasell, J. and Roser, M. (2023). Population Growth. *Our World in Data*. [online] Available at: https://ourworldindata.org/population-growth#explore-data-poverty.

Santra, R. (2023). *Tests for Stationarity in Time Series — Dickey Fuller Test & Augmented Dickey Fuller(ADF) Test*. [online] Medium. Available at: https://medium.com/@ritusantra/tests-for-stationarity-in-time-series-dickey-fuller-test-augmented-dickey-fuller-adf-test-d2e92e214360.

United Nations (2022a). *World Population Prospects - Population Division - United Nations*. [online] population.un.org. Available at: https://population.un.org/wpp/DefinitionOfProjectionScenarios/ [Accessed 11 Dec. 2023].

United Nations (2023a). *About Us*. [online] United Nations. Available at: https://www.un.org/en/about-us [Accessed 16 Dec. 2023].

United Nations (2023b). *Population*. [online] United Nations. Available at: https://www.un.org/en/global-issues/population [Accessed 24 Oct. 2023].

Wilmoth, J., Menozzi, C. and Bassarsky, L. (2022). *Why population growth matters for sustainable development POLICY BRIEF NO 130 Key messages*. [online] Available at: https://www.un.org/development/desa/pd/sites/www.un.org.development.desa.pd/files/undesa\_pd\_2022\_policy\_brief\_population\_growth.pdf [Accessed 27 Oct. 2023].

World101 from The Council on Foreign Relations (2022). *Global Population Growth Is Slowing Down*. [online] World101 from the Council on Foreign Relations. Available at: https://world101.cfr.org/global-era-issues/development/global-population-growth-slowing-down#:~:text=Studies%20differ%20about%20the%20exact [Accessed 24 Oct. 2023].

Yeung, J. (2024). *Japan’s population crisis was years in the making – and relief may be decades away*. [online] CNN. Available at: https://edition.cnn.com/2024/03/01/asia/japan-demographic-crisis-population-intl-hnk-dst/index.html.