INTRODUCTION

Migration processes are a phenomenon that has been occurring for centuries, and their importance to the world today is undeniable. Migration occurs when individuals, families, or entire populations move from one place to another, whether within a country or across international borders. This type of movement has had a significant impact on the development of civilizations and the spread of ideas, as well as on the development of countries and the world at large.

Migration processes are believed to have been a key factor in the development of countries. They allowed the spread of ideas and cultures, which in turn made the development of cities and nations possible, as well as the growth of trade and commerce. Migration processes also allowed for the intermingling of different cultures and the exchange of goods, services, and knowledge that enabled the growth of ideas and innovations.

Immigration and emigration of the population have also had a significant impact on the development of countries. People who migrate often bring with them new ideas, skills, and perspectives that can help drive economic growth and development. Migration also helps to diversify the population of a country, which in turn can help to create a more vibrant and diverse society. In addition, migration processes can help to reduce poverty.
and inequality in countries, as well as provide opportunities for individuals to escape oppressive or dangerous situations. But migration processes also can be quite burdensome for the financial systems of countries-recipients. Governments plan by always creating a budget that accounts for all countries’ expenditures. Alas, there are unpredictable circumstances that can hinder budgetary efficacy such as sudden environmental impacts and unforeseen migration waves are also a part of that category. Additional population means additional expenditures for their support which weighs down on the countries’ limited budgetary resources. One prime example of such a phenomenon is the massive migration of Ukrainian refugees into European countries after Russian aggression.

All in all, migration processes are an important part of everyday life in this world that has had a significant impact on the development of civilizations, the development of countries, and the global economy both positively and negatively. Migration processes have enabled the spread of ideas, and resources, as well as the growth of trade and commerce. These processes are always complex in their nature, which makes them a perfect subject for dissection and analysis as this will allow to not only understand what exactly causes the specific migration movement, and what can help prevent it or create it, but it also helps forecast these processes for future, hence why this topic is so important.

LITERATURE REVIEW

The ability to comprehend migration processes at least partially is immensely important for several reasons. The literature that describes and analyses population immigration and emigration processes dates back all the way to the 20th century [1-2]. Authors of multiple books were analysing how migration processes were influencing the countries-recipients. A lot of people thought at the time that immigration in more developed countries could lead to an economic problem as that would create more competition in the labour market and create an additional load for the financial systems. The increase of 10% in several immigrants in the country lowered the wages of the native population by less than 1% which is negligible. The decrease in wages of immigrants themselves was more significant, around 2-4%. So, authors using a neoclassical model of labour demand concluded that empirical data did not support the concern that immigration processes could be disruptive to the labour markets in America.

Similar conclusions were drawn by authors of two studies where they elaborated that there wasn’t a significant threat to economic prospects from immigrants in the United States [3-4]. Authors also noted that such simple empirical methodology had its’ downsides. One such issue was the fact that the data that they used in their calculations completely overlooked the insight that the skills of immigrants in the labour market were, in fact, divergent in different cohorts. Additionally, the productivity of these cohorts also differs throughout time as people adapt to new environments.

Further proving this point authors of another study concluded that the effects of immigrants on the wages of the native population largely depend on human capital levels of the immigrants themselves [5]. It became clear that there was not a significant problem at that time, but the data used during modelling was simply not sufficient and sophisticated enough to conduct more elaborate experiments and analyses.

In one book [6] authors were analyzing how after the events in 1990 when the dissolution of the Soviet Union took place a serious increase in east-to-west migration flows were happening in Central, Eastern and Southeastern European countries and how it affected the growth of post-soviet countries, their private sector activities, competitiveness public finances and ultimately growth. Noticeably a significant outflow of educated and young people was happening in Southeastern countries more so than in the Baltic and Central Europe regions. Authors disclose that the EU has significantly benefited from the inflow of young and well-educated labour force, and there is sizable research that points to the benefits of receiving countries in the European Union from cross-border labour mobility. By moving abroad, migrants were able to improve their welfare and the quality of life of their relatives back home.

Meanwhile, these processes have noticeably reduced the growth and income convergence in Central, Eastern and South-eastern European countries (countries-donors) because the size of the labour market has shrunk which led to adverse effects on productivity and to making the budget structure of the country less growth-friendly. Similarly, authors of another article [7] emphasized that the net effect of innovator emigration is detrimental to domestic knowledge access and leads to slowed growth of Indian regions.

There is plenty of evidence which indicates that migration processes are of utmost importance when it comes to countries’ development and prosperity. That includes both countries-donor and countries-recipients as it can be a positive thing and strenuous phenomenon. The potential and demographic structure of the migrating population plays a special role here. Some authors emphasize the importance of the intellectual capital of immigrants for the development of host countries.
[8-10]. However, as acknowledged in two papers discussing the results of research conducted in India, the flow of population is a driving force for growth in selected sectors of the economy also by providing a flexible and cheap source of labour [11-12]. Many publications highlight the impact of immigrants and their behaviour on such key economic variables as prices, income, and selected microeconomic aspects of economic activity [13-16]. Not without significance for the impact of migration on the economic and social life of the country is the issue of the mental health of refugees in the new environment. Authors such as [17] or [18] recognize the challenges that displaced persons face in this respect on the way to effective acculturation, and at the same time to maintain their own values taken from their home countries, while another study directly writes about the positive correlation of the mental health of refugees with structural and cognitive social capital they represent [19]. From the point of view of the countries of origin of migrants, in addition to the often-cited socio-economic effects of such an exodus for their economy, one of the articles points to the slightly less emphasized effect of migration, which may be changes in the gender structure of the population observed especially in less developed countries [20]. As of today, many have come up with multiple ways to analyze and scrutinize these processes. Stillwell, J. suggested that the use of the Poisson regression model framework might be optimal for explanatory analysis [21]. Such a model has been used for subnational migration to explain the effects of exogenous variables.

In another study [22] authors were assessing what conditions and indicators were affecting the population migration activity in Ukraine prior to Russian aggression. The authors were determining which indicators were more prevalent and important and their reliability by use of statistical analysis. The main 30 indicators can be divided into 5 different classes: demographic stability and public health status; education coverage; labour market and employment conditions; standard of living; economic development of the country/region. The results of the study showed that these processes were affected by first and foremost demographic situation, life expectancy, public health, and the upbringing of the young generation in a family. The tendency of mortality to overgrow the birth rates has tremendously impacted demographic reproduction causing catastrophic population decline. Although, it is worth noting that such a trend is present in a lot of countries, so it is worth focusing on migration flow control first. The creation of sustainable and adequate conditions for economic growth for the well-educated part of the population can hinder their desire to migrate and thus positively impact economic and demographic markers in Ukraine.

Yet another study that analyzed the social and economic development of Ukraine was assessing different factors that could play into migration intensity using The Granger causality test [23]. Authors concluded that migration processes can be beneficial in the short-term for the economy, by lowering the rate of unemployment, by simply diminishing the amount of population in a country, or by influencing disposable income, remittances, aggregate food expenditures as well as consumer price index. It still can negatively impact the economy overall as the high-quality labour force is decreasing and implementing a proper effective migration control policy can help address this issue.

Author [24] was assessing social, economic, and political institutions as an explanatory factor for migration processes using the gravity model which separates push as pull effects of various institutional attributes. The study shows that all factors play an important role when it comes to migration processes dissection and understanding although they vary significantly. Economic freedom has been shown to be the most influential, followed by political and social institutions. In addition, it was determined that political institutions don’t pose a significant push factor compared to economic and social.

In [25-27] authors forecast the level of health care expenditure in Ukraine for 2023-2024, considering the scale of migration and the fall in the level of GDP. In [28-30] authors discover the impact of women’s resistance to changing gender stereotypes, models, and inequality in migration issues.

All in all, there are more new modelling methods that can consider different factors, such as social, environmental, economic etc. Different models can use different data hence the need for model diversity. Migration is a multifaceted process that’s incredibly complex in its nature. The need to understand these processes is important for both countries-recipients and countries-donors to control them and create forecasts.

**AIMS AND OBJECTIVES**

The purpose of writing the article is to identify the key pull factors affecting immigration processes in the UK. To realize the goal, the following tasks were set and solved:

- develop a model for predicting immigration processes (using the example of Great Britain);
- identify key parameters affecting immigration processes.

The correlation regression analysis and the visualization methods were used to write the article.
METHODS

Bibliometric analysis was carried out with the VOSviewer_1.6.17 toolkit [30] to clarify the general contextual directions of scientific research aimed at identifying immigration issues. This theoretical block of research was realized based on 60992 PubMed papers 1856-2023, the title, abstract, or keywords of which contain such words as “immigration”.

Figure 1 reflects the co-occurrence between the key concepts that scientists highlight in their research to study immigration issues.

Thus, according to Figure 1, five contextual clusters of scientific research can be identified, namely:

▪ red cluster – covers scientific research focused on studying the impact of humans, pregnancy, health services, refugees and risks on the immigration process;
▪ green cluster – covers scientific research focused on evaluating the influence of male, female, adolescent, mental health, depression, social support on the immigration process;
▪ blue cluster – covers scientific research on the impact of demography, population dynamics, public policy and cultural factors on the immigration process;
▪ yellow cluster – covers scientific research focused on evaluating the influence of different diseases on the immigration process;
▪ purple cluster – covers scientific research on the influence of socioeconomic factors and historical events on the immigration process.

The relationship between author groups analysing the problems of immigration in its various aspects is shown in Figure 2.

To model the influence of different factors on migration processes in Great Britain a multiple linear regression was built using Python programming language. All data used during modelling was sourced from the Office for National Statistics – UK’s largest independent producer of official statistics, World Bank or GOV.UK – United Kingdom public sector information website.

Using current literature on the topic of migration processes, four main categories of data were chosen that could potentially have an impact on the modelling process, namely: economic, labour, housing and social.

Economic factors included GDP per capita, the number of new businesses per year, budget spendings per student and the average salary per year. A lot of current literature supports the use of these factors to represent the level of economic
development in a country which can also impact migration. People may choose to move from less developed countries to more developed ones in search of better living standards, higher wages, and more opportunities. Budget spendings per student could potentially motivate people to acquire higher education in the UK, being an opportunity for migrants.

Labour market factors included the unemployment rate and the employment rate. The availability of jobs and better wages in another country can be a major factor in people’s decision to migrate. If a person’s home country has high unemployment or low wages, they may choose to move to a country with better job opportunities.

Housing factors included the number of new buildings (apartments and private houses) whose construction was completed in the current year. Housing factors can also contribute to migration, as the availability and affordability of housing can be a major consideration for people when deciding whether to move. Since prices per square meter vary vastly across the country from region to region, the same goes for policies such as rent control or subsidies as well as taxonomy, making it hard to standardize data for international migration modelling, a more comprehensive factor was chosen that would describe permanent dwellings that have been completed in the United Kingdom during a financial year and are ready for use.

Social factors included population density, level of urbanization, and crime rate. People may move to urban areas in search of job opportunities, better access to education and healthcare, and a more vibrant cultural scene. On the other hand, people may also leave urban areas due to the high cost of living, traffic congestion, pollution, and lack of green spaces. Population density can also impact migration. High population density can lead to overcrowding, higher competition for resources, and more crime. As a result, people may choose to move to areas with lower population density in search of a higher quality of life and lower crime rates. Crime rate is another factor that can influence migration. High crime rates can make people feel unsafe and insecure in their homes and communities. In such cases, people may choose to move to areas with lower crime rates. Conversely, low crime rates can attract people to areas that are perceived as safer and more secure. The data used for modelling was taken for the past 21 years from 2000 to 2021 (Table 1).
During the modelling stage of research, multiple models have been built to isolate the most representative one. To choose the best variables that could influence the migration process first a multicollinearity test was performed to understand which variables could correlate with each other and thus hinder the overall results of the model. During the test, the most correlation was observed between 12 pairs (Table 2). Most of which contained the following variables: population density, urban population, employment/unemployment rate, crime rate and average income.

### Table 2. Most correlated pairs.

<table>
<thead>
<tr>
<th>Pair</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment rate / Unemployment rate</td>
<td>-0.904</td>
</tr>
<tr>
<td>Average income / GDP per capita</td>
<td>0.781</td>
</tr>
<tr>
<td>Urban population / Population density</td>
<td>0.998</td>
</tr>
<tr>
<td>Expenditure per student / Population density</td>
<td>0.907</td>
</tr>
<tr>
<td>New business / Population density</td>
<td>0.942</td>
</tr>
<tr>
<td>Crime / Population density</td>
<td>-0.880</td>
</tr>
<tr>
<td>Average income / Population density</td>
<td>0.745</td>
</tr>
<tr>
<td>Expenditure per student / Urban Population</td>
<td>0.923</td>
</tr>
<tr>
<td>New business / Urban Population</td>
<td>0.932</td>
</tr>
<tr>
<td>Crime / Urban Population</td>
<td>-0.884</td>
</tr>
<tr>
<td>Average income / Urban Population</td>
<td>0.776</td>
</tr>
<tr>
<td>Crime / Expenditure per student</td>
<td>-0.921</td>
</tr>
</tbody>
</table>

### RESULTS

During the modelling stage of research, multiple models have been built to isolate the most representative one. To choose the best variables that could influence the migration process first a multicollinearity test was performed to understand which variables could correlate with each other and thus hinder the overall results of the model. During the test, the most correlation was observed between 12 pairs (Table 2). Most of which contained the following variables: population density, urban population, employment/unemployment rate, crime rate and average income.
These data indicate that there is a strong indirect correlation between the employment rate and the unemployment rate \((-0.904)\), crime and population density \((-0.880)\), crime and urban population \((-0.884)\), crime and expenditure per student \((-0.921)\). There is also a strong direct correlation between urban population and population density (0.998), expenditure per student and population density (0.907), new business and population density (0.942), and expenditure per student and urban population (0.923).

In addition to the pairwise correlation coefficient, the variance inflation factor (VIF) was also used to determine the relationship between variables. This statistical concept provides to detect multicollinearity between independent variables in a multiple regression model. Most of the independent variables are closely intertwined with each other and other variables in the model, which would explain the correlation. Additionally, the major statistical insignificance of some of them made the process of variable elimination easier. As a labour indicator, an unemployment rate was chosen instead of the employment rate as it’s more precise at representing the labour market of the country.

The final model was built using 3 variables (GDP per capita, unemployment rate, and government expenditure per student) that could affect migration flows in the UK (Table 3).

### Table 3. The coefficients of the final regression model.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>t Stat</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>174.928008</td>
<td>73.07878</td>
<td>2.393691</td>
<td>0.0278</td>
</tr>
<tr>
<td>gdp_per_capita</td>
<td>0.006014</td>
<td>0.002159</td>
<td>2.785459</td>
<td>0.0122</td>
</tr>
<tr>
<td>unemp_rate</td>
<td>-14.232203</td>
<td>6.788531</td>
<td>-2.096507</td>
<td>0.0504</td>
</tr>
<tr>
<td>exp_per_stud</td>
<td>7.798610</td>
<td>2.994629</td>
<td>2.604199</td>
<td>0.0179</td>
</tr>
</tbody>
</table>

According to the results of the modelling process, almost all chosen variables are statistically significant as all the p-values were less than 0.05 (Prob. Likelihood ratio for unemp_rate in Redundant Variable Test = 0.0284 less than 0.05). The model itself can be considered adequate as Prob(F-statistic) = 0.000018 less than 0.05 and the coefficient of determination is approximately equal to 0.7 (Adj. R² = 0.695). During the analysis of potential autocorrelation in a model a Durbin-Watson statistical test was used showing results of 2.169, indicating there is no autocorrelation of first order present in the model. To check heteroskedasticity in a model a White statistical test was used. The results show that a corresponding p-value of the test statistic is 0.1966 which means that we fail to reject the null hypothesis of homoscedasticity presence in this model. This points to the fact that there is not sufficient evidence to say that heteroscedasticity is present in the final regression model. All the concludes that the final regression model is adequate and reliable (Formula 1):

\[
Immigration = 174.928 + 0.006 \times (GDP \text{ per capita}) - 14.232 \times (Unemp. \text{ rate}) + 7.799 \times (Exp. \text{ per student}) + \epsilon
\]  

(1)

From the results in the final model, we can determine, using the elasticity coefficient, that the more influential factors are the GDP per capita, government expenditure per student and unemployment rate (Table 4).

### Table 4. Elasticity coefficients for independent variables.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Elasticity coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita</td>
<td>0.4844</td>
</tr>
<tr>
<td>Government’s expenditure per student</td>
<td>0.3275</td>
</tr>
<tr>
<td>unemployment rate</td>
<td>-0.1566</td>
</tr>
</tbody>
</table>

With the help of this model, we can forecast immigrant numbers in the UK by using projected numbers of variables used. According to the results of the calculation in the close future, the number of immigrants should subside and diminish slightly (Table 5).

### Table 5. Immigrant numbers forecast until 2025.

<table>
<thead>
<tr>
<th>Year</th>
<th>immigrants</th>
<th>gdp_per_capita</th>
<th>unemp_rate</th>
<th>exp_per_stud</th>
</tr>
</thead>
<tbody>
<tr>
<td>2022</td>
<td>601.58</td>
<td>46510.4</td>
<td>3.66</td>
<td>25.52</td>
</tr>
<tr>
<td>2023</td>
<td>606.69</td>
<td>47046.14</td>
<td>3.62</td>
<td>25.69</td>
</tr>
<tr>
<td>2024</td>
<td>611.89</td>
<td>47581.87</td>
<td>3.58</td>
<td>25.87</td>
</tr>
<tr>
<td>2025</td>
<td>621.35</td>
<td>48117.61</td>
<td>3.24</td>
<td>26.05</td>
</tr>
</tbody>
</table>
We can compare these results to the forecast made in a report by Office for National Statistics (ONS) in the UK back in 2020. As we can see both immigration projections show an estimated downward trend in 2022 and the numbers themselves are quite close. According to the report made by the Office of National Statistics in 2022 about long-term international migration, the number of immigrants recorded in 2022 was 704,000 [32]. This additional inflow of immigrants can be partially explained by Ukrainian refugees, who fled their home country due to the war in Ukraine caused by Russian aggression (Table 6).

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecast (1000s)</th>
<th>ONS estimates (1000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2022</td>
<td>601.58</td>
<td>602.00</td>
</tr>
<tr>
<td>2023</td>
<td>606.69</td>
<td>589.00</td>
</tr>
<tr>
<td>2024</td>
<td>611.89</td>
<td>576.00</td>
</tr>
<tr>
<td>2025</td>
<td>621.35</td>
<td>563.00</td>
</tr>
</tbody>
</table>

As this model was not built for forecasting forced migrations and factors used in this in this model are not meant to take into account these processes, we can conclude that overall migration estimates of the model are really close to the ones presented by ONS in 2022 and show close future values with the ONS forecast, which means this model can be used to describe overall immigration flow into the country have a practical use.

DISCUSSION

To sum up, everything said above, the United Kingdom is a country with a diverse population that has been shaped by immigration over many years. Immigration has contributed to the UK's economic growth and cultural diversity, but it has also raised concerns about its impact on public services, wages, and social cohesion. The United Kingdom, like many other countries, has a complex immigration system that is designed to regulate the entry and residence of foreign nationals. Being a developed country with a lot of opportunities for possible migrants, immigration has been a hotly debated issue in the UK for many years, with different viewpoints on the benefits and drawbacks. Analyzing immigration processes is crucial for the UK and other countries as well to understand the economic, social, and legal impacts of immigration.

In this article, a regression model was built to analyze what key factors could contribute to the immigration flows of the UK as well as to make predictions of future migrant numbers to make according to financial decisions on the governmental level. Multiple articles have been reviewed, which helped to narrow the focus down to 4 main categories: economic (GDP per capita, number of new businesses registered at the end of calendar year, average income), social (population density, urbanization level, government's expenditure per student, crime rate), labour (unemployment rate, employment rate) and housing factors (new residential dwellings built).

The final model used 3 factors that help describe the immigration process in the UK. The results of the model point to the fact that immigrants are largely influenced by the economic development level of the country and by the possible opportunities in the labour market as well as the possibilities of acquiring higher education. Factors such as urbanization level, average income and a crime rate that could directly influence immigrants' comfort and living conditions don't play a significant role when choosing the UK as a migration destination. It should be noted though that a model in this article is built to analyze international immigration processes and not interregional ones. There is a plethora of literature pointing out that factors, which didn't make it to the final model, can be and have been successfully used to model migration processes, just in different scenarios, where indicators like crime rate and population density could influence which region would an immigrant choose to move into, but not significant enough to change the country of choice.

CONCLUSIONS

The forecasts made using the model in this article show the same trend as other reputable sources such as the Office for National Statistics with the preciseness that is comparable to the real result of the immigrant numbers in reports. Nonetheless, such a model does not consider hard-to-predict migration processes such as migrations forced by natural disasters or political conflicts, which could explain the variance between forecast results and real numbers. It should be noted that while the model presented in this article describes immigration processes in the UK by 82%, the intercept has high significance, which indicates that if all variables were to be dismissed, there are other processes that create immigration flows.
in the UK, possibly exogenous, as this article focuses on the influence of endogenous factors only, the ones, that the country has some level of control.

In summary, analysing immigration processes is essential for any country to understand the impacts of immigration on the economy, social systems, and legal framework. Precise forecasts using such models can enable countries to make informed decisions on immigration policies that balance their economic and social interests and comply with their legal obligations, not to mention help prevent possible epidemiologic occurrences, which is especially important today.

**ADDITIONAL INFORMATION**

**AUTHOR CONTRIBUTIONS**

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Writing – original draft: Tetiana Zatonatska, Anzhela Ignatyuk, Anton Putytskyi, Yehor Pashkevych

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МОДЕЛЮВАННЯ ТА ПРОГНОЗУВАННЯ ІММІГРАЦІЙНИХ ПРОЦЕСІВ У СПОЛУЧЕНОМУ КОРОЛІВСТВІ З ВИКОРИСТАННЯМ ЕНДОГЕННИХ ФАКТОРІВ (PULL FACTORS)

Дослідження сфокусоване на економетричному моделюванні імміграційних процесів у Сполученому Королівстві (Великобританії) з використанням ендогенних факторів. Стаття спрямована на вивчення впливу економічних, соціальних, житлових та інших показників на приплив іммігрантів до Великобританії. У статті використана регресійна модель, яка охоплює період із 2000 по 2021 р., для оцінки взаємозв’язків між ендогенними факторами у Великій Британії та імміграційними процесами. До ендогенних факторів (pull factors), які розглянуті в дослідженні, входять такі економічні індикатори, як: ВВП на душу населення, кількість новостворених підприємств на рік, бюджетні витрати на одного студента, середня зарплата на рік; соціальні індикатори, такі як: щільність населення, рівень урбанізації, рівень злочинності; житлові фактори, зокрема кількість новобудов; трудові фактори, зокрема безробіття та рівень зайнятості. Результати дослідження показують, що такі ключові фактори, як ВВП на душу населення, рівень безробіття, нові зареєстровані підприємства та державні витрати на одного студента, мають значний вплив на приплив іммігрантів. Навпаки, рівень злочинності, середня зарплата та показники щільності населення недостають вливають на міграцію іноземців до Великобританії. Висновки дослідження мають важливе значення для політиків і дослідників в розумінні динаміки імміграційних процесів і потенціалу впливу ключових ендогенних pull factors для створення довгострокових прогнозів, політики можуть розробити більш ефективну імміграційну політику та краще розподілити ресурси для підтримки іммігрантів і їх інтеграції в британське суспільство.

Ключові слова: імміграція, математичне моделювання, прогнозування, міграційні потоки, регресійний аналіз

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