PREDICTOR VARIABLES OF IMMIGRANT ROOTING: A MODEL USING MACHINE LEARNING

Jorge Díaz-Ramírez, José Berríos-Riquelme, Jorge Maluenda-Albornoz, Olaya Grau-Rengifo, Gustavo Castillo-Rozas and Carla Vidal-Figueroa

SUMMARY

Rooting is essential for the social and cultural integration of immigrants in the host country. This research aims to use machine learning techniques to explore predictor variables of the rooting process of South American immigrants in Spain. The study follows a cross-sectional design, with a sample of 634 immigrants. The main results indicate that low perceived prejudice, contact with Spaniards, and stable employment are important predictors of rooting. Future studies need to explore more deeply into the quality of contact and the work experience of immigrants. The discussion is focuses on the relationship between theory and results, with suggestions for improving the prediction of the rooting with machine learning. The results of this study are valuable for public policies aimed at immigrant integration.

Introduction

The rooting of the migrant population is one of the main challenges facing receiving societies, as this sense of belonging contributes positively to the social and cultural integration of the immigrant population (Gissi and Andrade, 2022; Gissi *et al*., 2023). To support the integration of immigrant populations, studies from the past decade have identified key factors that predict this process, allowing for their application based on their demonstrated impact. However, researchers have not yet examined the variables that predict rooting using modern analytical techniques, such as Machine Learning. Consequently, this article aims to evaluate the variables that predict the rooting of immigrants through a machine learning-based model. The South American immigrant population residing in Spain is taken as a case study, as it is the foreign group that has had the most significant impact on the social and economic agenda of this country during the 21st century (Gutiérrez Rodríguez *et al*., 2023). The significance of this study lies in the transformative potential of machine learning in the analysis of social data. These techniques can overcome the limitations of traditional methods, enhancing accuracy in predicting complex social phenomena. Identifying patterns and trends through machine learning is crucial for informing public policies and strategic planning, making this study highly relevant (Leist *et al*., 2021).

The structure of the article is as follows: the first section provides context for South American migration in Spain. The second section explains the relevance of rooting for this population. The third section describes the methodology, including the design, analysis, and results. Finally, the article discusses the theoretical implications of the findings and offers suggestions for future research on migration issues using Machine Learning techniques.

South American immigration in Spain

Throughout the 21st century, Spain has become a primary destination for a large flow of migrants from South America (García Martínez, 2023), and it is currently one of the countries with the largest South American population in the world (Gutiérrez Rodríguez *et al*., 2023). The economic boom Spain has experienced in recent years, combined with its privileged location as an entry point to Europe, explains this phenomenon, which has led many immigrants to choose Spain as their destination. The shared language and cultural similarities also drive

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VARIABLES PREDICTORAS DEL ARRAIGO INMIGRANTE: UN MODELO USANDO APRENDIZAJE AUTOMÁTICO

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RESUMEN

El arraigo es esencial para la integración social y cultural de los inmigrantes en el país de acogida. Esta investigación tiene como objetivo utilizar técnicas de aprendizaje automático para explorar las variables predictoras del proceso de arraigo de inmigrantes sudamericanos en España. El estudio sigue un diseño transversal con una muestra de 634 inmigrantes. Los principales resultados indican que un bajo prejuicio percibido, el contacto con españoles y un empleo estable son predictores importantes del arraigo. Futuros estudios deben profundizar en la calidad del contacto y la experiencia laboral de los inmigrantes. La discusión se centra en la relación entre la teoría y los resultados, con sugerencias para mejorar la predicción del arraigo mediante aprendizaje automático. Los resultados de este estudio son valiosos para las políticas públicas dirigidas a la integración de los inmigrantes.

VARIÁVEIS PREDITIVAS DO ENRAIZAMENTO DE IMIGRANTES: UM MODELO USANDO APRENDIZADO DE MÁQUINA

Jorge Díaz-Ramírez, José Berríos-Riquelme, Jorge Maluenda-Albornoz, Olaya Grau-Rengifo, Gustavo Castillo-Rozas e Carla Vidal-Figueroa

RESUMO

O enraizamento é essencial para a integração social e cultural dos imigrantes no país anfitrião. Esta pesquisa visa utilizar técnicas de aprendizado de máquina para explorar variáveis preditoras do enraizamento de imigrantes sul-americanos na Espanha. O estudo tem um desenho transversal, com uma amostra de 634 imigrantes. Os principais resultados indicam que a baixa percepção de preconceito, o contato com espanhóis e o emprego estável são preditores importantes do enraizamento. Estudos futuros devem explorar mais profundamente a qualidade do contato e a experiência de trabalho dos imigrantes. A discussão foca na relação entre a teoria e os resultados, com sugestões para melhorar a previsão do enraizamento com aprendizado de máquina. Os resultados deste estudo são valiosos para políticas públicas voltadas para a integração dos imigrantes.

migration, as they facilitate immigrants' integration into the labor market and social environments (Cañadas-Romero *et al*., 2024). In recent years, studies have focused on understanding how this population integrates into society, analyzing various psychosocial variables involved in this process. These studies have shown that this population embarks on a long-term migration project, contemplating family settlement and, in some cases, planning to stay permanently (Gutiérrez-Rodríguez *et al*., 2024). The sense of rootedness that immigrants develop in their new environment, as well as their engagement with new cultural practices, would determine their extended stay in the host society (Cañadas-Romero *et al*., 2024). The rooting of South American immigrants provides insight into how they relate to their migratory, personal, and family projects, as well as the patterns they follow to secure employment and organize their survival in the host country (Sampedro Gallego and Camarero Rioja, 2017). Evidence suggests that rooting is a key variable that promotes good mental health (Urzúa *et al*., 2019) and plays a fundamental role in the identity processes of immigrants within the host society, contributing to their well-being and favoring positive intergroup relations (Berríos-Riquelme *et al*., 2022).

Rooting of immigrants and its predictor variables

Rooting is the act of developing an emotional connection with a particular geographic area (Kyle *et al*., 2004; Morgan, 2010). The social sciences interpret this concept as the idea of "putting down roots" in a territory where a person decides to settle for an extended and indefinite period (Malkki, 1992; Quezada Ortega, 2007). From a migratory perspective, we understand this concept as a psychosocial variable that encompasses how immigrants develop a sense of belonging to the host society through territorial and sociocultural ties (Berríos-Riquelme *et al*., 2022).

The rooting process enables the understanding of immigrants' intentions to seek sociocultural integration strategies that facilitate their long-term stay in the receiving country (Roessler Vergara *et al*., 2022). Thus, rooting allows immigrants to relate positively with local communities and begin to develop a sense of belonging (Millán-Franco *et al*., 2019; Torrente *et al*., 2011), which ultimately results in a connection to the social and cultural aspects of the society they are entering (Berríos-Riquelme *et al*., 2022).

The importance of rooting as a psychosocial variable in migratory contexts lies in its ability to alleviate the emotional distress experienced by migrants due to leaving their past life behind (Morgan, 2010), and in its role in helping them cope with experiences of exclusion and discrimination, which they often face (Urzúa *et al*., 2019). Additionally, uprooting is linked to isolation and exclusion in the host society, potentially leading to mental health issues such as depression or anxiety (García Ballesteros *et al*., 2009). Although literature suggests that South American immigrants would have an easier time integrating into Spain due to historical and cultural ties, they still must navigate a series of variables that impact their process of rooting in

different ways (Sampedro Gallego and Camarero Rioja, 2017). The situation becomes challenging for these individuals, as their desire to root may be diminished, directly affecting their integration process. The personal experiences of immigrants play a significant role in shaping these variables, with perceived prejudice being one of the most important factors (Berríos-Riquelme *et al*., 2018). Literature also highlights the importance of contact with the majority group (Sánchez-Castelló *et al*., 2022), the nature of employment relationships (Gil-González *et al*., 2013), and the length of time spent in Spain (Torrente *et al*., 2011) in shaping the rooting process.

It is necessary to explain how these variables have affected the rooting of South American immigrants in Spain by examining the social context in which these people live, where the media and political parties have constructed a negative image of migration in the country. Firstly, the media have portrayed immigration as a threat to Spanish security and identity (Oller Alonso *et al*., 2021), which is why immigrants are often stigmatized and socially devalued (Berríos-Riquelme *et al*., 2018). Meanwhile, political parties have also contributed to constructing immigrants as a problem for society, claiming that they are an enemy that will change Spanish cultural identity and take over their jobs (Fernández Romero *et al*., 2021; Olmos Alcaraz, 2023). These beliefs have created a hostile climate for the immigrant population, as the Spanish population has relied on these beliefs to justify and manifest xenophobic attitudes towards the foreign population residing in the country (Narváez Llinares and Pérez-Rufí, 2022).

According to Roessler Vergara *et al.* (2022), the negative attitudes experienced by immigrants are crucial to consider when studying the foreign population's desire to settle in the country since the negative experiences they accumulate become a factor that decreases the possibility that they will feel the desire to continue living in the country. Therefore, this approach is adopted because the prejudice perceived by immigrants limits their positive interactions with nationals, hindering their inclusion process, given that when they feel rejected, they also feel no desire to integrate into a society that frowns upon them and, therefore, they avoid contact with nationals (Berríos-Riquelme *et al*., 2018). Additionally, prejudice constitutes a barrier that affects social life and how immigrants establish their intergroup relations (Jasinskaja-Lahti *et al*., 2007). Therefore, it is possible to hypothesize that perceived prejudice negatively affects the rooting of immigrants.

Researchers have extensively studied the impact of contact in the context of migration as another variable, suggesting that as immigrants and nationals interact more frequently, their intergroup relations will improve (Pettigrew and Tropp, 2006). The contact theory points out that the constant relationship between both groups allows mutual knowledge, decreases prejudices (Pettigrew and Tropp, 2008), and improves coexistence (Hayward *et al*., 2018). Simultaneously, constant interaction allows immigrants to learn to interact according to prevailing cultural patterns and to understand how to function in the new world (Kenfack *et al*., 2024). The relationship is also seen as emotional and instrumental support that contributes to strengthening the sense of community towards the place and culture where they are developing their lives (Millán-Franco *et al*., 2019). Thus, when immigrants have a larger amount of positive interactions with nationals, these will be reflected in a better integration process and, therefore, their desire to remain in the host society will be greater (Tropp *et al*., 2018). Regarding the above, it is possible to hypothesize that contact positively predicts immigrants' level of rooting.

The length of time immigrants reside in the host country is also a predictor variable of rooting. Literature indicates that this relationship is explained by the fact that the longer an immigrant is in the new country, the stronger their support networks become and the more frequently they participate in community activities (Torrente *et al*., 2011). These factors are necessary for immigrants to have significant opportunities to learn about prevailing cultural patterns, such as how to speak and express themselves (Gissi Barbieri *et al*., 2019). Meanwhile, with more years in the host society, their ties to the neighborhood where they live increase, enhancing the sense of feeling accepted and a greater desire to continue living in that society (Millán-Franco *et al*., 2019). Therefore, it is possible to hypothesize that years of residence in the destination country positively predict rooting.

The employment status of immigrants represents another variable in their level of rooting; however, it is necessary to differentiate how their contractual relationship is regulated, whether the person works with a contract or without one, and also to consider whether they are not working. Firstly, the employment contract plays a crucial role in the rooting process for employed immigrants, as they require this document to obtain and maintain the residence permit (Esteban-Peñas and Mendoza, 2023). Having a work contract also makes it possible to plan a medium- and long-term migration project (Berríos-Riquelme, 2021). The hypothesis is that an employment relationship regulated by an employment contract positively predicts rooting.

Considering the reality of migrants who work without a contract, they are generally in an irregular administrative situation, and the work they perform is usually dangerous and demanding (Briones-Vozmediano *et al*., 2022), which leads to immigrants living under a constant state of despair and frustration (Navarro-Gambín and Jansen, 2024). This situation would lead to them having little chance of feeling rooted. People who are not employed face a similar reality and will encounter structural barriers and restrictions that could enhance their exclusion (Carrasco, 2015), since work is the key that opens the doors to integration (Baglioni and Calò, 2023). Therefore, the hypothesis suggests that working without a contract negatively predicts rooting, and the hypothesis also suggests that being unemployed negatively predicts rooting.

The present research aims to evaluate the predictive variables of rooting through machine learning techniques, which will allow us to explain the extent to which certain variables affect the integration process of these individuals. The literature review suggests that four variables are implicated in the levels of attachment of the migrant population, which allows us to propose the following hypotheses:

1. Perceived prejudice is a negative predictor of immigrants' rooting.

2. Contact is a positive predictor of the level of immigrant attachment.

3. Years of residence in the destination country are a positive predictor of rooting.

4. An employment relationship regulated by an employment contract will positively predict rooting.

5. Working without a contract is a negative predictor of rooting.

6. Not having a job is a negative predictor of rooting.

Methodology

Participants

The present research had a non-experimental cross-sectional methodology and a non-probabilistic sample. Due to the impossibility of having a

defined sample frame, we established three inclusion criteria to ensure the sample was as homogeneous as possible: a) being a South American immigrant, b) having lived in Spain for more than one year, and c) being of legal age. The 724 South American immigrants agreed to answer the questionnaire using convenience sampling in public spaces, institutions, and different immigrant associations in Valencia (Spain). After purging the database, only 634 cases remained that contained all the necessary information to carry out the analysis, with 381 (60.1%) identifying themselves as female and 253 (39.9%) as male. The mean age of the participants was M = 36.63 (SD = 11.38). Regarding the country of origin of these individuals, the majority were from Chile (n= 165), Colombia (n= 156), Ecuador (n= 138), and Bolivia (n= 103), and the rest were from other countries (n= 72). Regarding their administrative status, most were in regular status (n= 586), and only a small group were in irregular status (n= 48). Concerning their employment status, the majority were working with a contract (n= 302), followed by those who were unemployed (n= 227), and finally, those who were working without a contract (n= 105).

Procedure

Researchers sampled various folkloric, sports, and recreational associations of immigrants in Valencia (Spain). They asked participants in these settings if they were interested in participating in the study. The organizers explained that participation would be voluntary, without compensation, and that they would treat their responses confidentially and anonymously. Participants then read and signed an informed consent form. Thus, the study adhered to the Declaration of Helsinki principles for human subjects research (World Medical Association, 2013). The participants self-administered the questionnaires, taking an average of 30 minutes to respond to each question.

Instrument

The first section of the questionnaire delved into the crucial sociodemographic variables that shape the experiences of Latin American immigrants in Spain: gender, nationality, age, employment status, years of residence in Spain, and administrative status. These variables are key to understanding this population's unique challenges and opportunities. The second section of the questionnaire utilized three scale variables: rooting, perceived emotional prejudice, and contact.

The Latin American Immigrant Rooting Scale (Torrente *et al*., 2011) is a comprehensive instrument that measures the degree of attachment of Latin American immigrants. In this study, we used the abbreviated version of eight items proposed by Berríos-Riquelme *et al*. (2022). These eight items comprehensively measure rooting, understood as the link with the place and the degree of closeness to the local culture. The items are in a five-category Likert-type response format, ranging from not at all (1) to very much (5). The minimum score one must obtain is eight, and the maximum is 40. The scale's internal consistency was good, according to Cronbach's Alpha (α= 0.868) and McDonald's Omega (ω= 0.870).

Perceived Emotional Bias (Frías-Navarro, 2015). This instrument assesses the prejudice immigrants perceive through the emotions that Spaniards express towards them. The emotions studied were insecurity, distrust, rejection, hostility, pity, hatred, indifference, and fear. The response format was Likert-type, with options ranging from not at all (1) to very much (5). The minimum score was eight, and the maximum was 40 points. The internal consistency values were good according to Cronbach's Alpha (α= 0.858) and McDonald's Omega (ω= 0.862).

Contact. Researchers assessed this variable by asking three questions. The first question was, *Is there any Spanish person within your closest friendships?*, which had two response options: "No" (1) and "Yes" (2). The second question was, *Do you share any activity unrelated to your work or studies with any Spanish person?* It had three response options: "Never" (1), "Sometimes" (2), and "Always" (3). The third question was, *How do you value your relationship with Spaniards?* The response options were: "Not Affective" (1), "Normal" (2), and "Affective" (3). We calculated the total value of the contact variable by adding up all the response options, resulting in a minimum score of three and a maximum of eight. The higher the score, the greater the degree of contact that immigrants have with Spaniards.

Data analysis

Machine Learning, which enables computers to learn autonomously how to use databases without executing specific programming for each task, was used for data analysis. Algorithms in this field analyze data to discover patterns and, based on them, make predictions or decisions (Díaz-Ramírez, 2024). Initially, preprocessing was carried out by running an Exploratory Data Analysis (EDA) and modeling, as they are essential to understanding the nature and inherent relationships of the data and identifying the most appropriate models to represent and predict these relationships (Díaz-Ramírez, 2021; Milo and Somech, 2020).

Preprocessing

The data preparation process was meticulous, starting with loading the corresponding file. We carefully eliminated columns that were judged irrelevant to the analysis and modeling. As a result, in the database, we refined and were left with a set of variables, including rooting, perceived prejudice, contact with Spaniards, years of residence in Spain, and employment status. We then categorized the numerical variables, where perceived prejudice, contact with Spaniards, and years of residence in Spain were recorded in sections according to the mean to separate them into "low" and "high" scores. The contract variable continued as a polytomous variable with three response options: the person works with a contract (with), the person is not working (no), and the person is working without a contract (without). Afterward, they were transformed into Dummy variables (Allen, 1997) so that the newly categorized variables would be appropriately treated as categorical and, thus, improve the control over them when performing the analysis in Pycaret. After applying the described transformations, we selected the variables of interest for the analysis. This refinement process culminates with creating a new dataset ready for further analysis and modeling, optimizing data quality, and establishing a solid base for the subsequent phases.

Exploratory data analysis

Exploratory Data Analysis (EDA) is a comprehensive technique for examining and understanding the structure and characteristics of data before delving into more advanced analyses (Komorowski *et al*., 2016). In our study, EDA played a pivotal role in visualizing the distribution of key variables and understanding the relative importance of the different characteristics of the target variable, rooting. The initial exploratory analysis focused on examining the distribution of categorical variables within the data set. Examining the distributions of the categorical variables revealed clear patterns within the data set (Table I). For example, the variables Contact and Residence show a predominance of "high," respectively, indicating generally high levels of contact and favorable

TABLE I
DISTRIBUTION OF FREQUENCIES OF CATEGORICAL VARIABLES

Variable	High	Low	With	No	Without	Total
Contact	515	119	-	-	-	634
Prejudice	72	562	-	-	-	634
Residence	511	123	-	-	-	634
Contract	-	-	302	227	105	634

residence conditions among the individuals studied. The Perceived Prejudice variable indicates that the "low" category includes most participants. In addition, the employment status variable shows a more varied distribution, with a tendency towards the existence of formal contracts.

Figure 1 presents a histogram showing the distribution of the variable rooting. The distribution shows two peaks, one around the low values of rooting and the other near the higher values, indicating a possible bimodality in the distribution of the variable. The more prominent peak at the upper end suggests a significant data concentration at higher rooting levels. The smoothed curve of the Kernel Density Estimation (KDE) overlaid confirms this observation, highlighting areas of higher and lower density records in the sample (Scott, 2015). Collectively, the histogram and KDE curve visually describe the variability of the variable rooting within the data set in detail, facilitating the identification of patterns and understanding of the centrality and dispersion of the data.

Modeling

At this stage, selecting the most suitable model to fit the data for identifying the predictor variables of rooting occurs. The preparation and analysis of the dataset are done using the PyCaret automation library (PyCaret 3.0, 2023). The preparation starts with configuring the modeling environment by specifying the data and the target variable to be predicted (rooting). Seventy percent of the data is used for training, and highly correlated variables are eliminated to prevent multicollinearity (PyCaret FS, 2023). Moreover, transformations are applied to improve the data distribution (PyCaret ST, 2023). After configuring the environment, several models are trained and compared with PyCaret's method, using the Mean Absolute Error (MAE) as a comparison criterion to select the best model to represent the data (Table II). MAE measures the average magnitude of prediction errors. Other metrics included were MSE, the average of the squared prediction errors; RMSE, the square root of MSE; RMSLE, for relative prediction errors; and MAPE, which expresses accuracy as a percentage.

When comparing the regression models presented in Table II, Ridge Regression emerges as the best model thanks to its Mean Absolute Error (MAE) of 4.6420, demonstrating its superiority for accurate and consistent predictions (Šinkovec *et al*., 2021). After implementing strategies to prevent multicollinearity, the model remains robust and has predictive capability, such as removing highly correlated variables in PyCaret. Ridge Regression's effectiveness, evidenced by its low MAE, can be attributed to its handling of multicollinearity (Duzan and Shariff, 2015) and also to its penalty methodology that adjusts the magnitude of the coefficients to prevent overfitting and optimize the balance between bias and variance (Arashi *et al*., 2021; Ogutu *et al*., 2012). This approach improves the model's generalization and contributes to its predictive performance, even on moderately sized data sets. Thus, the ability of Ridge Regression to provide accurate and consistent predictions, keeping all variables under consideration and adjusting their influence by penalizing, underlines its usefulness in identifying predictor variables of rooting. Therefore, the choice of

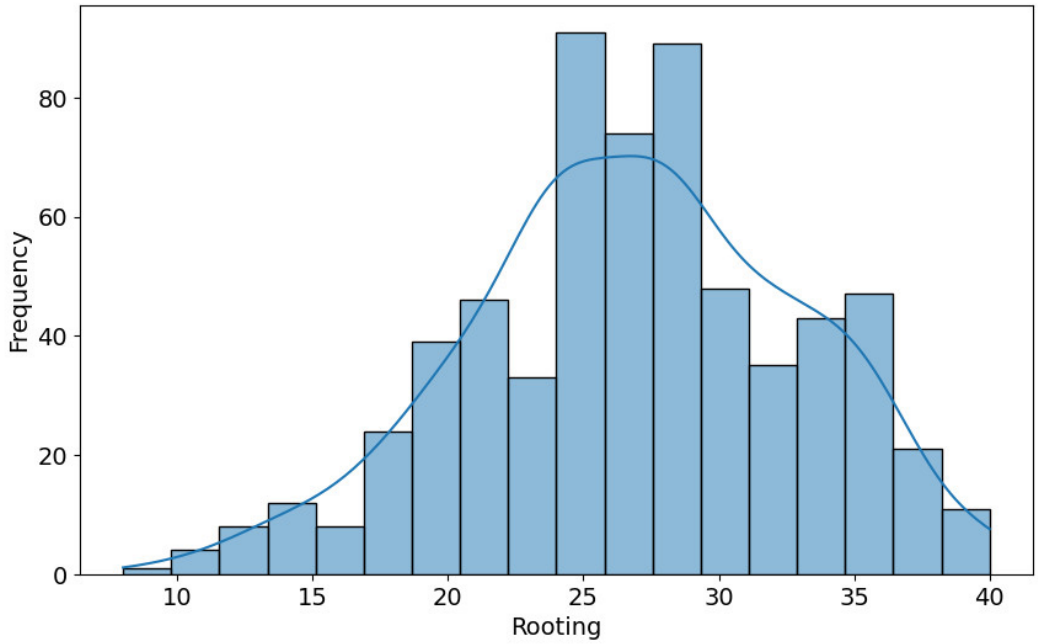

Figure 1: Distribution of rooting.

TABLE II
TOP 10 PYCARET TRAINING RESULTS

Model	MAE	MSE	RMSE	R2	RMSLE	MAPE
Ridge Regression	4.6420	33.9217	5.8147	0.0519	2.280	0.1972
Linear Regression	4.6432	33.9400	5.8162	0.0514	2.280	0.1972
Least Angle Regression	4.6432	33.9400	5.8162	0.0514	2.280	0.1972
Huber Regressor	4.6477	34.0002	5.8214	0.0495	2.283	0.1977
Bayesian Ridge	4.6581	33.9928	5.8219	0.0495	2.284	0.1979
Elastic Net	4.6591	34.0016	5.8224	0.0494	2.283	0.1979
Lasso Regression	4.6610	34.0299	5.8248	0.0486	2.285	0.1980
Lasso Least Angle Regression	4.6610	34.0299	5.8248	0.0486	2.285	0.1980
Light Gradient Boosting Machine	4.6745	34.3558	5.8525	0.0392	2.293	0.1983
Gradient Boosting Regressor	4.7011	34.7929	5.8892	0.0275	2.308	0.1995

MAE: measures the average magnitude of prediction errors, MSE: average of the squared prediction errors, RMSE: square root of MSE, RMSLE: relative prediction errors, MAPE: accuracy as a percentage.

Ridge Regression reflects a strategy to maximize accuracy and interpretability in the data model, ensuring reliable and high-quality predictions.

Results

The analysis of the variable rooting through the Ridge Regression model yielded three visual interpretations that shed light on the relative importance and sensitivity of the predictor variables.

Figure 2 shows that contractual conditions (represented by "with an employment contract" [works with a contract] and "without a contract" [works without a contract]) emerge as predictor variables of rooting, showing a strong link between the nature of the contract and the feeling of being part of Spanish society. Subsequently, we observe that frequent contact with Spaniards and a more extended residence in Spain significantly predict the rooting of South American immigrants. These findings underline the preponderance that employment status, degrees of intergroup contact with Spanish citizens, and years of residence in the country are the central axes in predicting the rooting of South American immigrants in Spain.

Figure 3 shows the impact of the permutation of the values for the variables on the model's predictive accuracy (Altmann *et al*., 2010). High contact with Spaniards has an inverse influence on the level of rooting. Having a stable employment situation regulated by a work contract or working without a contract also suggests a negative relationship for the rooting of South American immigrants. Furthermore, immigrants perceiving a low level of prejudice would encourage immigrant rooting. Interestingly, although the other variables are relatively less relevant, they also interact in the predictive model.

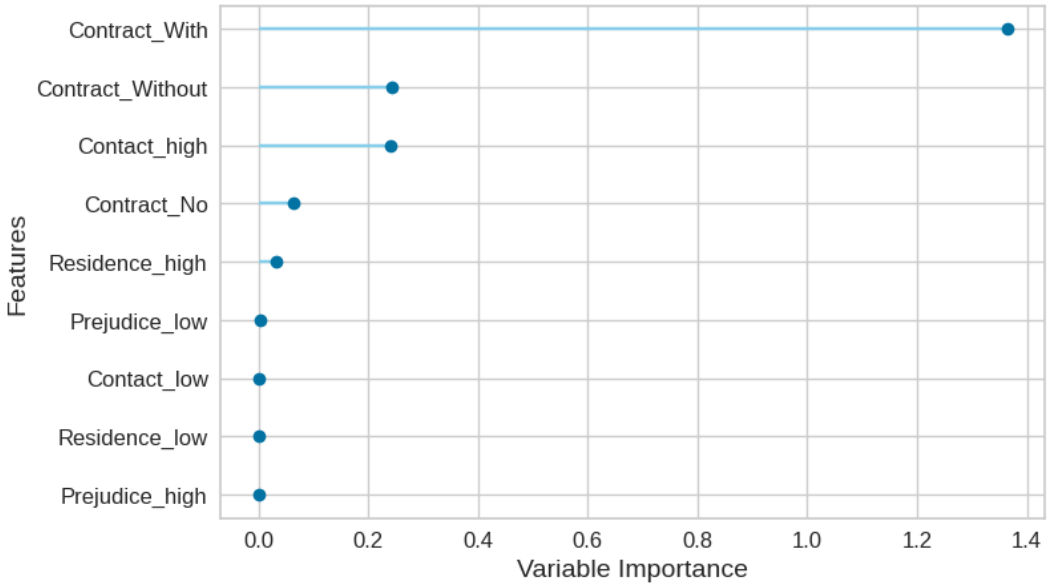

Figure 2: Features importance for Ridge Regression.

The sensitivity analysis results of Morris (1991) reinforce the preponderance that a high level of contact with Spanish people and a labor situation regulated by a contract are important predictors of rooting (Figure 4). The observed pattern consolidates the notion that the amount of contact and the labor situation regulated by a contract are important predictors of the rooting of South American immigrants in Spain. Additionally, the convergence index of 0.000 suggests that the estimates of the effects of the input variables achieved stability in the model's output and do not vary with the increase of more trajectories in the analysis. Finally, both the employment status and the amount of contact are determinants for the inverse prediction of the rooting of South American immigrants;

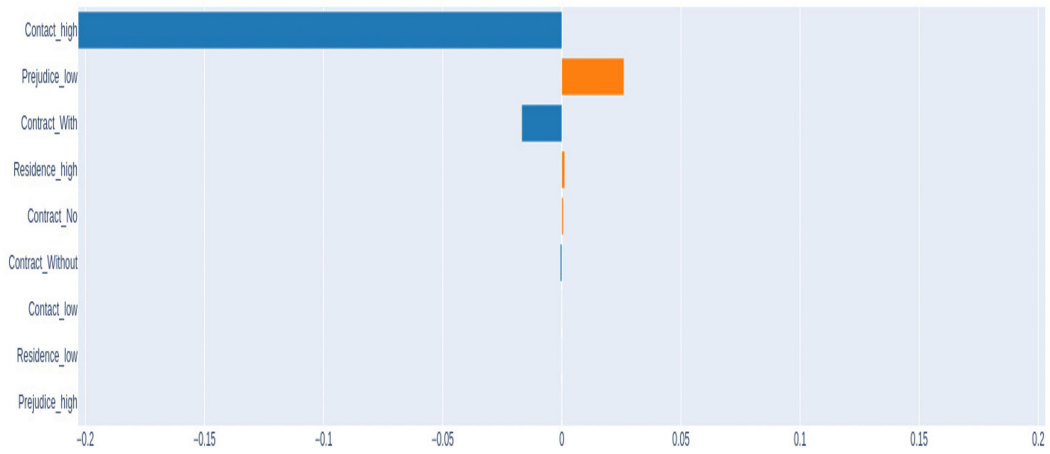

Figure 3: Significance of features by permutation.

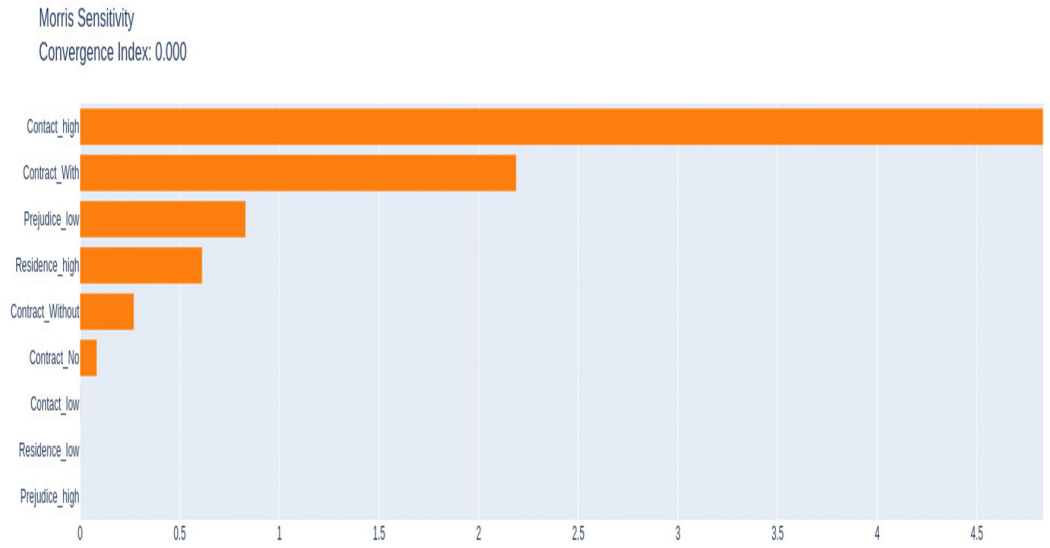

Figure 4. Morris sensitivity analysis.

moreover, perceiving little prejudice and more years in Spain will also influence the rooting variable, although its direct impact is minor.

Discussion

Rooting in the migrant population is a measure that allows us to understand the bond that these individuals have with the society that welcomes them. As such, it has become a fundamental piece for evaluating and understanding the integration of these people in the host society (Berríos-Riquelme *et al*., 2022). The present study sought to evaluate the predictive variables of rooting in South American immigrants in Spain through a predictive model using Machine Learning.

The results underline the regression model's usefulness in predicting rooting. They highlight that having a high level of contact with Spaniards, having a work contract, and perceiving little prejudice were the variables with the most significant weight and importance in the model for predicting the rooting of South American immigrants in Spain. Having a high level of contact with Spaniards and having a work contract were inverse predictors of immigrants' rooting in Spain; on the other hand, low prejudice was a positive predictor of immigrants' rooting in Spain.

Regarding the findings on the contact variable, it is possible to point out that having high contact with the Spanish population would predict the level of rootedness; however, the relationship found was inverse and contrary to the hypothesis. These findings are contrary to contact theory, which suggests that having high contact with the national population will be beneficial for intergroup relations (Pettigrew and Tropp, 2006) and for the integration of the migrant population (Kenfack *et al*., 2024). An explanation could be that the accumulation of negative experiences characterizes this level of contact, leading immigrants to feel unrooted in the host society due to specific situations in which the quality of contact plays a more essential role than its quantity (Stephan *et al*., 2000). The importance of the quality of contact in studies with minority groups has made it possible to explain the specific effects of this variable in contexts of intergroup relations (Frías-Navarro *et al*., 2020). This result opens new avenues for further research on contact theory in the context of international migration.

Regarding the contractual relationship of the immigrants, it was found that working with a contract predicted rooting; however, the relationship was inverse and contrary to the theory proposed, where having an employment contract would positively predict rooting. A possible explanation for this could be that immigrants are aware that Spaniards see them as a threat in the labor context (Berríos-Riquelme *et al*., 2018), and they could be victims of negative attitudes in this context (Agudelo-Suárez *et al*., 2009). Recent evidence supports the observed predictive relationship, showing that working with an employment contract does not free immigrants from negative experiences (Berríos-Riquelme *et al*., 2024). This result is contradictory with theory and the empirical evidence on the subject, making it a promising topic for further research.

Perceived prejudice was also a significant predictor of South American immigrant rooting when this variable had low levels. It is important to note that this finding reveals the importance of environments with intergroup respect, in which perceiving low prejudice would be a prominent predictor of good rooting levels. A novel

result, it is consistent with the literature on discrimination and prejudice, in which low levels of these negative attitudes would be beneficial for facilitating the correct insertion of the migrant population (Roessler Vergara *et al*., 2022). The analysis of these results is critical in pointing out that immigrants would have problems accessing positive relationships in the labor setting. Meanwhile, the predictive role of perceiving low prejudice would be consistent with an environment facilitating the rooting of the foreign population.

Further study of these variables as a whole will be beneficial to understand immigrants' relationships with the local population, as the willingness to take root does not only stem from the migration project itself but is also strongly influenced by the experiences individuals have in their intergroup relationships (Tropp *et al*., 2018).

The model tested in this study allows us to better understand the phenomenon of immigrant rooting, demonstrating the importance of working with methodologies rooted in Machine Learning techniques to analyze social data and identify complex patterns. Expanding this kind of work by adding more variables to the model could provide more precise insights into the factors that promote or hinder immigrant integration.

Understanding the relationship between the variables involved in the rooting of immigrants not only requires an exhaustive analysis of psychosocial variables but also an evaluation of structural factors. Based on this, the following suggestions are made for the implementation of public plans and policies that promote the integration of immigrants. First, policies should focus on promoting diversity, equality, and inclusion to foster a social environment in which immigrants feel supported in developing their rooting. A second key area for evaluation is the implementation of labor policies that encourage intergroup relations based on respect. Work, after all, is not just a factor of economic stability for immigrants; it is one of the main contexts in which they are supported in realizing their migration project (Berríos-Riquelme, 2021) and beginning their process of rooting (Baglioni and Calò, 2023).

Although the present research results are insightful, the study does have certain limitations that should be considered. The primary limitation is the non-probabilistic nature of the sample, which means the findings cannot be generalized to the entire migrant population in Spain, potentially affecting the external validity of the results. Additionally, the population studied consists solely of South American immigrants, most of whom were recruited from immigrant associations, which could have influenced their responses due to social desirability bias. In this regard, an area for improvement is the study's design, which does not allow for establishing cause-and-effect relationships. Future studies could address this limitation by using longitudinal designs to observe how the variables predicting rooting evolve over time.

Continuing in this line of research will help identify emotional and behavioral processes that explain rooting. Therefore, we offer the following suggestions for future research. The first result from the contact variable shows no evidence of an association in the hypothesized direction. A suggestion would be to consider a variable that evaluates the quality of contact that immigrants maintain in their intergroup relations. Another useful approach could involve complementing quantitative research with qualitative methods that allow a deeper exploration of the motivations immigrants attribute to their intergroup interactions. Additionally, further investigation is needed into why immigrants with permanent contracts might present better levels of rooting. This phenomenon remains underexplored in the literature and warrants further academic inquiry. Finally, future research could benefit from exploring more complex models that incorporate additional variables, such as migratory status, gender, or whether the immigrant has applied for nationality in the receiving country. Structural factors like migration policies and access to social services should also be considered, as they play a pivotal role in shaping the immigrant experience.

In conclusion, the evidence presented in this study emphasizes the importance of advanced Machine Learning techniques in creating deep and accurate predictive models for social phenomena like rooting. In the current era of migration, understanding how immigrants become rooted in host societies is crucial, as this variable will influence their overall development and integration. The findings presented here will be valuable for future transdisciplinary approaches, enabling the design of more effective public intervention strategies aimed at promoting the integration of migrant populations.

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