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Migration as a diffusion process: the case of Bologna municipality

Ida D'Attoma

Department of Statistical Sciences, University of Bologna, Via delle Belle Arti 41, 40126, Bologna, Italy Ida.dattoma2@unibo.it

Camila Cid

Department of Statistical Sciences, University of Bologna, Viale Quirico Filopanti, 5, 40126 Bologna, Italy camila.ciddiaz@unibo.it

Tassinari Giorgio

Department of Statistical Sciences, University of Bologna, Via delle Belle Arti 41, 40126, Bologna, Italy giorgio.tassinari@unibo.it

1. Introduction and Theoretical Framework

The demographic change is currently taking place, characterized by depopulation in certain areas due to phenomena such as population aging, emigration, and declining fertility rates. Italy is a clear representative of this reality, as measurements and projections from the Italian National Institute of Statistics indicate a progressive decline in population throughout the country (ISTAT, 2023).

In this context, it is interesting to understand why this phenomenon is also present in the northern region of the country, which is highly industrialized, with high levels of quality of life and higher per capita income. According to official predictions, while the northern part of the country does not show as rapid a decline as the central and southern regions of Italy, it is still projected to reduce its population by 2.7 million inhabitants (ISTAT, 2023).

In this regard, we are interested in understanding the depopulation phenomenon, with a special focus on emigration from municipalities with high standards of living, such as the municipality of Bologna. Bologna is the seventh most populous municipality in Italy with about 392,800 residents as of Dec. 31, 2022. Among the features worth mentioning is that Bologna confirms itself as an attractive city, as shown by the migration balance, particularly active with the South and the Islands and with foreign countries. 44 percent of immigrants in Bologna are between the ages of 25 to 34 years old and, among them, more than 80 percent are Italian (Comune di Bologna, 2021).

To study the emigration flow of the inhabitants of Bologna, the diffusionist paradigm was used, which has been widely utilized in marketing but has also been applied in various fields of research (Rogers, 2003).

For this analysis, in a first stage, emigration from Bologna was examined through the Bass diffusion model (Bass, 1969). According to this model, in a market analysis context, the diffusion of new behaviours is driven by two types of communication: external, which includes advertising and public awareness campaigns, and internal, which includes social influence, word-of-mouth, and imitation. These two factors give rise to two categories of adopters: innovators, who are primarily receptive to external sources of information, and imitators, who adopt in response to interactions with earlier adopters (Bass, 1969).

As second step, the analysis was complemented with a more structuralist approach (Palloni, 2001), by estimating regression models to address the association of innovation and imitation coefficients derived from the Bass model with sociodemographic and socioeconomic variables. Regarding the latter, the study focused on the economic conditions of the selected destination, allowing us to elucidate whether factors such as unemployment rate, median income, or property values are determinants in the decision to migrate.

2. Data

For this research, we are working with administrative repeated cross-sectional data from public and official sources. To describe the phenomenon of emigration for the Bologna case, data on emigrants were retrieved from the 'Comune di Bologna' website with reference to the period from 1986 to 2023.

However, for the estimation of the Bass model by destinations, the number of emigrants from the Bologna municipality to different regions of the country between the years 2013 and 2023 was used, because the official sites do not provide sociodemographic and socioeconomic information in the required detail to perform these analyses.

To estimate the regression models different data sources were employed (see Table 1). In particular, data from Bologna municipality were used to gather information on the sociodemographic characteristics of emigrants from Bologna between the years 2013 and 2023. Additionally, information between the years 2013 and 2023 on the socio-economic variables (i.e., unemployment rate and median annual household income in the destination regions) was obtained from the Istat website. Finally, information regarding real estate prices in the destination regions between the years 2013 and 2023 was obtained from the "Agenzia delle entrate" website.

Table 1. Sources of information

Variable	Description	Source	Available at:
Region	Destination regions of emigrants originating from the municipality of Bologna	Comune di Bologna	https://inumeridibolognametropolitana.it/dati-statistici/emigrati-provincia-di-destinazione-serie-storica
Citizenship*	The percentage of emigrants from Bologna who hold Italian citizenship	Comune di Bologna	https://inumeridibolognametropolitana.it/dati-statistici/emigrati-provincia-di-destinazione-serie-storica
Age*	The percentage of emigrants from Bologna aged between 30 and 39	Comune di Bologna	https://inumeridibolognametropolitana.it/dati-statistici/emigrati-provincia-di-destinazione-serie-storica
Sex*	The percentage of emigrants from Bologna who are male	Comune di Bologna	https://inumeridibolognametropolitana.it/dati-statistici/emigrati-provincia-di-destinazione-serie-storica
Unemployment rate	Average unemployment rates between the years 2013 and 2023 by destination region.	Istat	http://dati.istat.it/index.aspx?queryid=20744
Minimum real estate prices	Average minimum real estate prices between the years 2013 and 2023 (in euros) by destination region.	Agenzia delle entrate	https://www.agenziaentrate.gov.it/portale/web/guest/schede/fabbricatiterreni/omi/banche-dati/quotazioni-immobiliari
Median annual household income	Annual average household income between the years 2013 and 2023 (in euros) by destination region.	Istat	http://dati.istat.it/Index.aspx?QueryId=22919

*Variables in percentages terms were introduced in the model as dummy variables; =1 in correspondence of the percentage of each category of interest in the emigrant population during the analyzed period.

3. Descriptive analysis

According to emigration data from 1986 to 2023, there has been an upward trend, from 8,954 to 12,411 cases. However, this trend has not been constant, showing significant fluctuations, such as

in 1996, when there was a decrease with 8,468 cases recorded. Similarly, 9,877 cases were recorded in 2014(Comune di Bologna, 2023).

As for the destinations chosen by emigrants, it emerges that in most cases they opt for other municipalities in Northern Italy. Much less frequently, between 1997 and 2012, Southern Italy stood out, but since 2013 it has been overtaken by destinations abroad (Comune di Bologna, 2023).

Focusing on internal migration, in most cases emigrants choose another city in the same province of Bologna. Second, they move to another region and, to a lesser extent, to another province in the Emilia-Romagna region (see Table 2).

As for the Italian regions, Emilia Romagna stands out with significantly higher values compared to other regions, where the destination province with the highest number of cases throughout the period is Bologna. In second place is Lombardy, which, except for the pandemic years, shows a steady increase over time, reaching its highest value in 2022 with 702 cases (Comune di Bologna, 2023).

Table 2. Residential relocations between Italian regions (From 2013 to 2023)

Years	In the same region				Between different regions		Total	Percentage variation
	Within the same province (Bologna)	%	Between different province	%	Absolute values	%		
2013	5.056	47,9	1.189	11,3	4.316	40,9	10.561	
2014	4.711	47,7	1.137	11,5	4.029	40,8	9.877	-6,9
2015	4.890	48,7	1.116	11,1	4.035	40,2	10.041	1,6
2016	5.083	48,4	1.196	11,4	4.218	40,2	10.497	4,3
2017	5.178	48,9	1.221	11,5	4.196	39,6	10.595	0,9
2018	5.281	49,7	1.219	11,5	4.123	38,8	10.623	0,3
2019	5.882	49,7	1.329	11,2	4.621	39,1	11.832	10,2
2020	5.444	48,3	1.291	11,4	4.542	40,3	11.277	-4,9
2021	5.894	50,0	1.436	12,2	4.456	37,8	11.786	4,3
2022	6.314	50,0	1.496	11,8	4.824	38,2	12.634	6,7
2023	5.961	48,0	1.457	11,7	4.993	40,2	12.411	-1,8

Source: Authors' elaboration based on data from the Municipality of Bologna.

4. Methodology

To study the emigration flow of Bologna inhabitants, the standard Bass model (Bass, 1969) was estimated, which besides being the most well-known diffusion model, is also considered the most parsimonious (Parker, 1994)

The Bass model considers three fundamental parameters for its implementation: firstly, there is the potential market size (m), interpreted as the number of people who could potentially emigrate to a particular region; secondly, there is the coefficient of innovation (p), understood as the probability that a person decides to emigrate to a specific region independently of the influence of others; and finally, the coefficient of imitation (q), interpreted as the probability that a person decides to emigrate to a region due to the influence of others.

The formal representation of the Bass Model is a first-order differential equation as in (1):

$$z'(t) = \left[p + q\frac{z(t)}{m}\right][m - z(t)],\ t > 0 \quad (1)$$

where, in an emigration study context, the variation of emigrants by destination z'(t) over time is proportional to the residual susceptible population of emigrants (m - z(t)) and z(t) represents the cumulative number of emigrants by destination at time t.

The model coefficients were obtained for each of the Italian regions chosen as destination by emigrants from the municipality of Bologna. The software R Studio and the DIMORA package (Zanghi et al. 2023) were used.

Once obtained estimated parameters by destinations, following the approach by Kurdgelashvili et al. (2019), two linear regressions were performed: one where the dependent variable is the estimated innovation coefficient (p) by different destination regions with socioeconomic variables and potentially sociodemographic variables as independent variables; and another where the dependent variable is the estimated imitation coefficient (q) by different destination regions with socioeconomic variables related to the destination region and potentially sociodemographic variables of the emigrants as independent variables.

5. Preliminary results

The estimated Bass models for destination regions of emigrants from the municipality of Bologna show a high level of goodness of fit across all regions. The values of Relative MSE are significantly less than 1, and the R^2 values are close to 1 (See Table 3).

Results showed that most regions exhibit a higher coefficient of imitation (q) than innovation (p), indicating that the decision to emigrate is more driven by the influence of others who have already emigrated, rather than a personal decision to do so.

Importantly, as reported in Table 3, regions such as Emilia Romagna, Veneto, and abroad show a significantly higher coefficient of imitation (q), suggesting that imitation plays a crucial role in the decision to emigrate in these areas. On the other hand, regions with the highest coefficients of innovation (p) are primarily Calabria, Campania, and Sicily. This indicates that in Southern Italy, there is a greater tendency towards independent emigration decisions not heavily influenced by social factors, which could suggest motivations such as returning to one's region of origin or reuniting with family members.

Table 3. Results of the standard Bass models by destination region

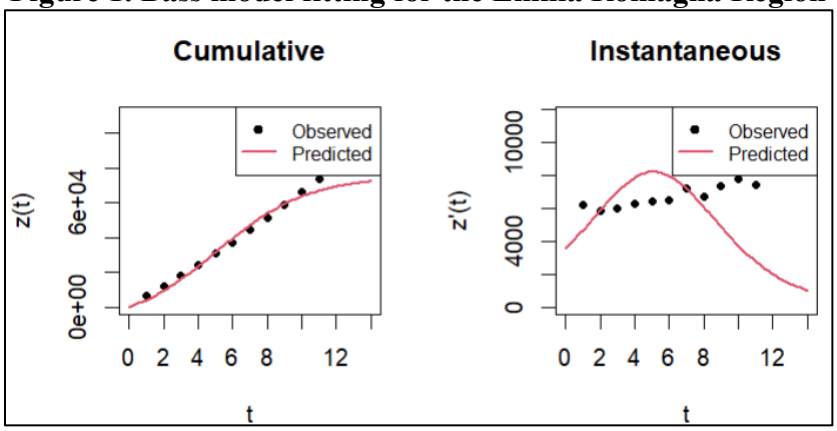
	2013-2023										
REGION	**m**	**S.E. m**	**p-value**	**$\hat{p}$**	**S.E. $\hat{p}$**	**p-value**	**$\hat{q}$**	**S.E. $\hat{q}$**	**p-value**	**R^2**	**RMSE**
Abruzzo	2385	8.73	0.000	0.041	0.000	0.000	0.126	0.001	0.000	0.998	0.005
Basilicata	1498	59.69	0.000	0.029	0.001	0.000	0.039	0.002	0.000	0.999	0.004
Calabria	2655	11.21	0.000	0.065	0.000	0.000	0.065	0.001	0.000	1000	0.001
Campania	4134	3.83	0.000	0.058	0.000	0.000	0.162	0.000	0.000	0.999	0.003
E. Romagna	74781	1.08	0.000	0.048	0.000	0.000	0.338	0.000	0.000	0.994	0.017
Friuli-VG	1583	15.42	0.000	0.032	0.000	0.000	0.113	0.001	0.000	1.000	0.001
Lazio	4002	3.96	0.000	0.054	0.000	0.000	0.171	0.000	0.000	0.999	0.003
Liguria	1848	21.14	0.000	0.037	0.000	0.000	0.074	0.001	0.000	0.999	0.004
Lombardia	7277	2.02	0.000	0.046	0.000	0.000	0.261	0.000	0.000	0.997	0.008
Marche	3006	5.43	0.000	0.047	0.000	0.000	0.147	0.000	0.000	0.998	0.006
Molise	703	60.55	0.000	0.033	0.003	0.000	0.014	0.005	0.000	0.998	0.006
Piemonte	2458	8.24	0.000	0.036	0.000	0.000	0.155	0.001	0.000	0.999	0.004
Puglia	4326	3.19	0.000	0.053	0.000	0.000	0.181	0.000	0.000	0.997	0.008
Sardegna	1835	21.72	0.000	0.038	0.000	0.000	0.073	0.001	0.000	0.999	0.003
Sicilia	3424	4.73	0.000	0.055	0.000	0.000	0.141	0.000	0.000	0.998	0.005
Toscana	3752	4.28	0.000	0.051	0.000	0.000	0.171	0.000	0.000	0.999	0.003
Trent-Alto Adige	1779	28.93	0.000	0.035	0.000	0.000	0.094	0.002	0.000	0.999	0.003
Umbria	1118	27.81	0.000	0.028	0.001	0.000	0.134	0.003	0.000	1.000	0.000
Valle d'Aosta	134	NA	NA	0.022	NA	NA	0.031	NA	NA	0.996	0.013
Veneto	4190	3.46	0.000	0.048	0.000	0.000	0.195	0.000	0.000	0.998	0.005
Estero	14232	1.42	0.000	0.049	0.000	0.000	0.303	0.000	0.000	0.997	0.008

Source: Authors' elaboration based on data from the Municipality of Bologna

With reference to 'Cumulative' and 'Instantaneous' graphs obtained using the standard Bass model to glean insights into the emigration process for each region studied, it is noteworthy that for all analysed regions, the Bass model captures the overall trend of cumulative adoption quite well, fitting the general behaviour of accumulated data over time. This is consistent with the Bass model's definition as a growth model designed to fit a cumulative or integration function of data. However, the same cannot be said for instantaneous adoption, as in most cases the models fail to fully capture annual fluctuations, resulting in a divergence between observed and predicted values.

Regarding the trajectory of the cumulative curve, most regions exhibit an initial increase in the rate of emigration, followed by stabilization, and in some cases, a slight decrease towards the end of the analysed period. This trajectory can be observed in the Emilia Romagna region (See Figure 1).

Figure 1. Bass model fitting for the Emilia Romagna Region



Source: Authors' elaboration based on data from the Municipality of Bologna

Furthermore, regarding the regression models performed, it is noteworthy that both models showed statistically significant parameters. In the model aiming to explain the innovation coefficient - p- (Model 1), the significant variables are the unemployment rate and the median annual income. While, in the model aiming to explain the imitation coefficient - q- (Model 2), the significant variables are the unemployment rate, minimum real estate prices, and median annual income.

Table 4. Innovation coefficient regression model

Model 1: p coefficient as dependent variable					
Variable	**Estimate**	**S.E.**	**t value**	**Pr(>|t|)**	
Intercept	-1.16e-01	3.20e-02	3.62e+03	2.28e-03	**
Unemployment Rate	4.11e-03	7.00e-04	5.87e+03	2.36e-05	***
Minimum real estate prices	-2.43e-03	6.13e-03	-3.95e-01	6.97e-01	
Median annual household income	3.80e-06	8.50e-04	4.48e+03	3.83e-04	***
Model 2: q coefficient as dependent variable					
Intercept	-9.31e-01	2.75e-01	-3.382	3.80e-03	**
Unemployment Rate	1.70e-02	5.92e-03	2.873	1.10e-02	*
Minimum real estate prices	-1.20e-04	5.47e-05	-2.183	4.43e-02	*
Median annual household income	3.14e-05	7.46e-06	4.202	6.75e-04	***

*** p < 0.001, ** p < 0.01, * p < 0.05

Source: Authors' elaboration of occicial sources of data (see Table 1)

6. Conclusion

In summary, the standard Bass model shows a good fit for all regions of Italy and abroad, as confirmed by the R^2, the Relative MSE, and the accumulation curve. However, the instantaneous adoption rate is not fully captured by the studied models.

Regarding the coefficients obtained through the Bass model, the imitation coefficient is higher in most of the areas studied, with the highest values found in the northern regions compared to the southern regions of Italy. This indicates that social influence is more decisive in these areas, suggesting different emigration patterns between the two geographical zones.

In reference to the estimated regression models, the socioeconomic variables turned out to be significant for both models. This suggests that emigrants, when deciding the emigration destination seek better living conditions. This is especially true when we consider the variable “Median annual household income”, which is significant in both models, and the variable "minimum real estate prices," which is significant for the imitation coefficient. In the case of the unemployment rate, the result is counterintuitive and therefore needs to be studied more thoroughly in future research. This future research could, for example, examine geographical differences in migration decisions.

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