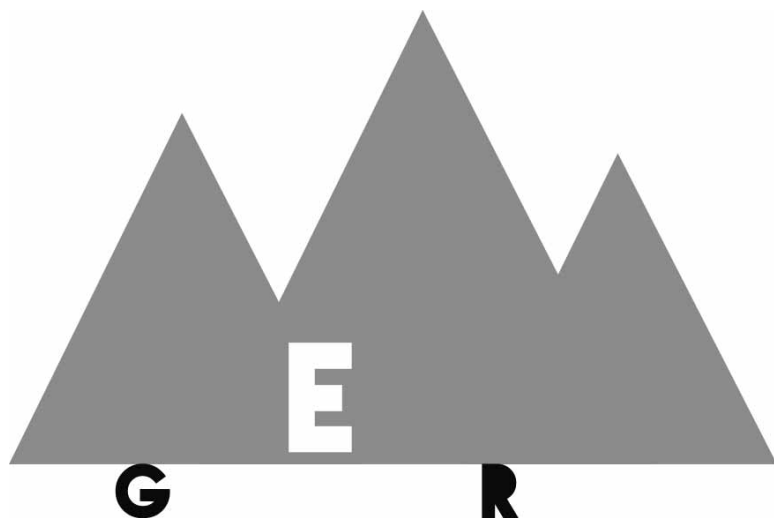


Forecasting Rural Depopulation in Spain



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Forecasting Rural Depopulation in Spain

Highlights:

1. We forecast that the rural population in Spain will increase from 7.9 to 8.2 million by 2040.
2. Half of the Spanish provinces will undergo rural population decline by 2040, particularly those in Northwest Spain.
3. Rural depopulation is expected to accelerate.

Abstract: Population projections and forecasts below the regional level are widely used by governments for spatial planning, including service provision and infrastructure. However, projections and forecasts are often produced only at national and regional scales. We use autoregressive integrated moving average (ARIMA) models to forecast the rural population size of the 50 Spanish provinces up to 2040. Our results predict that the rural population in Spain will increase from 7.9 to 8.2 million inhabitants until 2040, but 25 out of 50 provinces will experience rural population shrinkage, particularly those in Northwest Spain. For instance, Ourense, Zamora, and León are forecasted to lose more than 30 % of the rural population. Additionally, depopulation is expected to accelerate across provinces affected by rural population shrinkage.

Keywords: Population forecasting, rural areas, ARIMA, rural depopulation, Spain.

Predicciones de despoblación rural en España

Ideas clave:

1. Prevemos que la población rural en España se incrementará de 7,9 a 8,2 millones para 2040.
2. La mitad de las provincias españolas experimentarán un descenso de la población rural hasta 2040, especialmente aquellas en el noroeste de España.
3. Se prevé una aceleración de la despoblación rural.

Resumen: Las proyecciones y predicciones de población por debajo del nivel regional son ampliamente utilizados por los gobiernos para la planificación territorial, incluyendo la provisión de servicios e infraestructuras. Sin embargo, las proyecciones y predicciones se suelen producir únicamente a escala nacional y regional. Utilizamos modelos autorregresivos integrados de media móvil (ARIMA) para predecir el tamaño de la población rural en las 50 provincias españolas hasta 2040. Nuestros resultados prevén que la población rural en España crecerá de 7,9 a 8,2 millones de habitantes hasta 2040, pero 25 de las 50 provincias experimentarán una disminución de la población rural, particularmente aquellas en el noroeste de España. Por ejemplo, se prevé que Ourense, Zamora y León pierdan más del 30 % de la población rural. Además, se espera que la despoblación se acelere en las provincias afectadas por el declive de la población rural.

Palabras clave: Predicciones de población, áreas rurales, ARIMA, despoblación rural, España.

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1. Introduction

Population projections and forecasts are often produced at national and regional scales, which can mask territorial heterogeneity within large geographic units, such as differences in population trends between urban and rural areas. This is the case with the Spanish National Statistics Institute (INE), which produces population projections at the national and provincial levels. Most population projection and forecast methods are developed for broad spatial units (Booth, 2006). For example, the cohort-component model is often unsuitable for areas below the regional level (Wilson et al., 2022). Population projection and forecasting approaches below the regional scale remain underdeveloped, although recent efforts have been made using various methods, such as extrapolative models, simplified cohort-component approaches, downscaling techniques, microsimulation, and machine learning. Among these methods, extrapolative models tend to be more accurate to forecast population in small areas, require simple calculations and minimal input data (Wilson et al., 2022). These models are based on past trends and involve linear or exponential extrapolations. In this Rural Graphic, we use ARIMA models, a type of extrapolative method, to forecast the rural population in the Spanish provinces through 2040. Specifically, we aim to explore whether the rural population in each province is expected to increase or decrease over the next two decades.

2. Data and methods

We used population counts between 2000 and 2020 from the INE as input data and ARIMA models to forecast the rural population across the 50 Spanish provinces through 2040¹. We aggregated results at the provincial level to obtain population forecast at the national level. Rural areas were selected by excluding municipalities within urban areas (as classified by the Spanish Ministry of Transport and Sustainable Mobility) and those with populations larger than 10,000 inhabitants. Although data for 2021–2023 were available, we did not include this information due to unusual and temporary population gains resulting from internal migration during COVID-19 (González-Leonardo et al., 2022). This unusual period could affect the accuracy of ARIMA models, which rely on historical data to produce forecasts.

ARIMA models consist of three elements: autoregressive (AR), integrated (I), and moving average (MA) components. These elements represent the long-term, short-term, and stochastic trends of a time series, respectively. The AR and MA components control temporal autocorrelation in a time series through two mechanisms. The first assumes that a variable (Y) at time t is explained by its past values, while the second considers Y_t as a function of current and past moving averages of error terms, where current deviations from the mean depend on previous deviations. Fitting a time series with AR and MA parameters requires the data to be weakly stationary, meaning the covariance is time-invariant and depends only on the lag between current and past values. However, weak stationarity in time-series data is rare. Therefore, AR and MA elements must be integrated, and time series must be differentiated using the I component to achieve stationarity. We used the ARIMA specification 'Random Walk with Drift' as it provided the best fit for observed trends, assessed using unit root tests for stationarity and the Akaike Information Criterion. Results include 95 % confidence intervals. Forecasts were performed in RStudio, using the packages *tseries*, *forecast*, and *astsa*, with *ggplot2* and *geofacet* for visualization.

1• We used data since 2000 as input because annual population counts became available in 1998 and data for 1998 and 1999 were not reliable.

3. Results

Figure 1 shows the observed rural population in the Spanish provinces from 2000 to 2020, and forecasted to 2040 (see Table A1 in the Appendix). ARIMA models predict that the rural population in Spain will increase from 7.9 to 8.2 million until 2040 (+2.9 %). However, they forecast rural population decline in 25 out of 50 provinces, where depopulation levels are expected to accelerate. Population decline is forecasted to exceed -15 % in the rural areas of Valladolid, Badajoz, Albacete, Ciudad Real, Cáceres, Salamanca, Lugo, Asturias, Ourense, Zamora, and León, with values reaching -30 % in the latter three provinces. A Coruña, Córdoba, Ávila, Palencia, and Jaén are expected to register rates of population change between -10 % and -15 %, while declines below -10 % are anticipated in Granada, Pontevedra, Cuenca, Cádiz, Zaragoza, Soria, Segovia, Teruel, and Burgos.

ARIMA models forecast rural population growth in half of the provinces but predict a slowdown in their growth rates. The largest increases will occur in Baleares, Madrid, Alicante, Guadalajara, Almería, Barcelona, and Girona, exceeding 20 %. Population size in Toledo, Santa Cruz de Tenerife, Tarragona, Valencia, La Rioja, Málaga, Navarra, Castellón, and Las Palmas is expected to increase between 10 % and 15 %, while growth rates will register values below 10 % in Huesca, Lérida, Álava, Murcia, Gipuzkoa, Cantabria, Huelva, Bizkaia, and Sevilla.

4. Discussion and conclusion

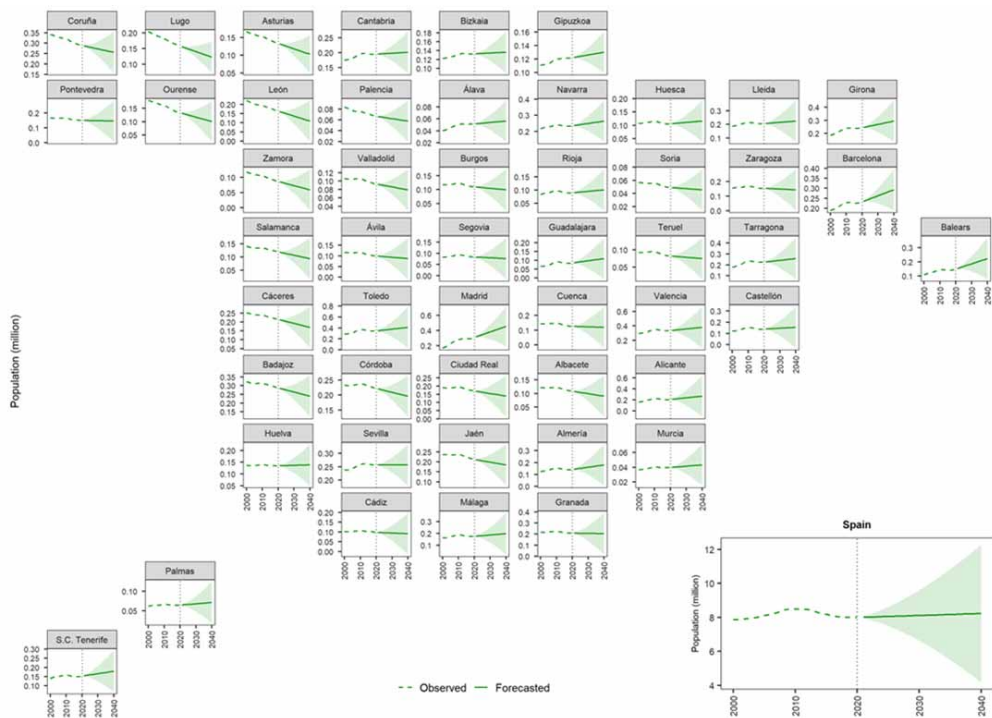
Our results forecast that half of the Spanish provinces will experience rural population shrinkage over the next two decades. Additionally, population decline is expected to accelerate, particularly in depopulated provinces across Northwest Spain. The INE (2024) projects that only 12 of the 50 provinces will experience population

decline by 2040, with rates below -8 %². Thus, our findings suggest that several provinces projected to experience population growth will be affected by rural depopulation. This reinforces the need to conduct population projections and forecasts below the regional scale to capture spatial heterogeneity.

Regarding the limitations of this work, we must consider that ARIMA models rely solely on historical data. They are powerful when population trends remain somehow unchanged but cannot predict unexpected changes in demographic components, such as the sudden increase in immigration occurred over the first decade of the XXI century (Collantes et al., 2014; González-Leonardo et al., 2023). We must also acknowledge that our results display high levels of uncertainty. Future lines of research could measure the accuracy of our results in retrospective forecasts, or by comparing population forecasts for larger geographical scales with aggregated individual forecasts. Our study could be expanded by using different methods of population projections and forecasts, such as the simplified cohort component approach, downscaling methods, or machine learning models. Future work could also conduct population forecasts at the municipal level. However, this task is challenging because such a detailed scale includes small and random population counts.

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- 2• The INE uses the cohort component method, a deterministic approach, to produce population projections at the provincial level, while we use ARIMA models to perform probabilistic population forecasts for rural areas within Spanish provinces. The INE projects that the provinces of Zamora, Jaén, Palencia, Asturias, León, Badajoz, Córdoba, Cáceres, Lugo, Salamanca, Pontevedra, Ciudad Real will experience a population decline of less than 8 % by 2040, while our forecasts predict that most of these provinces will lose more than 15 % of their rural population in the same period.

Figure 1.
Rural population in the Spanish provinces from 2000 to 2020 and forecasted to 2040



Source: Own elaboration using data from the Spanish National Statistics Institute (INE).

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Appendix of the manuscript "Forecasting rural depopulation in Spain

Table A1.

Rural population in the Spanish provinces in 2000 and 2020, and forecasted to 2040; population change in 2000-20, and forecasted in 2020-40

Province	Population			Population change (%)	
	2000	2020	2040	2000-20	2020-40
León	220.694	163.512	109.172	-25,9	-33,2
Zamora	118.229	87.032	59.072	-26,4	-32,1
Ourense	180.406	133.862	100.982	-25,8	-24,6
Asturias	166.559	133.540	102.900	-19,8	-22,9
Lugo	203.941	158.256	122.776	-22,4	-22,4
Salamanca	140.894	119.784	94.044	-15,0	-21,5
Cáceres	250.205	215.633	169.973	-13,8	-21,2
Ciudad Real	189.979	171.543	138.523	-9,7	-19,2
Albacete	120.938	108.575	90.275	-10,2	-16,9
Badajoz	322.331	287.384	239.964	-10,8	-16,5
Valladolid	105.537	93.263	79.223	-11,6	-15,1
Jaén	237.278	212.881	184.481	-10,3	-13,3
Palencia	83.832	66.683	57.803	-20,5	-13,3
Ávila	117.148	99.295	87.275	-15,2	-12,1
Córdoba	233.522	222.084	196.264	-4,9	-11,6
A Coruña	341.738	289.036	256.196	-15,4	-11,4
Burgos	117.818	110.106	99.326	-6,5	-9,8
Teruel	92.855	81.930	74.530	-11,8	-9,0
Segovia	82.596	83.498	76.338	1,1	-8,6
Soria	56.823	49.063	45.563	-13,7	-7,1
Zaragoza	154.529	153.018	142.958	-1,0	-6,6
Cádiz	100.782	97.696	91.396	-3,1	-6,4
Cuenca	143.856	126.013	118.913	-12,4	-5,6
Pontevedra	168.077	149.963	145.723	-10,8	-2,8
Granada	218.692	207.982	203.562	-4,9	-2,1
Sevilla	237.224	256.676	256.756	8,2	0,0
Bizkaia	122.363	132.758	136.258	8,5	2,6
Huelva	137.670	134.950	138.710	-2,0	2,8
Total	7.867.901	7.998.073	8.226.433	1,7	2,9
Cantabria	174.112	194.748	201.228	11,9	3,3
Gipuzkoa	110.782	121.964	130.024	10,1	6,6
Murcia	36.735	39.799	43.219	8,3	8,6
Álava	40.159	51.562	56.342	28,4	9,3
Lérida	186.454	205.232	224.312	10,1	9,3
Huesca	107.027	105.606	115.866	-1,3	9,7
Palmas	62.080	64.366	71.206	3,7	10,6
Castellón	120.282	138.901	154.401	15,5	11,2
Navarra	216.858	235.115	264.235	8,4	12,4
Málaga	161.591	174.947	196.947	8,3	12,6
Rioja	83.955	89.980	101.340	7,2	12,6
Valencia	296.165	335.829	379.809	13,4	13,1
Tarragona	177.749	225.687	257.587	27,0	14,1
S.C. Tenerife	138.363	152.885	178.905	10,5	17,0
Toledo	286.058	345.591	409.951	20,8	18,6
Girona	186.755	244.799	295.059	31,1	20,5
Barcelona	188.453	231.910	292.930	23,1	26,3
Almería	125.715	142.089	180.589	13,0	27,1
Guadalajara	65.120	85.234	109.574	30,9	28,6
Alicante	158.840	205.890	266.350	29,6	29,4
Madrid	168.159	309.767	454.567	84,2	46,7
Baleares	109.973	150.156	223.036	36,5	48,5

Source: Own elaboration using data from the Spanish National Statistics Institute (INE).