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# Examining the Effects of Different Policy Approaches to Rural Depopulation Across Spanish Territories: Evidence From a Multi-Scenario Simulation Study

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## ABSTRACT

Rural depopulation linked to aging populations, economic decline, and reduced public services has accelerated migration to urban centres in various parts of the European Union and increasingly attracts the attention of policymakers. This study employs the SPANDAM system dynamics model to evaluate the effectiveness of different policy approaches across three representative Spanish rural territories (*Zamora*, *Pirineo Navarro*, and *Vitigudino*) through five simulated scenarios: *business-as-usual* (BS), *macroeconomic focus* (PS1), *rural economic development* (PS2), *service-centred approach* (PS3), and *combined strategy* (PS4). Results demonstrate that while targeted interventions can improve socioeconomic indicators and slow demographic decline, only the comprehensive strategy (PS4) combining economic and service policies showed significant impacts, nearly stabilizing *Zamora*'s population and reducing the decline in *Pirineo Navarro* to a very slow pace. However, even this integrated approach failed to fully reverse depopulation in areas with severe demographic deterioration like *Vitigudino*, highlighting how initial conditions critically determine policy effectiveness. The findings yield several key insights: (1) national economic improvements (PS1) have minimal local impact in the absence of concrete policies on the territory, underscoring the need for place-based strategies; (2) larger municipalities benefit more than smaller municipalities from many of the policies implemented due to economies of scale; and (3) the implementation of partial policies (PS2 and PS3) improves the quality of life of the inhabitants, but does not halt the depopulation process. These points underscore the imperative for enhanced multi-level governance coordination to enable integrated policy interventions that can meaningfully counteract rural depopulation.

## 1 | Introduction

Rural depopulation is a major socio-economic challenge across Europe, particularly affecting regions in Southern and Eastern Europe. It is driven by multiple interrelated factors, including aging populations, economic stagnation and unemployment, shifts in agricultural and industrial structures, deteriorating environmental conditions and a lack of

education and health service provision (Barakat 2015), resulting in outmigration to urban centres (Alcaide Muñoz et al. 2024; Cejudo and Navarro 2023; European Commission 2024; Karcagi Kováts and Katona Kovács 2012; OECD 2021; Ubarevičienė et al. 2025). It threatens economic viability, exacerbates spatial inequalities, and places additional pressure on public services and infrastructure (OECD 2021). Given its far-reaching consequences, rural

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depopulation has gained increasing attention from policy-makers at both the European Union (EU) and national levels, with a range of counteracting strategies, such as the European Rural Pact (European Commission 2021). Despite these efforts, depopulation persists, raising questions about the effectiveness of current policy approaches.

Institutional efforts to address rural depopulation within the EU have primarily been framed within broader rural development strategies, including the EU's Rural Development Programs (RDs), the Rural Pact or the Rural Action Plan and cohesion policy measures aimed at fostering economic resilience in lagging regions, such as the European Regional and Development Fund (ERDF) or modifications to the Common Agricultural Policy (CAP) to adapt it to future challenges (European Commission 2024; Eurostat 2024). These strategies emphasize infrastructure investment, digital connectivity, business incentives, and social services as key tools to retain and attract populations in rural areas (European Commission 2021). However, implementation varies significantly from country to country (Czibere et al. 2021; Dax and Copus 2022). While some states emphasize financial support for rural businesses and farms, others focus on decentralization, regional governance reforms, or targeted tax incentives (Serra et al. 2023). Additionally, inhabitants of European rural areas have pointed out the urgent need to create and improve infrastructure, access to facilities and care, social and leisure services, as well as digital connectivity and employment (European Commission 2021).

Evaluations of these policies show mixed results and highlight a tendency towards one-size-fits-all solutions, which often fail to account for local conditions (Pinilla and Sáez 2021; Viccaro et al. 2021). Quantitative analyses increasingly use computational models like econometric and agent-based models to explore trends and behaviours (Alamá-Sabater et al. 2021; Krushel et al. 2014; Reynaud et al. 2020; Silveira et al. 2006). However, these often miss complex feedback loops or macroeconomic drivers. System dynamics modelling, adept at capturing such interdependencies, is underutilized in depopulation studies. Existing applications rarely use it for scenario-based policy analysis or to explore how national policies interact with local contexts—a critical gap given the EU's push for place-based, holistic strategies (European Commission 2021).

Thus, there is a limited understanding of how national policies interact with local conditions to either exacerbate or mitigate rural depopulation. The effectiveness of policies is often contingent on regional economic structures, labour markets, and institutional capacities, yet comparative studies systematically assessing these interactions remain limited. While qualitative research has argued for greater alignment between national and local strategies (Dax and Fischer 2018), quantitative and scenario-based analyses exploring different national policy configurations remain scarce. This lack of systematic modelling approaches complicates the assessment of long-term effects of alternative policy scenarios on rural depopulation dynamics. We address these gaps by investigating the effects of different policy strategies, including national economic development, on rural depopulation at the local level. Specifically, we answer the following questions:

1. How do national developments influence rural population change?

2. How do rural development policies and the strengthening of social services affect demographic trends in different local territories?

In response, we employ an explorative scenario analysis using an adapted version of the Spanish Demographic Dynamics Assessment Model (SPANDAM), applied to three representative case studies in Spain: the regions of *Vitigudino* and *Pirineo Navarro*, and the province of *Zamora*. This system dynamics model is particularly well-suited for capturing feedback mechanisms between demographic trends, economic development, and policy interventions. By applying SPANDAM to account for different national socio-economic developments and policy strategies, we show how varying strategies might shape rural futures under different assumptions.

The article is structured in line with this approach. First, in Section 2, we present the background of models used to study rural depopulation and mitigation policies, providing a deeper justification for our work's contribution. Next, in Section 3, we introduce the SPANDAM model, specifically the version used in this analysis. In Section 4, we then present the selected case studies and their current contexts. In Section 5, we outline the developed scenarios and the corresponding policies. Subsequently, in Section 6, we present the simulation results of the three case studies. Finally, in Section 7, we discuss and summarize our findings, acknowledge the limitations of our study, and identify areas for further research and policy refinement in addressing rural depopulation in Europe.

## 2 | Modelling Approaches and Gaps in Depopulation Policy Analysis

The use of models to study depopulation is a growing line of research. In recent decades, various types of models have emerged to analyse this phenomenon. This methodological diversity is reflected in the literature, encompassing approaches such as econometrics to diagnose drivers and causal conditions of depopulation (Alamá-Sabater et al. 2021; Reynaud et al. 2020; San-Martín González and Soler-Vaya 2024); machine learning techniques for prediction of depopulation risk (Jato-Espino and Mayor-Vitoria 2023); projection models for detailed demographic forecasting (Ballas et al. 2005; Hori et al. 2021); agent-based models to simulate decentralized migration decisions (Krushel et al. 2014; Silveira et al. 2006); and economic equilibrium models that analyse the effects of depopulation on economic variables or how depopulation can be prevented (Hagihara and Asahi 2016; McArthur et al. 2014).

A common drawback of many of these models is their inability to capture the fundamental feedback loop between population loss and the deterioration of socio-demographic conditions, which in turn fuels further depopulation. In this regard, system dynamics models possess a distinct advantage, as they are inherently designed to represent such feedback loops natively (Serman 2000). These models are particularly suited for simulating the “vicious circles” or systemic traps characteristic of depopulation processes, such as the self-reinforcing cycle linking demographic decline to aging, the loss of services, and the reduction of economic activity, or the critical thresholds below which decline becomes irreversible (Navarro and Tapiador 2019). Consequently, they offer a powerful framework for testing policy

interventions aimed at breaking these negative cycles and managing complex socio-demographic systems under stress.

Within the relatively limited corpus of system dynamics models applied to rural depopulation, we find studies of varying focus. Some are highly theoretical, operating at a level of abstraction that distances them from the applied analysis of this article (Figueiredo and Pereira 2011; Márton 2022). Others, while of significant interest, focus on historical depopulation phenomena and thus also diverge from our analysis (Cole and Flenley 2008; Tenza et al. 2019). Furthermore, there are some that focus more on the consequences of depopulation (e.g., environmental sustainability) than on the depopulation phenomenon itself (Lazar et al. 2022); these also diverge from our work.

The academic work most closely aligned with our own consists of models that focus on contemporary depopulation using data from specific case studies. The earliest among these is Kopainsky (2005), who developed a model for a Swiss mountain region integrating demographic and economic dimensions to simulate the feedback loops between labour markets, capital investment, entrepreneurship, and migration. Refsgaard and Johnson (2010) created a model for a Norwegian county, linking agriculture, rural development, and quality of life to analyse how agricultural subsidies and economic diversification affect migration patterns. Vidal-Legaz et al. (2013) modelled a Spanish municipality to analyse trade-offs between socio-economic development and ecosystem services, with endogenous migration driven by relative income, employment, landscape value, and service availability. Finally, Navarro and Tapiador (2019) developed a model, using data from Spain, that simulates critical thresholds and feedback loops between demographic structure, economic vitality, and quality of life, identifying a 'critical mass' below which decline becomes irreversible.

Regarding the policy analysis in these works, some do not evaluate specific policies per se but instead focus on understanding systemic dynamics to inform future design (Navarro and Tapiador 2019; Vidal-Legaz et al. 2013). Those that analyse policies in a strict sense typically do so by focusing on policies applied to the territorial economy in general or to specific economic sectors. For instance, they evaluate agricultural subsidies (Refsgaard and Johnson 2010) or investment and entrepreneurship support (Kopainsky 2005). This focus on primarily economic policies represents a limitation when compared to the broader literature on policies to mitigate depopulation (Loras-Gimeno et al. 2025). This broader literature includes, in addition to policies directly or indirectly focused on the economy, a significant number of policies aimed at strengthening social services.

Against this backdrop, our study makes several contributions. First, it directly addresses this gap by incorporating a comprehensive suite of policies centred on social services—including healthcare, education, other public services, and transport and communications infrastructure—which have been under-represented in quantitative system dynamics analyses of depopulation. Second, it expands the application of this methodology by providing a structured, comparative assessment of how different national policy strategies interact with local conditions, explicitly exploring their synergistic effects and potential trade-offs. Third, through a scenario-based approach grounded in these comparisons, the study generates forward-looking,

quantitative insights that can directly inform robust, evidence-based policy decisions at local, national, and EU levels.

### 3 | Methods

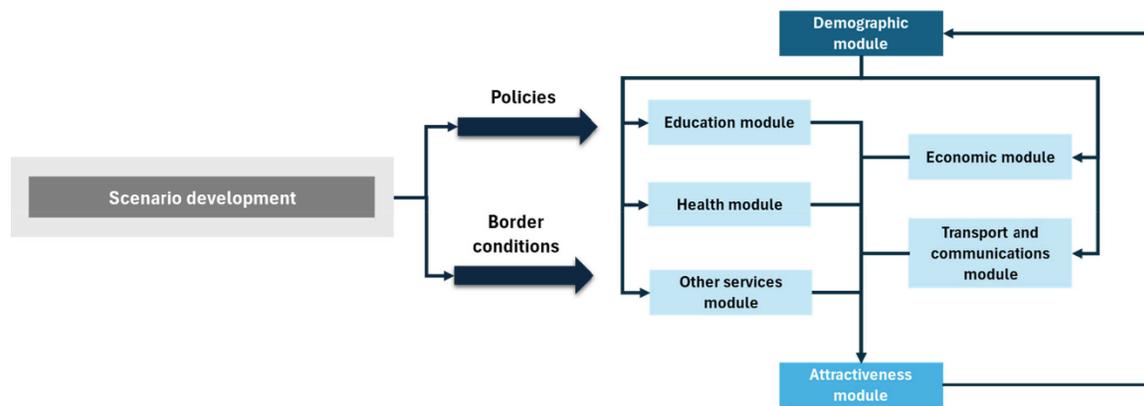
This study employs a simulation-based methodology to investigate rural population dynamics. The core analysis is conducted using SPANDAM, a system dynamics model that simulates demographic and socio-economic trends for sub-national territories under various policy scenarios. SPANDAM's system dynamics basis necessarily implies an interdisciplinary approach to demographic issues comprising multiple relevant dimensions such as social and economic conditions, political priorities or migration flows within a holistic framework (Navarro and Tapiador 2019; Refsgaard and Johnson 2010).

The model consists of seven interconnected modules—Demography, Economy, Health, Education, Transport and Communication, Other Services, and Attractiveness—whose values change dynamically and endogenously over time, influenced by policies, external conditions, and interactions between modules. The demographic module computes the evolution of the population. This evolution is influenced by the territory's attractiveness for both current inhabitants and potential residents.

The Attractiveness module calculates a general composite indicator that aggregates the territory's appeal across the socio-economic dimensions represented in the model (Economy, Health, Education, Transport and Communication, and Other Services). Each of these five dimensions generates its own specific indicator based on a set of variables. To aggregate these variables into a single indicator per dimension, they are first normalized to a scale of 70 to 130. This normalization is based on data from all Spanish municipalities, where a score of 70 corresponds to the municipalities in the worst situation for that variable, and 130 corresponds to those in the best, having first excluded outliers in both cases. Consequently, the resulting indicators for each dimension also fall within the 70–130 range, providing immediate information on the relative standing of the analysed regions compared to all Spanish municipalities. These specific indicators are then combined to produce the general attractiveness indicator,<sup>1</sup> which in turn influences both emigration and immigration rates. Figure 1 schematically represents these relationships.

Within this framework, the demographic module operates as follows: the population is divided by sex and age into 202 categories (male and female, and ages ranging from 0 to 100 years or more). The population at each point in time is computed based on the population from the previous time step, as well as births, deaths, emigration, and immigration.<sup>2</sup> To derive the number of births and deaths, exogenous fertility and mortality rates are used, which depend on scenarios provided by the *Centre d'Estudis Demogràfics* (CED). These scenarios, in turn, are based on data from the *Instituto Nacional de Estadística* (INE). For the calculation of emigration and immigration, rates are endogenously determined within the model using an attractiveness indicator.

In turn, the specific indicators for the socio-economic modules are calculated from a set of variables within each module. Table 1 lists the variables making up each of the five indicators



**FIGURE 1** | General outline of the model and the methodology followed for the development of the scenarios.

and specifies their calculation method or relationship with other variables. For further details, Supporting Material 1 gives a deeper explanation of the model's operation and Llases (2025) provides the model parameters for the case studies and their corresponding data sources.

This model structure allows to conduct quantitative analyses of rural territories of various sizes, from areas with only a few villages with small population sizes to whole provinces. It is thus a handy tool to conduct comparative analyses between different rural territories. Although SPANDAM has been developed and calibrated based on Spanish rural territories, it can be adapted to analyse demographic and depopulation developments in other countries in Europe given the parallels in the underlying drivers of socio-economic and demographic change.

## 4 | Case Studies

### 4.1 | Overview

We test the effects of different policy packages on three Spanish rural territories: *Zamora*, *Pirineo Navarro* and *Vitigudino*. The case studies were selected based on two complementary criteria. First, and primarily, they are representative of distinct yet common typologies of rural depopulation in Spain at different territorial scales and socio-economic contexts. *Zamora* represents a depopulating province with medium-sized towns; *Pirineo Navarro* exemplifies isolated mountainous areas with a seasonal tourism economy; and *Vitigudino* typifies small, dispersed municipalities in agrarian regions with severe demographic aging. Second, these territories were characterized by high data availability regarding the model variables, a practical prerequisite for robust calibration and simulation. While the specific simulation results are derived from these Spanish case studies, the findings and the methodological approach can be extrapolated to analyse demographic trajectories in other European territories with comparable characteristics.

The first selected territory is the province of *Zamora*, located in Castilla y León, one of the Autonomous Communities most affected by depopulation. It is situated about 250 km from Madrid and 100 km from the regional capital, Valladolid, distances that accentuate its peripherality. *Zamora* has lost over a third of its population in the period from 1971 to 2020. Projections follow this trend due to its aging population and lack of youth migrations (Díez Modino and Pardo Fanjul 2020). Its

economy remains heavily reliant on a declining primary sector and despite its cultural heritage and natural attractions, the region's tourism potential remains underdeveloped, seasonal, and insufficient to counter depopulation. The biggest threats for *Zamora* are the removal of social services, together with the increase of unsustainable energy and megafarm initiatives with negative impacts on landscape and the environment in general.

The second case study is the *Pirineo Navarro*, located in the Autonomous Community of Navarra, which includes 30 municipalities designated as 'extreme risk for depopulation territories' by the regional authorities (Cámara de Comptos de Navarra 2024). This case is representative of depopulation dynamics in rural, isolated, and mountainous areas, where the low population density of 3.8 inhabitants/km<sup>2</sup> decreases steadily. The population is mainly composed of aged adults while the younger population is moving to Pamplona, the most populated city in Navarra, some 50–100 km away, looking for better paid jobs, as well as social and health benefits. Traditionally, the local economy has been based on transhumant livestock farming, forestry, and small-scale agriculture, sectors that are now in decline. However, in contrast to other cases of depopulation, the territory currently boasts a well-established tourism and recreational sector, built on winter sports, nature tourism, hiking, and rural tourism. The Plan for *Pirineo Navarro*, developed in June 2020, considers a series of objectives related to education, employment and entrepreneurship promotion, infrastructure and connectivity improvements, and cultural and natural heritage protection and preservation, among others, as tools to fight depopulation trends (Gobierno de 2020).

The last case study is the *Vitigudino* region, located in the province of Salamanca and formed by 56 municipalities that together sum only 15,000 inhabitants. The region has been losing population since the beginning of the 21st century (Bustos Gisbert 2018). *Vitigudino's* municipalities are small, poorly connected, and far from large population centres, which leads to a very low population density in comparison with the province's average (Picado 2021). Its geography is characterized by the canyon landscape of the *Arribes del Duero*, which holds the status of a natural park. This park represents its main tourist asset, offering potential for rural and nature tourism, but it remains a niche market with limited economic impact. Agriculture is the dominant economic activity, characterized by a mix of extensive dryland farming

**TABLE 1** | List of the variables included in the five specific indicators and the general attractiveness indicator.

Indicator	Variables	Calculation method	
Economic	Average number of businesses per municipality	Endogenous, depending on the number of workers and the average size of companies.	
	Average income per person	Endogenous, related to GDPpc at national level. Additionally, policies can be applied to increase it above the endogenously calculated level.	
	Unemployment rate	Endogenous, related to the national unemployment rate. Additionally, policies can be applied to reduce it below the endogenously calculated level.	
	Temporariness rate	Exogenous. Depends on the policies applied to the model.	
Health	Diversification index		
	Time to a health centre	All variables related to the time required to access a specific service follow the same calculation method. The process starts with the number of municipalities that offer the service within the territory. Initially, this number is based on historical data. From there, it evolves depending on the population per municipality: if the population increases, the number of services is expanded, and if it decreases, the number of services is reduced. Additionally, services can be added as part of a specific policy applied to the territory. In the specific case of healthcare and educational services, the calculation is also influenced by national public spending on health and education per capita. When spending increases, the number of inhabitants required to establish (or maintain) a specific service in a municipality decreases, thereby altering the number of services available in the territory.	
	Time to a hospital		
	Time to a pharmacy		
Time to an emergency service			
Education	Time to a childcare centre	Using the number of municipalities that provide the service, the time required to access the service is calculated for those municipalities that do not offer it. This time decreases as the number of municipalities with the service increases (as it becomes more likely that a nearby municipality will provide the service). Finally, a population-weighted average of the time to access the service is calculated for the entire territory. Municipalities that offer the service are assigned to a time of zero, while those without the service are assigned the previously calculated time.	
	Time to a recreational company		
	Time to a pre-school or primary centre		
	Time to a secondary education school		
	Time to a baccalaureate or professional training centre		
	Time to a public university		
Other services	Time to a company offering extracurricular training services	Using the number of municipalities that provide the service, the time required to access the service is calculated for those municipalities that do not offer it. This time decreases as the number of municipalities with the service increases (as it becomes more likely that a nearby municipality will provide the service). Finally, a population-weighted average of the time to access the service is calculated for the entire territory. Municipalities that offer the service are assigned to a time of zero, while those without the service are assigned the previously calculated time.	
	Time to a post office		
	Time to a bank office		
	Time to a library		
	Time to a police station		
	Presence of a bar		
Transportation and communications	Time to an entertainment company	Municipalities that offer the service are assigned to a time of zero, while those without the service are assigned the previously calculated time.	
	Time to a day centre		
	Internet coverage		Exogenous. Depends on the policies applied to the model.
	Time to a train station		Same calculation method as the rest of the services.
	Time to a highway		
Attractiveness	Time to a fuel station	The calculation of both the specific and the general indicators follows the method described in Equations 26 to 29 of the Supporting Material 1. The variables comprising the specific indicators are listed in this table. The general indicator is calculated, in turn, using the five specific indicators.	
	Time to a taxi service		
	Economic indicator		
	Health indicator		
	Education indicator		
Other services indicator			
Transportation and communications indicator			

(cereals, legumes) and increasingly important irrigated crops near the Duero River, alongside almond and olive groves. However, the sector faces challenges of low profitability and generational renewal. There are some municipalities of the

region with birth rates above the average for rural areas. However, due to the elevated level of aging inhabitants, together with the lack of arrival of younger population, the region shows an uncertain future in population terms.

The geographic location of the case studies is shown in Figure 2. Their selection enables a robust comparative assessment of depopulation policies, as they all suffer from acute population decline yet exhibit distinct socio-economic characteristics.

## 4.2 | Current Situation of the Case Studies

The current situation of the three case studies, in the dimensions represented by the model, can be described by showing the value of a series of key variables and indicators in the initial year of the simulation. These key values are presented in Figure 3 and Table 2. Specifically, Figure 3a shows the values of the specific attractiveness indicators for the model's socio-economic dimensions (Economy, Education, Health, Transport & Communications, and Other Services). Figure 3b plots three variables related to the demographic dynamics of the territories: the annual population growth rate, the natural growth rate, and the net migration rate. Table 2 provides additional context of the economic and demographic characteristics of the three territories.

As shown in Figure 3a, the composite attractiveness indicators reveal significant differences. *Zamora* is generally better positioned vis-à-vis the other two cases. Its economic indicator stands at 107.1, while in *Pirineo Navarro* it is 100.9 and in *Vitigudino* it is 94.6. The educational indicator is also superior in *Zamora* (106.6) compared to 81.8 in *Pirineo Navarro* and 83.2 in *Vitigudino*. In terms of healthcare and other services, the situation is not as unfavourable for the latter two territories. The healthcare indicator is 112.4 for *Zamora*, 98.9 for *Pirineo Navarro*, and 96.9 for *Vitigudino*, while the indicator for other services is 111.7, 95.3, and 93.3, respectively. Finally, the 'transportation and communications' indicator reveals an unfavourable situation for *Pirineo Navarro* and *Vitigudino*, with

values of 81.9 and 85.0, respectively, while *Zamora* exhibits a value of 113.0. The fact that *Zamora* is a territory with larger populations, better service provision, and improved infrastructure explains its greater population attractiveness.

Regarding their demographic situation, illustrated in Figure 3b, *Vitigudino* is the territory with the worst situation, with a rate of  $-22.4\%$ , followed by *Pirineo Navarro*, with a rate of  $-11.4\%$ , and closely behind, though slightly better off, *Zamora* with a rate of  $-11.1\%$ . These negative rates are due to both negative migratory balances and negative natural growths. The migratory balance of *Vitigudino* stands at  $-4.6\%$ , while those of *Pirineo Navarro* and *Zamora*, closer to 0, are at  $-1.0\%$  and  $-0.8\%$ , respectively. Natural growth is also lower in *Vitigudino*, with a rate of  $-17.8\%$ , followed by *Pirineo Navarro*, with a rate of  $-10.4\%$ , and by *Zamora*, with a rate of  $-10.3\%$ . Thus, all cases are in a rather unfavourable demographic situation but among them, the initial conditions in *Vitigudino* are clearly the worst.

The data in Table 2 provide a deeper understanding of the underlying structural conditions. *Zamora* is a significantly larger and more urban territory, with a younger average age of 51.1 and a balanced sex ratio of 98.1. Its economic fabric is more developed, featuring a notably higher average of 56.0 businesses per municipality and a diversification index of 3.9, although it also faces a higher unemployment rate of 15.1%. *Pirineo Navarro*, despite its small population of 4920, shows a relatively favourable profile with the highest average net income of €17,927, the lowest unemployment rate at 9.7%, and a moderate average age of 52.6. However, its highly skewed sex ratio of 122.6 indicates a significant gender imbalance. *Vitigudino* has the oldest population, with an average age of 56.7, and the lowest average net income of €12,892, which aligns with its poor performance in the attractiveness indicators and demographic dynamics.

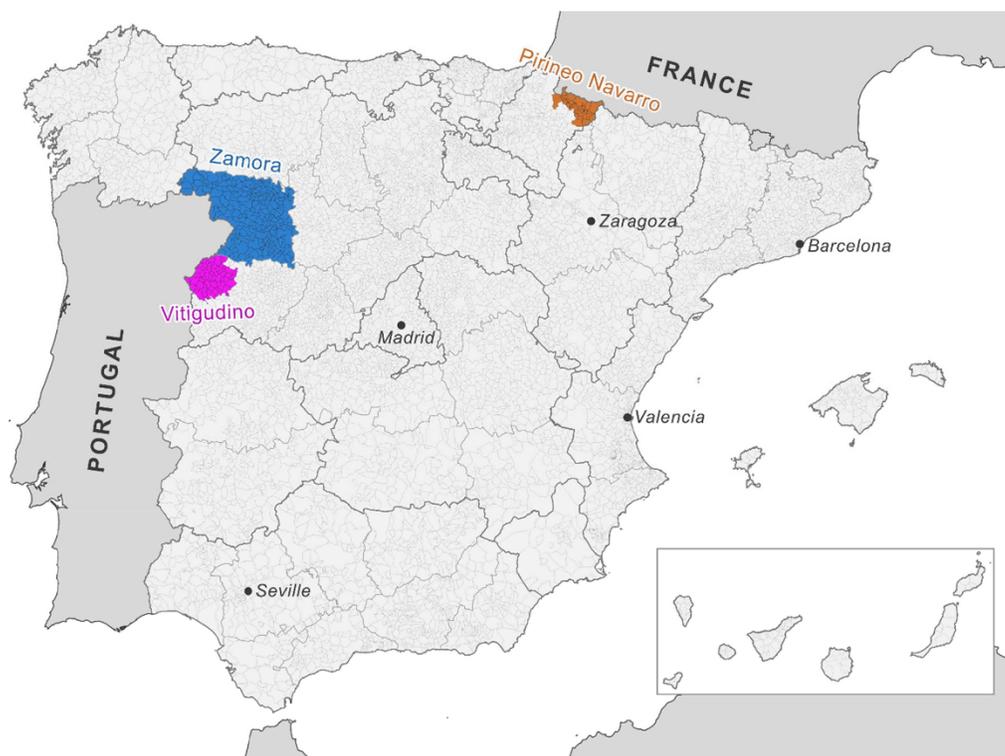
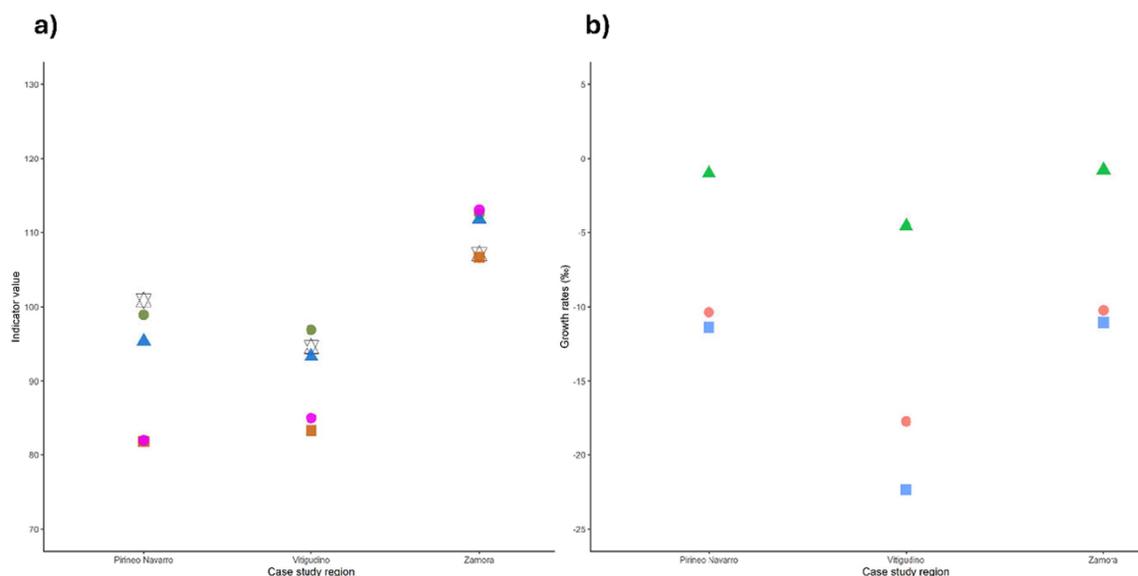


FIGURE 2 | Map of Spain with the territories of Pirineo Navarro, Vitigudino, and Zamora marked in colour.



**FIGURE 3** | (a) Economic (black star), Health (orange square), Education (green circle), Other services (blue triangle) and Transport-and-communications (pink circle) indicator of the three case studies. (b) Population growth rate (blue square), net migration ratio (green triangle) and natural growth rate (red circle) of the case studies.

**TABLE 2** | Key economic and demographic values of the case studies at the start of the simulation.

	<i>Vitigudino</i>	<i>Pirineo Navarro</i>	<i>Zamora</i>
Total population	14,804	4920	167,215
Average age	56.7	52.6	51.1
Sex ratio	107.7	122.6	98.1
Average number of businesses per municipality	19.3	22.9	56.0
Diversification index	3.1	3.1	3.9
Unemployment rate	12.2%	9.7%	15.1%
Temporariness rate	29.4%	24.6%	28.2%
Average net income	€12,892	€17,927	€12,960

As expected, the ranking of the case studies from least to most favourable demographic situation corresponds to their relative standing in the socio-economic dimensions shown in Figure 3a. However, the demographic values shown in Figure 3b for *Zamora* and *Pirineo Navarro* are surprisingly similar, despite the notable difference in their socio-economic indicators. This suggests that other latent factors or specific local dynamics may be influencing the demographic outcomes in *Pirineo Navarro*, partially offsetting its structural disadvantages.

## 5 | Scenarios

The policy scenarios were developed through a three-step methodology. First, a policy inventory was compiled through a semi-systematic literature review. The inventory drew primarily on the recent systematic review by Loras-Gimeno et al. (2025) and was supplemented by additional key sources (Dax and Copus 2022; Karcagi Kováts and Katona Kovács 2012; Mileto and Vegas López-Manzanares 2024; Pinilla and Sáez 2021). The identified policies were classified into two broad types: ‘rural economic development policies’ and ‘social service policies’. Second, these policy types were mapped onto the

intervention capabilities of the SPANDAM model, leading to the drafting of a baseline scenario and four policy-driven scenarios that represent distinct strategic approaches. Third, the narrative storylines were translated into quantitative model parameters and boundary conditions for simulation.

### 5.1 | Scenario Storylines

#### 5.1.1 | Baseline/No Policy Scenario (BS): Neglect of Rural Areas and Depopulation Issues

In this scenario, macroeconomic development follows a business-as-usual trajectory and isolated local efforts to improve the socio-economic situation in rural territories remain ineffective in the absence of strong national and European strategies for rural development.

#### 5.1.2 | Policy Scenario 1 (PS1): Focus on Macroeconomic Development

In this scenario, national policies focus primarily on macroeconomic development without differentiating much between

urban and rural areas. The government tries to improve key indicators of national socio-economic development such as GDP, employment, education, and health expenses per capita, but initiatives from the European level such as the LEADER programme do not receive particular national support.

### 5.1.3 | Policy Scenario 2 (PS2): Fostering Rural Economic Development

In this scenario, rural development policies focusing on economic development are designed and implemented based on effective coordination between the local, provincial, national, and European level. The national level has particular importance given the focus on economic, fiscal and infrastructure policies. Thus, for several decades, consistent efforts are made to expand the road and internet infrastructure in rural areas to make rural areas attractive to businesses through tax cuts and vocational training for workers, and to increase incentives for workers through economic subsidies aimed at improving working conditions and housing for workers. The combined effect of these policies is expected to foster economic diversity and to strengthen rural economy to curb or even reverse depopulation trends.

### 5.1.4 | Policy Scenario 3 (PS3): Service-Centred Approach

In this scenario, national strategies to halt depopulation focus on financing, promoting, and coordinating the expansion of social services that are expected to sustain the population in rural areas. Educational services focus on the provision of primary and secondary education as well as baccalaureate and professional training centres to prevent parents from having to move to bigger municipalities to shorten their children's way to school. Given the rejection of telemedicine, rather than extending internet coverage and building up connections with urban doctors, national strategies regarding improved health services focus on building and maintaining small health centres and pharmacies. Additionally, other social services are installed to increase the social capital in small municipalities such as a bar, a police station, and an entertainment company.

### 5.1.5 | Policy Scenario 4 (PS4): Combining Economic Development and Social Services

In this scenario, combating rural depopulation and strengthening local economies moves to the top of the national and European political agenda. Population ageing, especially in rural areas, is identified as a major problem and the downsides of degraded rural areas receive renewed media attention. Consequently, policies of rural economic development and improved social services provision are combined to increase the chances of reversing depopulation tendencies in rural areas.

## 5.2 | Quantification

For every scenario storyline, there is a set of policies and boundary conditions that have been quantified according to the scenario. The boundary conditions correspond to four national variables: GDP per capita, employment rate, public spending on education per person, and public spending on healthcare per person. GDP per capita and employment rate evolve following current trends or according to the OECD's long-term scenarios

(Guillemette and Château 2023), depending on the chosen scenario. For public spending on education per person and public spending on healthcare per person, it has been assumed that they remain constant relative to GDP per capita.

On the other hand, policies are of two kinds: those related to the economy and transport/communications infrastructure, and those related to education, healthcare, and other services. The former are more heterogeneous (variations in diversification, temporary work rates, travel time to highways, internet connectivity, etc.), while the latter always involve adding services of a type specific (primary schools, health centres, pharmacies, etc.) to the characteristics of each case study. However, all policies are applied gradually, with services, income, or ratios being added linearly from the start of the simulation until the year 2050.

The specific values for the policies were selected to generate substantial improvements in the territories, which can influence their attractiveness and, consequently, their demographic trajectory. Simultaneously, we ensured these values were realistic, avoiding improvements to the economic situation or service provision that exceed what can be considered reasonable. To achieve this, the values observed across all Spanish municipalities for the policy-targeted variables were used as a "scale" in most cases. These data were available precisely because they had already been collected and used for the calibration of the model. As shown in Table 3 which outlines the policies and boundary conditions for the five simulated scenarios this reference to the general situation in Spanish municipalities is made explicit for service provision improvements. The only exception is the internet coverage policy. Its target value was not based on the national municipal average but was instead defined in line with the Spanish government's stated objectives for this sector (MINECO 2022).

## 6 | Results

This section presents and interprets the results of the simulated scenarios for each case study. While the simulated policies consistently generate improvements in regional attractiveness and moderate demographic decline, their impact varies significantly across case studies.

### 6.1 | Vitigudino

*Vitigudino* is a clear example of how political intervention can improve attractiveness conditions but fail to halt the depopulation process. This outcome stems from the interaction between policy effects and the region's entrenched negative demographic momentum.

A comparative analysis of the attractiveness indicators reveals distinct trends, as summarized in Figure 4. First, the economic attractiveness indicator increases in all scenarios. This happens because the national economy evolves favourably in all scenarios, and very favourably in the PS1 scenario. Even so, local intervention is essential: When there is no direct intervention in the economic dimension or when the national economy evolves in line with current trends (BS and PS3 scenarios), the attractiveness indicator increases modestly, rising from 94.6 to

**TABLE 3** | Summary of the policies and boundary conditions included in the simulations of the three case studies.

Scenario	Policies	Boundary conditions
BS	No policies	The fertility rates increase slightly, and the mortality rates decrease slightly, according to the projections from the INE. GDPpc of Spain increases according to the cumulative growth rate for the period 2008–2023. The national employment rate rises, reaching the historical peak of 2007 by the final year of the simulation. Public per capita spending on healthcare and education at the national level grows at the same rate as GDP per capita.
PS1	No policies	The fertility rates increase slightly, and the mortality rates decrease slightly, according to the projections from the INE. GDPpc of Spain and the national employment rate increase according to the OECD long term scenarios. <sup>a</sup> Public per capita spending on healthcare and education at the national level grows at the same rate as GDP per capita.
PS2	The diversification index reaches the Spanish average if it is below it. The temporary employment rate is reduced to 20%. An additional 2% is added to the employment rate, which is calculated endogenously for the region. An extra €1,000 (in constant 2021 prices) is added to the net income of residents. Services related to the transportation dimension (taxi service and gas stations) reach 50% of the Spanish average in the region. Internet coverage with a minimum of 100 Mbps reaches 100% of the municipalities in the region. Travel time to a train station or a highway/motorway is reduced by 10%.	Same boundary conditions as baseline.
PS3	Services corresponding to the healthcare, education, and other service sectors reach 50% of the Spanish average.	Same boundary conditions as baseline.
PS4	The policies of PS2 and PS3 are combined.	Same boundary conditions as baseline.

<sup>a</sup>The OECD scenarios are considerably more optimistic than those proposed here, which are limited to following the trends observed in recent years.

98.2 and 98.5, respectively. In the PS1 scenario, it increases slightly more, reaching a value of 100.6. And the highest results occur when specific policies are implemented, as in the PS2 and PS4 scenarios, with values around 103.

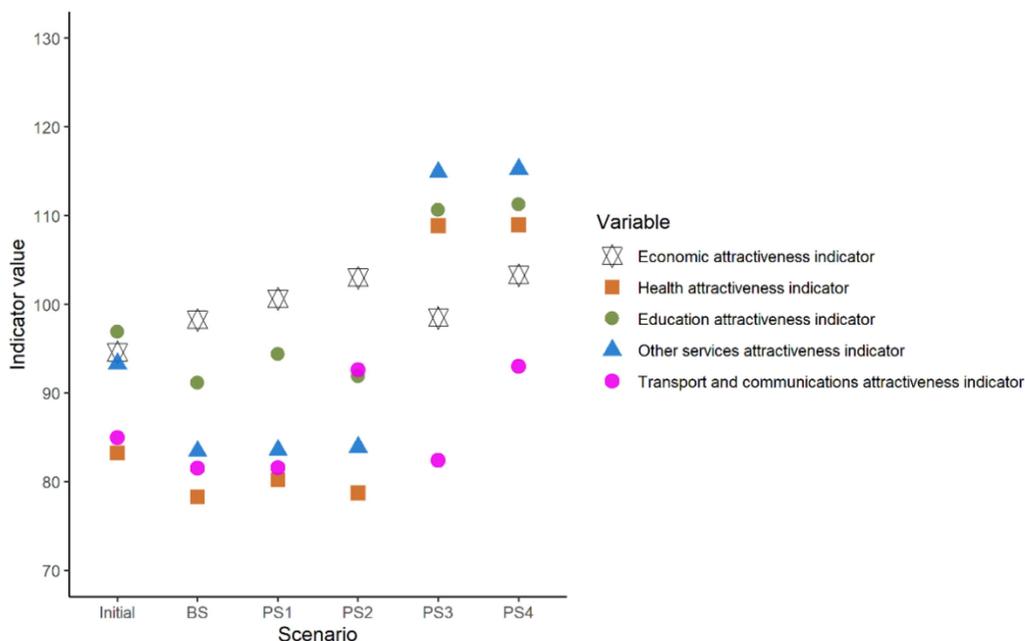
On the other hand, the transportation and communications indicator exhibits a more concerning trend, highlighting its dependency on direct investment. Firstly, it should be noted that the indicator worsens when there is no targeted intervention in the territory. Additionally, the value of the indicator at by 2075 in the PS1 scenario is remarkably similar to that in the BS and PS3 scenarios. In these scenarios, the indicator drops from 85.0 at the start of the simulation to around 82. Finally, in the PS2 scenario, the indicator reaches a value of 92.6, and in the PS4 scenario, it reaches 93.0.

This pattern of decline without intervention is systemic. All indicators related to ease of access to certain services exhibit similar behaviours: they increase when there are political interventions aim at enhancing the provision of such services and decrease in all other cases. This occurs because, as the

depopulation trend in *Vitigudino* cannot be halted, the provision of services, which is calculated endogenously in the model, gradually declines. This decline can only be stopped if there is a political intervention specifically designed to address it.

In line with this explanation, there are notable improvements when there is an intervention aimed at improving access to services (PS3 and PS4). For example, in PS4, the health indicator reaches a value of 111.3, the education indicator reaches 109.0, and the other services indicator reaches 115.3. Conversely, absent those interventions, the indicators, which already started from a low value, decrease even further. For instance, in the BS scenario, the health indicator drops to 91.2, the education indicator to 78.3, and the other services indicator to 83.4.

Despite improvements in living conditions across several scenarios, the dynamic of depopulation fails to be halted or reversed. The data illustrates a mitigation of decline, not a recovery. In the BS, which yields the worst outcome, population decreases from 14,471 to 5181 while in PS4, which achieves the



**FIGURE 4** | Value of Vitigudino's attractiveness indicators at the beginning and end of the simulation in the five scenarios.

best result, it declines only to 7795. The difference is notable, but it can hardly be considered positive.

A closer look at the components of population change explains this persistent decline. Population growth rate improves significantly, especially in scenarios where policies aimed at improving access to services are implemented. However, in none of the scenarios it becomes positive; in fact, at no point it reaches  $-5\%$ . This is due primarily to a very low rate of natural population growth. Overall, this rate improves throughout the simulation for two reasons. First, fertility and mortality projections are slightly favourable, as indicated in the previous section. Second, the decrease in the average age, which is more pronounced when policies are more intensive and the migration balance is higher (in any case, the average age decreases due to the passing of the initially very elderly population). However, even with this improvement, the rate remains very low and prevents the population growth rate from becoming positive, even in scenarios where positive migration balances are achieved.

Furthermore, the migration balance reflects both the positive effects of policy implementation and their insufficiency to reverse the depopulation dynamic. Since the policies are applied gradually until 2050, the migration balance increases during the period from the start of the simulation to that year. However, once the policies cease, the ongoing population decline causes a renewed erosion of the socio-economic situation, leading the migration balance to decline. In fact, in the PS2 scenario, the final migration balance is worse than at the start, mirroring the outcomes of the BS and PS1 scenarios, where no specific policies for territorial development were applied. Only in the PS3 and PS4 scenarios is the improvement more substantial, and even then, a positive migration balance by the simulation's end is achieved solely in the latter.

Figure 5 shows the main descriptive variables of the demographic dynamics for *Vitigudino*.

## 6.2 | *Pirineo Navarro*

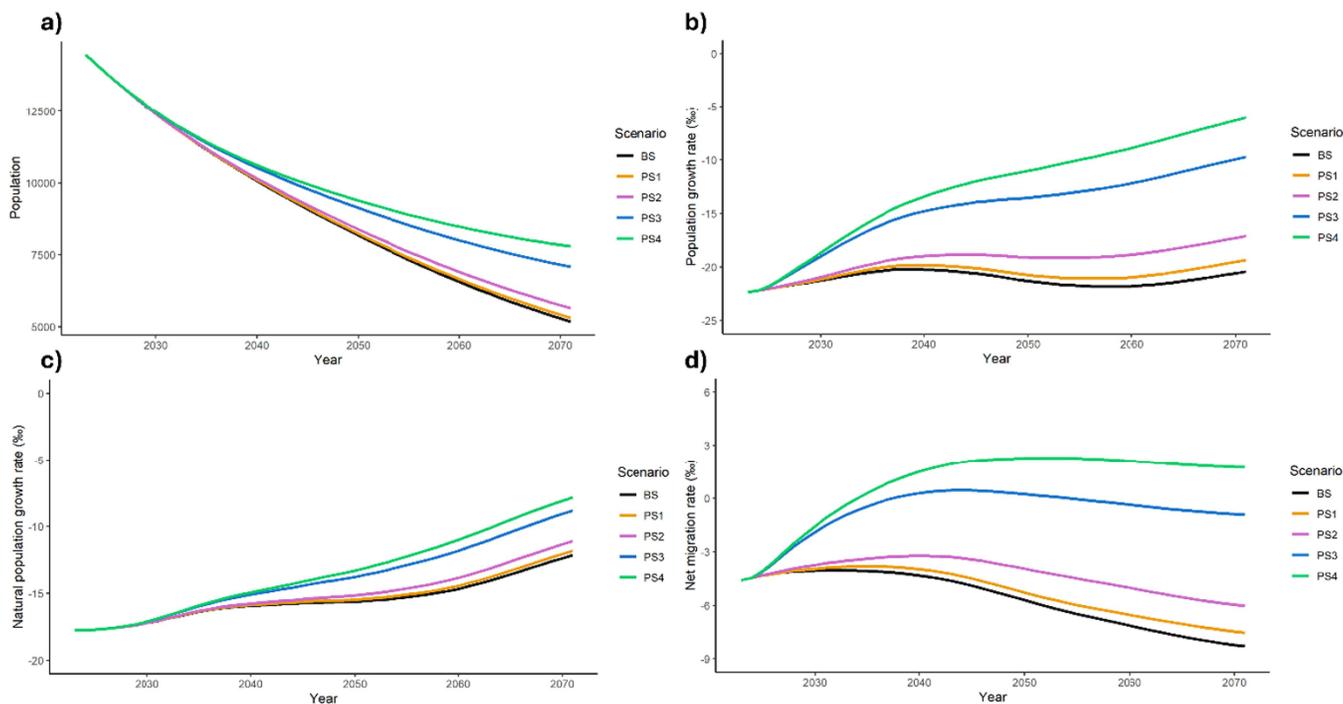
The case of *Pirineo Navarro* provides a contrasting yet complementary perspective to *Vitigudino*. Its significantly more favourable initial demographic conditions allow the simulated policies to achieve a more substantial impact. This comparative advantage results in a more responsive system, where intervention not only improves key indicators but also translates into a tangible deceleration of depopulation.

As in the previous case study, the economic indicator improves slightly in all scenarios due to the better national situation. With an initial indicator value of 100.9, in the BS, PS1, and PS3 scenarios, the indicator reaches around 103 by 2075, while in the PS2 and PS4 scenarios, it rises to 104.3 and 104.4, respectively.

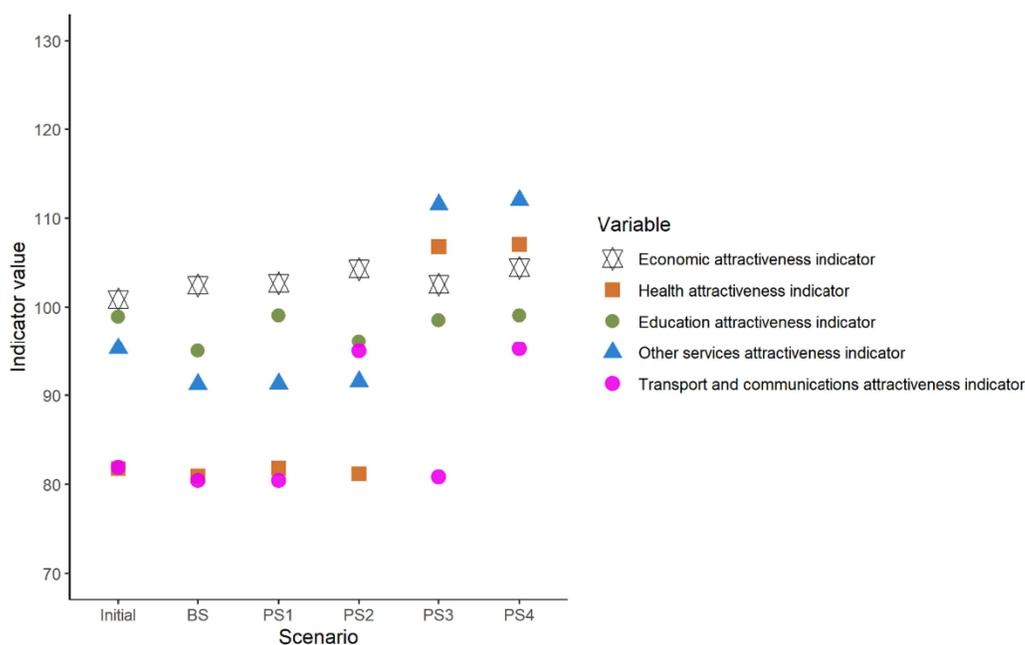
In the area of transport and communications, the indicator improves when there is intervention and worsens when there is none. However, the decline is smaller than in *Vitigudino*. This key difference is directly explained by the demographic context: The population decline is less severe in *Pirineo Navarro*, and the transport services included in the model that depend on population (e.g., taxi services and gas stations) are not as negatively affected. In the PS2 and PS4 scenarios, where the indicator grows, it increases from the initial 81.9 to around 95. Alternatively, in the BS, PS1, and PS3 scenarios, the indicator decreases to values between 80 and 81.

The behaviour of the indicators corresponding to services is very similar to that of *Vitigudino*. The only difference lies in healthcare. Here, growth is very modest. This is due to how policies are designed, which aim to achieve a certain percentage of the Spanish average, focusing more intensely on the weakest dimensions. Since the provision of healthcare services in *Pirineo Navarro* is close to the Spanish average, the intensity of the policies applied is weak.

Figure 6 shows the value of the different attractiveness indicators in *Pirineo Navarro* at the beginning and end of the simulation.



**FIGURE 5** | (a) Evolution of the population in Vitigudino. (b) Vitigudino's population growth rate. (c) Natural growth rate of the population in Vitigudino. (d) Net migration rate of Vitigudino.



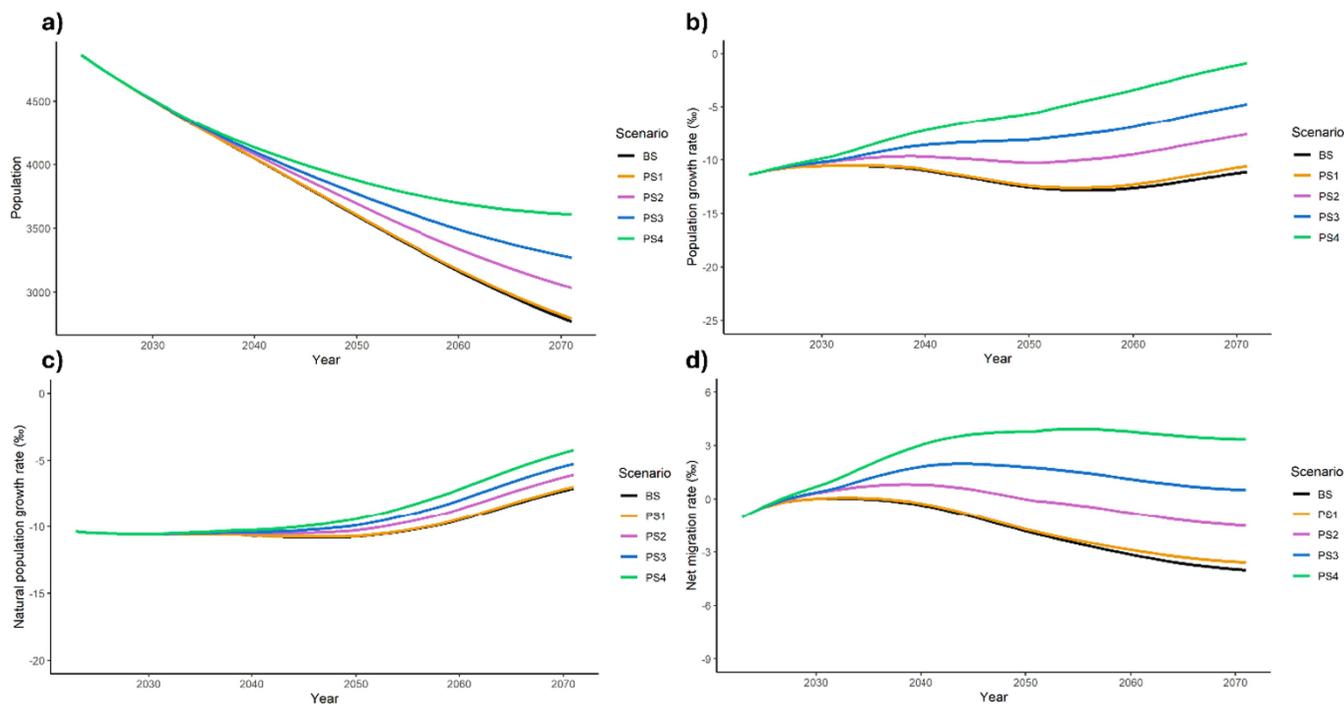
**FIGURE 6** | Value of Pirineo Navarro's attractiveness indicators at the beginning and end of the simulation in the five scenarios.

The demographic outcomes for *Pirineo Navarro* are markedly better than those for *Vitigudino*, a difference primarily attributable to its more favourable initial conditions. In the best scenario (PS4), the population declines from 4863 to 3610, whereas in the baseline (BS) it falls to 2771.

Crucially, the rate of depopulation slows significantly under effective policy packages. In the PS4 scenario, the population growth rate improves to  $-0.8\%$  by 2075. This performance starkly contrasts with *Vitigudino*, where no scenario exceeded

$-5\%$ ; in *Pirineo Navarro*, the PS3 scenario also surpasses this threshold, finishing at  $-4.8\%$ .

This deceleration is driven by a stronger migration balance coupled with a less negative natural growth rate. The migration balance in the PS4 scenario achieves a rate near  $4\%$ . While all scenarios show an initial improvement followed by a decline, this downturn is far more gradual in PS4. Notably, the PS3 scenario also concludes with a positive migration balance, while the three remaining scenarios end worse than they began.



**FIGURE 7** | (a) Evolution of the population in Pirineo Navarro. (b) Pirineo Navarro's population growth rate. (c) Natural growth rate of the population in Pirineo Navarro. (d) Net migration rate of Pirineo Navarro.

Concurrently, the natural growth rate improves from an initial  $-10.4\%$  to  $-4.2\%$  in PS4 and  $-7.1\%$  in BS. The drivers—slightly improved fertility and mortality rates and a decreasing average age—mirror those in *Vitigudino*. However, *Pirineo Navarro's* stronger starting buffer amplifies the positive synergy with migration gains, rendering its demographic system more responsive to policy intervention.

Figure 7 illustrates the evolution of these key demographic variables across all five scenarios for *Pirineo Navarro*.

### 6.3 | Zamora

*Zamora* emerges as the most responsive case study, illustrating how a favourable initial structure, amplified by policy, can counter depopulation. This greater responsiveness stems from two inherent advantages. First, its demographic starting point is slightly better than that of *Pirineo Navarro*. Second, the region contains larger municipalities, which reduces the average travel time to access services. These structural benefits magnify the impact of policy interventions. Furthermore, the larger municipal scale means that improvements in external boundary conditions yield more substantial effects within the region.

This structural advantage is clearly reflected in *Zamora's* economic, healthcare, and educational indicators (Figure 8), which show greater improvement under the PS1 scenario than observed in the other case studies. For instance, the economic indicator, which starts the simulation at 107.1, increases to 113.6 in the BS scenario and to 116.9 in the PS1 scenario, coming quite close to the scenarios where there is direct intervention in the region's economy (PS2 and PS4), in which the indicator reaches 118.7. A similar pattern holds for social services. While the healthcare and education indicators in the BS scenario decline from 112.5 to 106.7 to 110.3 and 103.5,

respectively, the PS1 scenario sees them rise to 114.5 and 110.1. Meanwhile, direct policy intervention in these areas (PS3 and PS4) pushes these indicators to approximately 117. It is noteworthy that, in both the economic and healthcare indicators, *Zamora* is the only case of the three where the PS1 scenario comes closer to the PS4 than to the BS.

Transport and other services indicators fare similarly to those of the *Pirineo Navarro* and *Vitigudino*, although both indicators show higher final values in *Zamora* (when comparing the same scenario). This consistent outperformance across all dimensions underscores *Zamora's* relative structural strength.

Another noteworthy aspect of *Zamora's* indicators is their low dispersion and their comparatively smaller increase—though not their final value—in scenarios with local intervention, relative to the other case studies. This occurs because *Zamora's* more favourable initial attractiveness causes policies to reach a point of diminishing returns. When indicators are already relatively high, achieving further gains requires proportionally greater effort.

*Zamora's* superior performance in attractiveness translates directly into the most promising demographic outcomes of the three case studies. Its simulated population trends come closest to reversing the depopulation process. Although the total population declines in all scenarios (Figure 9), the decisive finding is the evolution of the growth rate. In the PS4 scenario, the population growth rate rises to values nearing zero. This near-stabilization constitutes a fundamental difference from the other two regions.

As in the other case studies, this improvement in the population growth rate stems from gains in both natural growth and migration balances. However, in the case of *Zamora*, this is combined with an initial situation that is not as deteriorated as that of *Vitigudino*, generally higher attractiveness indicators,

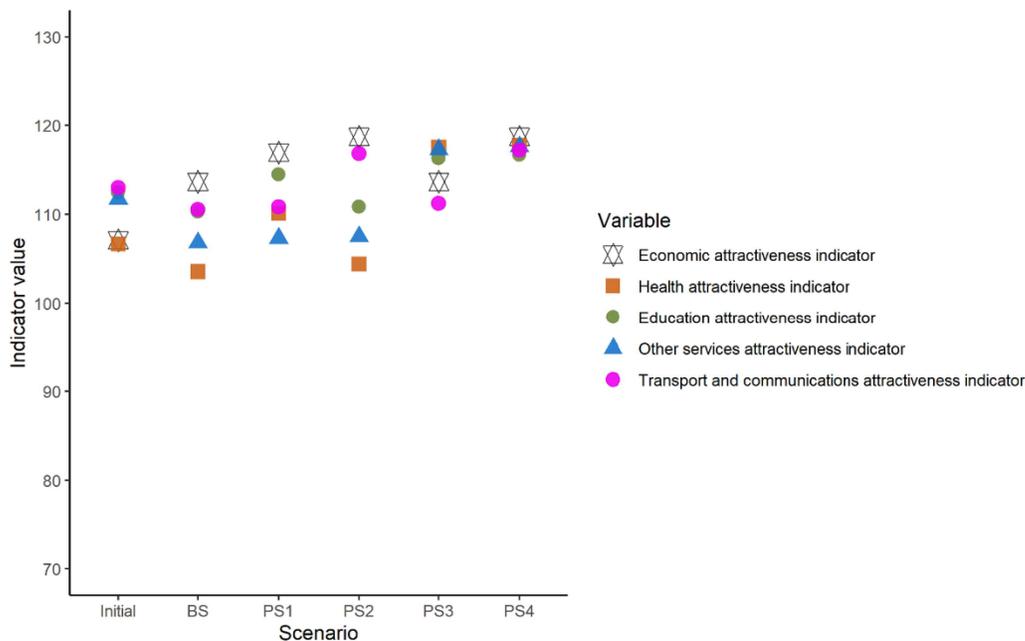


FIGURE 8 | Value of Zamora's attractiveness indicators at the beginning and end of the simulation in the five scenarios.

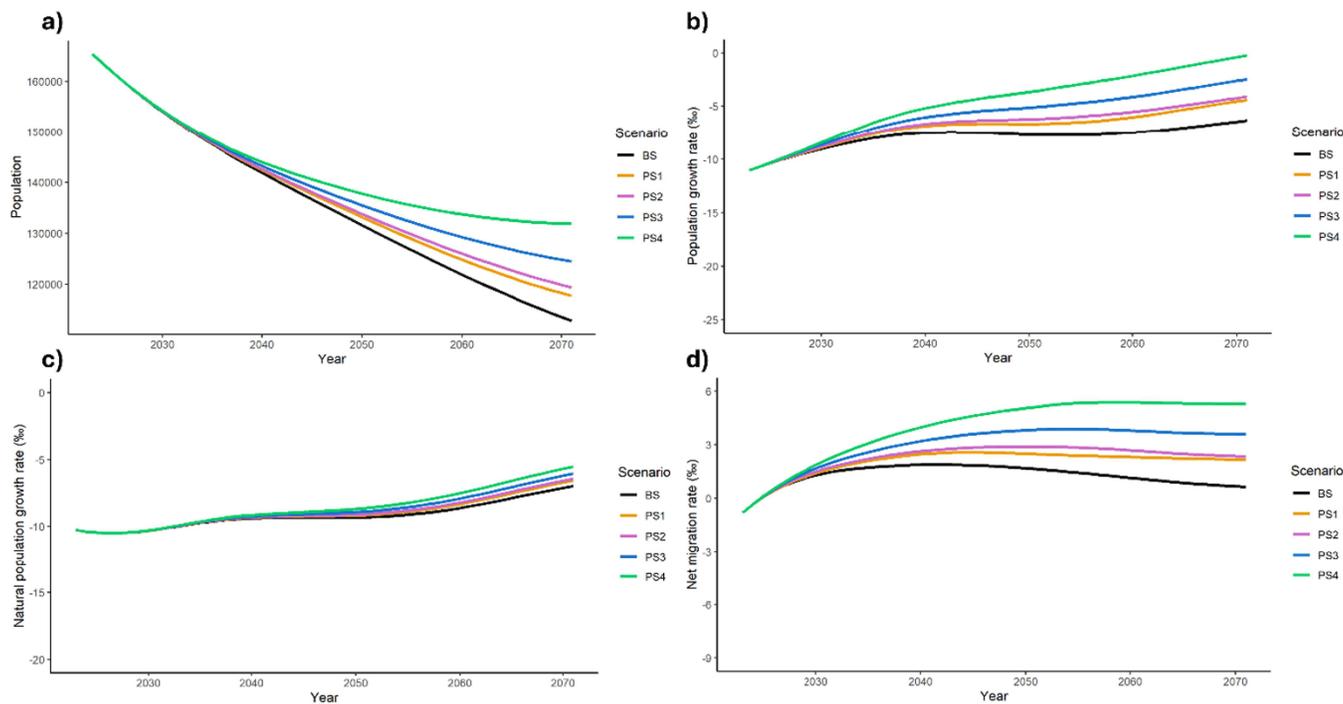


FIGURE 9 | (a) Evolution of the population in Zamora. (b) Zamora's population growth rate. (c) Natural growth rate of the population in Zamora. (d) Net migration rate of Zamora.

and the existence of larger municipalities, which increase the impact of improved boundary conditions and intensify the effect of the inclusion of new services in the region. This latter advantage is related to the geographic concentration of the population. The more concentrated the population is in larger municipalities, the greater is the reduction in the time to access a specific service in the region if that service is first established in the largest municipalities. All these characteristics make it easier for *Zamora* to break the vicious cycle of depopulation than for the other two case studies.

## 7 | Discussion and Conclusions

The demographic evolution of a territory is the result of the interaction between two fundamental forces: the initial socio-demographic conditions and the impact of public policies specifically designed to influence that evolution. Our simulations using the SPANDAM model confirm, in line with the literature, that the effectiveness of any intervention is critically conditioned by the initial conditions of each region (Coghe 2022). Territories like *Zamora*, which start from a more favourable

demographic and structural base, show a significantly greater capacity to respond to policy stimuli. In these areas, population decline is slower, and the deterioration of local services and economic conditions is less severe, allowing public policies to exert more pronounced compensatory effects. A key element of this “initial advantage” is the geographical distribution of the population. Regions with more consolidated urban centres and less dispersion benefit from economies of scale that amplify the effectiveness of interventions (Mileto and Vegas López-Manzanares 2024; Sysner 2020; Viñuela 2022), a dynamic that partly explains the divergent outcomes between territories facing similar challenges.

Regarding policy design, the results are conclusive and reinforce previous findings: interventions focused directly on the territory (PS2, PS3, and PS4) consistently produce better outcomes than general improvements in macroeconomic and national framework conditions (PS1). This confirms that isolated macroeconomic strategies are insufficient to address a problem of a territorial nature (Martínez-Carrasco Pleite and Colino Sueiras 2024; Williams et al. 2021). In particular, the PS4 scenario, which integrates measures for economic development, improvement of social services, and infrastructure strengthening, proves to be the most effective. This finding underscores, in line with recent studies (Bruno et al. 2021; Rodríguez-Rodríguez and Larrubia Vargas 2022), the imperative need to adopt comprehensive policy packages that simultaneously address the multiple dimensions of the problem—economic, social, and infrastructural—rather than relying on isolated or narrowly focused measures.

On the other hand, our findings reinforce the notion, widely documented (Bruno et al. 2021; Makkonen and Inkinen 2023; Otovescu and Otovescu 2019; Paniagua 2021; Ubarevičienė et al. 2025), that depopulation is a persistent and complex phenomenon. Its causes—aging, economic stagnation, loss of services (Coghe 2022; Slack and Jensen 2020)—are deeply rooted and feed into a vicious cycle. This structural nature demands, as has been repeatedly noted (Bruno et al. 2021; Williams et al. 2021), that interventions be conceived and planned with a long-term perspective and sustained political effort. Only then can there be hope of breaking this cycle.

However, both our simulations and the reviewed literature recognize that, in contexts of extreme demographic decline, stopping or reversing the trend can be extraordinarily difficult (Coghe 2022). Furthermore, this reality must be framed within the competition for public and human resources. In a context of budgetary and mobility constraints, policies that succeed in attracting or retaining population in certain areas may consequently generate displacement effects or relative loss in others (Sysner 2020). Therefore, it is unrealistic to expect all declining areas to experience simultaneous growth; public intervention inevitably involves establishing priorities and accepting certain territorial trade-offs. In cases where it is extremely difficult to halt or reverse the depopulation trend, the ultimate goal of public action must transcend the demographic question and focus on maximizing the well-being of the resident population. Improving their quality of life, expanding their economic opportunities, and guaranteeing access to essential social services is not only a valuable goal in itself (Barakat 2015; Olga Wesołowska 2023) but also lays the necessary groundwork so

that, in the future and given a change in structural conditions, the demographic viability of the territory can be restored.

Finally, it is important to note the limitations of this study and outline avenues for future research. The SPANDAM model, while proving to be a valuable tool for analysing complex interrelations, is a simplified representation that, like any system dynamics model, relies on assumptions and formalizations (Hara 2020; Randall and Koppenhaver 2004). Its calibration has been performed for the Spanish context, which limits the direct generalization of the results. A fruitful future line of work would be the adaptation and application of the model to other regions, both in Europe and other parts of the world, with similar challenges. This would allow for transnational comparative analyses and validate the transferability of its lessons. Furthermore, the model prioritizes quantitative and structural variables; incorporating qualitative dimensions, such as social capital or cultural identity, represents a methodological challenge that could enrich future analyses. Similarly, complementing this approach with detailed cost-benefit analyses of the simulated policies, measuring not only economic but also social costs (Scandizzo 2021), would be of great value for guiding decision-making and optimizing the allocation of always-scarce resources in the fight against depopulation.

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#### Conflicts of Interest

The authors report no conflicts of interest.

#### Endnotes

<sup>1</sup> The process of building the indicators incorporates techniques and frameworks described in OECD (2008), Mazziotta and Pareto (2016; 2018), and INE (2020).

<sup>2</sup> The procedure for calculating the population is inspired by Willekens and Drewe (1984), although the endogenization of emigration and immigration rates is an original contribution of SPANDAM.

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### Supporting Information

Additional supporting information can be found online in the Supporting Information section.  
Supporting Material 1.