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The role of infrastructures in rural depopulation. An econometric analysis

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ABSTRACT: The aim of this article is to contribute to the analysis of the causes of rural depopulation and, particularly, the role of infrastructures. We build a panel data set with the 78 municipalities of a region in Northern Spain, Asturias. We estimate an econometric model where rural population is explained by a set of economic and infrastructure variables as well as some characteristics of the municipalities. The main results show the importance of infrastructures to maintain rural population. The presence of a medium–size town in the municipality helps to fix the population in the countryside. However, the income gap with urban municipalities contributes to reduce rural population.

El papel de las infraestructuras en la despoblación rural. Un análisis econométrico

RESUMEN: El objetivo de este artículo es estudiar las causas de la despoblación rural y, en particular, el papel de las infraestructuras. Para ello, se construye un panel de datos de los 78 municipios de Asturias, una región del norte de España. Se estima un modelo econométrico en el que la población rural se explica por un conjunto de variables económicas y la disponibilidad de infraestructuras, así como por algunas características de los municipios. Los resultados muestran la importancia de las infraestructuras y la presencia de una ciudad de tamaño medio en el municipio para fijar la población en el campo. Sin embargo, la diferencia de ingresos con los municipios urbanos contribuye a reducir la población rural.

KEYWORDS / *PALABRAS CLAVE*: Econometrics, Infrastructures, Municipalities, Rural depopulation / *Econometría, Infraestructuras, Municipios, Despoblación rural.*

JEL Classification / *Clasificación JEL*: J11, R23, O15, C23.

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1. Introduction

There is wide concern about the decline in rural population. Nowadays, many rural communities face the challenge of halting depopulation. In many countries, the migratory pattern of people moving out of rural areas has been going on for a long time. The concern about this decline is not recent. For example, Hibbard (1912) had already stated that “The alarm over the decrease in the rural population is nothing new”.

Rural people migrate to cities in search of a better life. In particular, they look for higher paid jobs but also for public services which are not so readily available in rural areas, such as better healthcare or more educational opportunities. The existence of social amenities, such as retail stores, banking services, and leisure places are also important pull–factors to attract rural people to cities. Besides those factors, young people also migrate due to the perception that urban lifestyle is more attractive than that of the countryside.

In Spain, this problem is acute (e.g., Collantes & Pinilla, 2011). Most rural areas across the country have seen declining populations for decades. Rural depopulation has emptied vast areas in the interior of the country[1]. In 1900, half of the Spanish population lived in municipalities with less than 5,000 inhabitants, but in 2011 that number decreased to just 13 %, while the population of Spain grew by 153 % in the same period. Population density in 2011 was 93 persons/km2, while in the interior was just 22, and only 6 in municipalities with less than 1,000 people. For this reason, the interior of Spain is popularly known as *la España vacía* (empty Spain). In fact, Spain is the European country with the largest area of depopulated land. In a recent study on scarcely populated areas in southern Europe, Burillo Cuadrado *et al*. (2019) show that just 5 percent of the population lives in 53 percent of the territory.

The Spanish government has clearly stated its intention to redress decades of rural decline. In 2020, the government announced an $11.9 billion plan earmarked for population regeneration. The plan consists of 130 measures to try to enhance rural areas’ attractivity. This aid package involves extending the 5G telephone network across Spain, the development of technologically smart cities in rural areas and regional innovation centers.

In this paper we analyze the evolution of rural population in Asturias, a region in Northern Spain. We have assembled a panel data set of 78 municipalities during the years 1998–2019. We make use of very detailed information about each municipality provided by the Asturian Statistical Institute (SADEI). An important feature of our paper is that rural population is calculated for each municipality using population

[1] We call interior of the country to the six regions with no coast, excluding Madrid. They make up 53 percent of the Spanish territory.

data at the parish level. Previous literature proceeds in a different way by classifying the municipalities as rural or urban, by setting some type of threshold and then considering all the population in rural municipalities as rural population. This procedure may result in overcounting rural people since, for example, if the limit to consider a county as rural is 10,000 people (e.g., Collantes *et al.,* 2014), and there is a county with 9,500 people living in a city and just 400 dispersed in rural settlements, the whole population of the county (9,900 people) would be counted as rural.

Our main interest is to study the role played by the existence of infrastructures in rural areas. While it is commonly argued that the lack of infrastructures is a determinant of rural depopulation, there are not many studies that have tested this hypothesis since there is usually few data about physical infrastructures at the municipality level. Additionally, the results of the papers that have tackled this topic are inconclusive. Voss & Chi (2006) argue that "following a thorough review of the relevant literature, the notion that highway expansion leads to increased population growth in the vicinity of the improved infrastructure finds only weak and often conflicting support".

We estimate an econometric model to explain the differences in the levels of rural population across municipalities and over time. Other papers that use an econometric approach are Liu *et al.* (2017), and San Juan & Sunyer (2019). Our model uses a broad set of explanatory variables that include the economic situation of the municipality (non–agricultural production, agricultural productivity, urban–rural income gap), the endowment of infrastructures (hospitals, highways, railway, schools), and some characteristics of the municipality that define its life conditions (altitude, distance to the main cities of the region, presence of an important town).

The paper is structured as follows. Section 2 briefly reviews the literature on the dynamics of rural population. Section 3 describes the data and the variables used in the empirical model. Section 4 contains the results of the estimation of the empirical model. Section 5 concludes.

2. Literature review

In this section we review a subset of a large literature which has analyzed the problem of rural depopulation from several perspectives. First, we summarize papers that measure rural depopulation. Second, we review a set of studies that try to explain its causes.

2.1. Measuring the extent of rural depopulation

The decline in rural population is well documented. We can trace academic studies on this issue back to the early years of the past century. For example, Cance (1912) reported that, between 1890 and 1912, the rural population of New England had declined in every state except Massachusetts.

Saville (1957) studied depopulation in rural England and Wales between 1851 and 1951, finding that agriculture had employed a quarter of the males aged 20 and over in 1851 whereas by the end of the century the proportion was below 10 percent. This decline was related to the new labor demand which was concentrated in the coal mining and industrial areas.

Cawley (1994) uses data from 157 rural districts in the Republic of Ireland to study rural population decline during the period 1971-1991. Despite the high growth rate of population in Ireland in those decades, most of the smallest rural districts lost population. In the period 1971-1981, 24 out of the 78 rural districts with less than 10,000 people in 1971 registered a decline in population. The same pattern continued in the 1980s but with a higher rate of decline, with 62 small districts losing population.

As shown by the aforementioned papers (a selection of a very wide literature), the empirical evidence is that rural areas have lost and still are losing population. A relevant question is whether this process of population decline will ever reach an end. Rural areas are not without their advantages, including quiet environment, less pollution, lower crime rate, and cheaper cost of living than in cities. Over a hundred years ago, Cance (1912) had already mentioned the “back to the land” movement in two directions: Toward small farms and toward country homes for urban dwellers.

In fact, a recent strand of literature has found that the population of some rural areas, after decades of decline, has begun to increase. Beale (1976) was apparently the first researcher to draw attention to this process, while Berry (1976) coined the term ‘counterurbanization’ to refer to it. However, the most recent empirical evidence about this phenomenon is mixed. In the United States, by 1980 non–metropolitan growth rates again had fallen behind those in metropolitan counties, while in Britain, Champion (1987) demonstrated that rural population growth peaked in the early 1970s, only to fall again during the subsequent decade.

2.1. Explaining rural depopulation

Most of the studies that measure the extent of rural depopulation do not attempt to explain its causes. Two are the main approaches followed in the literature to study the causes of the decline in rural population: The use of questionnaires and the estimation of econometric models.

One example of the use of questionnaires is Drudy & Wallace (1972). They examine the rural depopulation process in four typical rural communities of Great Britain between 1951 and 1971. All of them registered a decline in population during the study period. A questionnaire to 392 school-leavers revealed that the migration decision was related to the level of occupational aspiration as well as to dissatisfaction with the local community.

One of the first papers to explain changes in rural population using an econometric model is Goetz & Debertin (1996). They study the effect of federal farm programs using data of U.S. non-metro counties from 1980 to 1990. Surprisingly, they find that the volume of farm program payments as a share of crop and livestock cash marketing receipts is positively related to higher rates of population loss. Additionally, counties with more off-farm employment, larger values of land and buildings per farm and the share of livestock earnings as a percentage of total farm receipts, experienced less population out-migration.

Huang *et al*. (2002) analyze the factors causing the population of rural counties to grow or decline over the 1950-1990 period using a random sample of counties in the midwest and the south of the U.S. They consider a county as rural if total urban population is under 20,000 and has a farm population of at least 400. They regress the percentage changes in county population on a broad set of variables, finding that counties with more diversified rural economies and higher farm income have faster population growth.

One of the main factors behind rural depopulation is the distance to “big” cities. Dijkstra & Poelman (2008) analyze this issue in EU regions. They consider a region to be close to a city if more than half of its residents can drive to the center of a city of at least 50,000 inhabitants within 45 minutes; otherwise, it is considered remote. They find that only remote regions have negative population growth. The figures are clear: The average population density in remote rural regions is half that of rural regions close to a city; and four out of five remote rural regions either had a loss of population or grew more slowly than their country’s growth rate.

A topic that has recently received the attention of researchers is the effect of natural amenities (scenic beauties, recreational sites…) not only on county income (e.g., Deller *et al.,* 2001) but also on population growth (e.g., Chi & Marcouiller, 2011).

Some of these studies find that rural areas characterized by high levels of natural amenities experience relatively greater population growth than areas lacking desirable natural contexts. But measuring amenities is not simple. The United States Department of Agriculture (USDA) has developed a natural amenities scale, which is a measure of the physical characteristics of a county that enhance the location as a place to live. The scale is constructed by combining six variables that reflect environmental qualities most people prefer. These measures are warm winter, winter sun, temperate summer, low summer humidity, topographic variation, and water area. McGranahan (1999) discovered that counties with low scores on this index lost population over the 1970-1996 period.

Rupasingha *et al*. (2015) study the determinants of migration in the US not only from rural (non–metro) to urban (metro) counties but also from urban to rural counties for two different periods, 1995-2000 and 2005-2009. They use aggregate county-to-county migration flows data to estimate a gravity equation using a Poisson regression model. Their results show that population density, distance to urban areas, industry mix, employment growth, natural amenities, and percentage of older people are key factors underlying the decision to migrate.

San Juan & Sunyer (2019) estimate an econometric model where the dependent variable is the rate of the population growth in Spanish municipalities during the period 2000-2013. The per capita income-gap with urban areas, the growth of the working population, and the aging rate in rural areas appear to be the main drivers of rural depopulation.

Alamá-Sabater *et al*. (2019) study the factors that affect rural depopulation using data at the municipality level from the Spanish region of Valencia. They assess the conditions for a location being potentially at high risk of depopulation, finding that low accessibility is a sufficient condition for high depopulation risk. Additionally, the lack of economic dynamism, the absence of public infrastructure and having a neighboring dynamic municipality lead to depopulation.

Melo *et al*. (2021) estimate several regression models to investigate the relationship between rural population change and road accessibility to cities of different sizes in Portugal between 1991 and 2011. The results show that road accessibility to the urban areas influences positively rural population growth. The positive effects of proximity are statistically significant for medium-size cities (i.e., between 20,000 and 99,999 people), but not always for small and large cities.

3. Data

Asturias is located in the middle of the northern coast of Spain and has slightly more than one million inhabitants. The main agricultural activity is livestock production. Asturias has always been a region with high rural population, but it has also been one of the main industrial regions in Spain, with some big industries demanding employment and therefore contributing to the rural migration from the wings of the region (mostly agricultural) to the center of the region where the largest firms of the main industries (steel, ship building, coal mining) were located. However, in recent decades some of these industries went into crisis.

We have assembled a panel data set of the 78 Asturian municipalities from 1998-2019. The population data come from the Municipal Register, carried out by the Spanish Statistical Institute (INE) and the Asturian Statistical Institute (SADEI).

3.1. Defining rural population

The first challenge is to define rural population. Over a century ago, Bowley (1914) had already warned about this problem: "Rural population might be defined either from consideration of its density, or of its occupations, or from its position in the scheme of local administration; or it might be taken as the residual of the population of the Kingdom after that of a scheduled list of boroughs and towns had been abstracted".

The main difficulty stems from the fact that rural population is not equivalent to farm population. Rural population may reside not just in the open countryside but also in villages and part of them work in non–farm activities. So, the challenge is to set a criterion by which a village is not considered rural anymore and becomes urban.

International organizations use different definitions of rural. Eurostat defines 'urban clusters' as a cluster of contiguous grid cells of 1 km^2 with a population density of at least 300 inhabitants per km^2 and a minimum population of 5,000 inhabitants (Eurostat, 2012). The rest of the territory is considered rural. The OECD classifies "local units" as rural if their population density is below 150 inhabitants per square kilometer (OECD, 2011)[2]. The US Census Bureau defines rural as any population residing not in an urban area, which are areas with at least 2,500 people (Ratcliffe *et al.,* 2016)[3].

[2] In 2009, the OECD Working Party on Territorial Indicators approved a refinement of the OECD regional typology in order to include an accessibility criterion, based on the driving time needed to reach a highly populated center. As a result, rural regions were split into two groups: Predominantly Rural Close to a City and Predominantly Rural Remote.

[3] "Non–metro" is not synonymous with rural. Metropolitan Statistical Areas or "metro" areas are defined at the county level, and most counties have a mix of urban and rural areas. In fact, according to the latest American Community Survey, 54 percent of people living in rural areas are within a metro area.

Many empirical studies use data at the municipality level and define rural municipalities as those with population below a certain threshold. For example, Huang *et al.* (2002) consider a county as rural if total urban population is under 20,000 and has a farm population of at least 400. Setting the threshold at the municipality level may not be the best way to define rurality. Two municipalities may have the same number of people below the threshold but one may have all the inhabitants living in one city while the other one may have the population dispersed in small rural settlements.

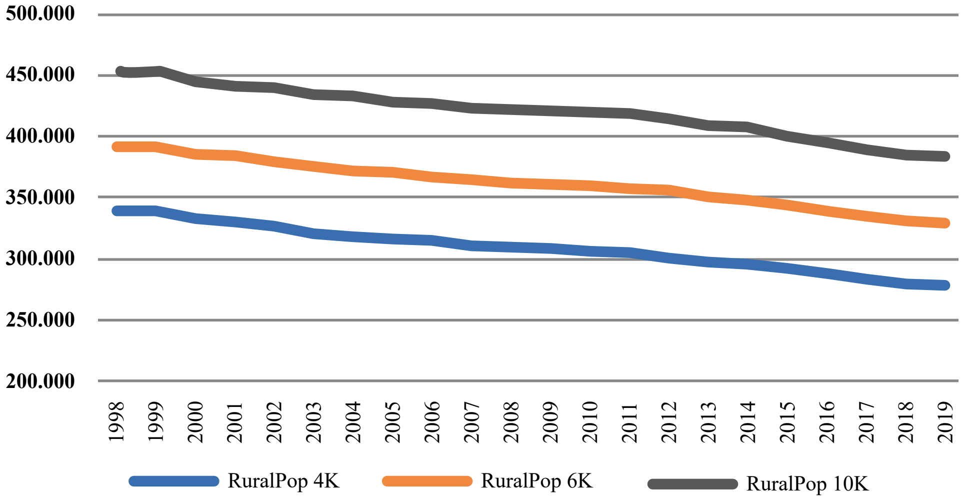
The originality of this study is that in order to compute the rural population at the municipality level we count the rural population living in parishes, which is a subdivision of a municipality[4]. There are 857 parishes in the 78 municipalities of Asturias. This fine level of granularity allows us to estimate rural population with high precision. Using a high level of disaggregation to delimit rurality is very important since, otherwise, the rural population is misestimated.

We do so for each municipality based on the number of people that live in parishes below a certain limit. For example, our variable RuralPop_4K includes the people in a municipality that live in parishes with less than four thousand people. In our empirical analysis we have considered two other variables which use higher thresholds of six and ten thousand people. Obviously, the higher the threshold, the larger the number of people counted as rural.

The evolution of the rural population in Asturias using the three definitions can be seen in Figure 1. The three variables show a clear linear decreasing pattern. This negative trend is shared by almost all municipalities, although there are a few exceptions.

[4] Sørensen *et al*. (2021) also use data at the parish level to study the effect of school closure on rural population.

FIGURE 1
Evolution of the rural population in Asturias (1998-2019)



Source: Own elaboration from Municipal Register data.

3.2. Explanatory variables

In the literature, the main reasons for rural outmigration have been divided into two categories: economic factors and quality of living issues. Economic related migration has to do with the income-gap with urban areas, which is mainly related to the availability of higher paid jobs in more industrialized areas. Quality of living issues are associated to the lack of basic social infrastructures, such as schools, hospitals, or transport infrastructures (highways, railway), to the low provision of other services of general interest (bank branches, shopping malls, entertainment places,…), as well as to some characteristics of the municipalities (climate, distance to big urban centers,…). Therefore, we will consider in our regression model three groups of variables which are summarized in Table 1[5]:

a) Economic factors

- Importance of non-agricultural sectors: The presence of firms in rural areas is expected to reduce the incentive to migrate to urban centers. For example, Alamá-Sabater *et al.* (2019) consider business density (number of firms per 000 people) as a factor that helps to keep population in the countryside. Since the number of firms does not take into account its size, we include the percent of

[5] Most of the explanatory variables have been provided by SADEI. The infrastructure variables, such as distances to the nearest hospital or highway, were not available and we had to build them up.

gross value added in the non-agricultural sectors as an indicator of the capacity of the municipality to absorb labor (NONAGPROD).

- Profitability of agriculture: Agricultural and livestock production are the main economic activities in rural areas. If these activities are profitable, the incentive to leave is smaller. As an indicator of profitability, we include the gross value added per worker in this sector (AGPRODUCTIVITY). To the best of our knowledge, this variable has not been previously used in the literature, although Goetz & Debertin (1996) use a similar variable, 'earnings in agriculture'.

- Income Gap: It has been widely recognized that the income gap between urban and rural areas is a main driver of depopulation (e.g., San Juan & Sunyer, 2019). We include the difference in real terms between net family income in the capital of the region and in each municipality (INCOMEGAP). Many studies use the per capita income of the municipality (e.g., Huang *et al.,* 2002) but we consider that relative income better adjusts to the explanation of rural outmigration[6].

b) Infraestructures

- Distance to the nearest hospital: We measure the distance from the capital of the municipality to the nearest hospital in terms of time (TIMEHOSPITAL)[7]. Despite the importance of this variable, very few population studies consider the access to healthcare services. One exception is Alamá-Sabater *et al*. (2019) who also include the distance to the nearest hospital to explain the probability of a municipality to lose rural population.

- Distance to the nearest highway: Highways improve the connectivity of rural areas. We expect that the farther the nearest highway, the higher the probability of leaving the municipality. This variable was not available in the public statistics and we had to construct it. Since it takes a while to build highways, especially in regions with sloppy landscape such as Asturias, new highways are put into service by pieces, which made it difficult to compute a measure of distance to a highway. We measure this variable as the distance in kilometers to the connecting point of the nearest highway (DISTHIGHWAY).

- Presence of a train station: While people travel mostly by car, having access to railway services improves the connectivity of municipalities. We reflect this aspect by including a dummy variable that takes value 1 if there is a train station in the municipality (RAILWAY). Melo *et al.* (2021) consider the number of train stations.

[6] We also measured the income–gap as the ratio of the capital and the municipality per capita incomes. The results were very similar to those using the difference.

[7] The computation of distances was done using Google Maps taking into account the type of road existing at each moment (in particular, the existence of highways).

- Educational infrastructures: The existence of education centers is expected to decrease the probability of migration. We have chosen two indicators of educational infrastructures: Primary schools and high schools. In the empirical model we use a binary variable (1 = yes, 0 = no) to reflect the presence in the municipality of at least one primary school (PRIMARYSCHOOL) and one high school (HIGHSCHOOL). While the relationship between the existence of primary schools in the municipality and rural population has been widely studied, mainly by rural sociologists (e.g., Sørensen *et al.,* 2021), we think that the presence of high schools may also influence the decision of families to leave or stay. Alternatively, Huang *et al.* (2002) use the per capita expenditure in education in the municipality.

c) Municipality characteristics

- Climate: Weather conditions are an important factor in migration decisions. The main factors that define a particular weather are temperature, precipitation, sunlight, wind and snow, among others. Asturias is a very mountainous region and the municipalities located in the mountains have poor weather, which makes living conditions rather difficult, especially in wintertime. We have chosen to proxy weather by the altitude of the municipality capital (ALTITUDE) since this variable is related with the factors previously mentioned. Similarly, Melo *et al.* (2021) use the average slope steepness of the Portuguese districts.

- Being on the coast: Counties on the coast present several advantages, such as better weather, as well as richer soil and flatter land, which help farmers in their activity. We include a dummy variable that takes value 1 for municipalities along the coastline (COAST).

- Distance to a "big" city: One of the reasons to leave the countryside is the distance to an urban center, since rural population lacks many of the services present in big cities (shopping malls, banks, movie theatres ...). We have measured the distance to a "big" city for each municipality as the minimum distance to a city larger than 50,000 people (DISTBIGCITY)[8]. Just three cities in Asturias hold more than 50,000 inhabitants (Oviedo, Gijón, and Avilés) and they do so during the whole sample period, making this variable constant over time.

- Urbanization: The presence of urban areas within the municipality reduces the need to migrate. Gutiérrez *et al.* (2020) note that proximity to an urban area contribute to demographic dynamism of rural settlements. We have included a binary variable that takes value 1 if there is at least one town with more than 5,000 people in the municipality (CITY5K). Liu *et al.* (2017) take into account this aspect by including the percent of people living in urban areas.

[8] The population threshold to define a city as "big" differs across studies. For example, Huang *et al.* (2002) considered the distance to the nearest city larger than 100,000 people, while Liu *et al.* (2017) defined "big" as larger than 1 million people. Merino & Prats (2020) consider the distance to the capital of the province.

We have also added two control variables which were necessary for a correct specification of the model. First, we have included the agricultural area of the municipality (AGRICAREA) since the dependent variable is in levels (number of rural population) and one would expect to find larger rural populations in larger municipalities. Second, we have added a time trend (TREND) to control for the effect of time–varying unobserved variables (common to all municipalities) that affect the evolution of rural population over time. Since we expect the movement of rural population to slow down during the economic recession, we have also interacted the time trend with a dummy variable that takes value 1 between 2009 and 2019 (D_2009)[9].

TABLE 1
Description of the variables

Variable	Description	Unit	Source
RuralPop_4K	People in a municipality that live in parishes with less than four thousand people	(000 people)	Municipal Registers (INE, SADEI)
RuralPop_6K	People in a municipality that live in parishes with less than six thousand people	(000 people)	Municipal Registers (INE, SADEI)
RuralPop_10K	People in a municipality that live in parishes with less than ten thousand people	(000 people)	Municipal Registers (INE, SADEI)
Economic factors			
NonAgProd	Gross value added in the non-agricultural sectors	Percent	SADEI
AgProductivity	Gross value added per worker in Agriculture	(000€/worker)	SADEI
IncomeGap	Difference between net family income in the capital of the region and in each municipality	(000€, in real terms)	SADEI
Infrastructures			
TimeHospital	Distance to the nearest hospital from the capital of each municipality	Minutes	Google Maps, Portal de salud del Principado de Asturias
DistHighway	Distance to the connecting point of the nearest highway from the capital of each municipality	Kilometers	Google Maps, Red de Carreteras del Principado de Asturias
Railway	Dummy variable that takes value 1 if there is a train station in the municipality	(1/0)	Renfe, Ministerio de Fomento
Educational infrastructures			
PrimarySchool	Dummy variable that reflects the presence in the municipality of at least one primary school	(1/0)	SADEI
HighSchool	Dummy variable that reflects the presence in the municipality of at least one high school	(1/0)	SADEI

[9] The worst of the crisis was between 2009 and 2014, which were the years with negative GDP growth, and after then the Spanish economy started to recover. We have tried different configurations of our crisis dummy but the best results are obtained when the dummy starts in 2009 until the end of the sample period. This is in part due to the fact that the labor markets in the urban areas took longer to recover..

Municipality characteristics			
Altitude	Altitude of the municipality capital	Metres	SADEI
Coast	Dummy variable that takes value 1 for municipalities along the coastline	(1/0)	Elaborated
DistBigCity	Minimum distance to a city larger than 50,000 people from the capital of each municipality	Kilometers	Google Maps
City5K	Dummy variable that takes value 1 if there is at least one town with more than 5,000 people in the municipality	(1/0)	Elaborated
AgricArea	Agricultural area of the municipality	Square kilometers	SADEI
Trend	Time trend		Elaborated
D_2009	Dummy variable that takes value 1 between 2009 and 2019	(1/0)	Elaborated

Source: Own elaboration.

Table 2 contains descriptive statistics of the variables used in the empirical analysis[10]. The three rural population variables decrease over time. The decline rate varies inversely with the threshold, ranging from -18 % for 4K to -15 % for 10K. Both, the share of non–agricultural GDP and the agricultural labor productivity increase during the sample period, while the urban–rural income–gap in 2019 is less than in 1998. The evolution of rural income has been positive in the last decades in part due to many farmers quitting their activity. For example, in the dairy sector there were production quotas until 2015 and when dairy farmers abandon milk production their quota is taken up by others that stay in business making their farms larger and their income higher. Gardner (1974) finds that farm population decline is associated with an increase in rural income.

With regards to infrastructures, the large investments in public roads have made it possible to reduce the average distance to a highway from an average of 65 km to just 15. The construction of new highways has allowed to reduce the average distance to the nearest hospital from 33 to 28 minutes. The number of municipalities with operative railway infrastructure has not changed since 1998, with just 46 % of them holding a railway station. The Primary Education Law of 1945 established that there should be a school in each rural town (for every 250 inhabitants) but in the 1970s, due to dropping enrollment a process of concentration of village schools started to take place. As a result of this process of rural school consolidation several municipalities were lacking this type of school during the sample period. So, the variation in the public services variables is mainly across municipalities, since some of them lack variability over time.

[10] Other variables that affect quality of living, such as digital connectivity, were not included due to lack of data.

TABLE 2

Descriptive statistics (1998 – 2019)

	1998		2019	
	Mean	St. Dev.	Mean	St. Dev.
RuralPop_4K	4,370	4,266	3,581	3,885
RuralPop_6K	5,043	5,217	4,228	4,754
RuralPop_10K	5,814	5,888	4,925	5,232
AgricArea	42.52	38.99	56.23	55.75
NonAgProd (%)	0.82	0.15	0.90	0.08
AgProductivity (000€/worker)	15.44	17.64	25.16	10.21
IncomeGap (000€)	2.82	1.21	2.39	1.33
TimeHospital (min.)	33.12	21.90	28.44	18.16
DistHighway (km)	64.31	50.54	14.65	17.92
Railway (1/0)	0.46	0.50	0.46	0.50
PrimarySchool (1/0)	0.84	0.36	0.84	0.36
HighSchool (1/0)	0.42	0.49	0.44	0.50
Altitude (m)	239	207	239	207
Coast (1/0)	0.26	0.44	0.26	0.44
DistBigCity (km)	60.62	44.05	60.62	44.05
City5K (1/0)	0.38	0.48	0.37	0.47

Source: Own elaboration.

4. Estimation and results

Our empirical model is the following:

$$L\_Y_{it} = \beta_0 + \beta_1 L\_AgricArea_i + \beta_2\, P\_NonAgProd_{it} + \beta_3\, L\_AgProductivity_{it} + \beta_4\, IncomeGap_{it} + \beta_5\, L\_TimeHospital_{it} + \beta_6\, L\_DistHighway_{it} + \beta_7\, D\_Railway_{it} + \beta_8\, D\_PrimarySchool_{it} + \beta_9\, D\_HighSchool_{it} + \beta_{10}\, L\_Altitude_i + \beta_{11}\, D\_Coast_i + \beta_{12}\, L\_DistBigCity_i + \beta_{13}\, D\_City5K_{it} + \beta_{14}\, Trend_t + \beta_{15} Trend_t * D\_2009 + \varepsilon_{it}$$

where subscript i indicates municipality and subscript t represents time. The dependent variable and most of the continuous independent variables are in logs, as indicated by an 'L_'. The 'D_' and 'P_' stand for dummy and proportion, respectively. The variable income–gap is not in logs since it takes on negative values for some observations[11].

The estimation of above equation by Ordinary Least Squares for the three dependent variables described previously is displayed in Table 3[12]. It is important to note that in our empirical strategy we make use of all 78 municipalities. This differs from other studies (e.g., San Juan & Sunyer, 2019) where municipalities are first classified as urban or rural and then the evolution of population is analyzed just in the rural municipalities (considering all the inhabitants in a rural municipality as rural population).

TABLE 3
Estimation of the population equation

	Rural Population < 4000		Rural Population < 6000		Rural Population < 10000	
	Coef.	t–ratio	Coef.	t–ratio	Coef.	t–ratio
Constant	5.031***	17.58	5.819***	25.95	5.296***	28.02
L_AgricArea	0.698***	19.65	0.397***	20.89	0.408***	25.09
P_NonAgProd	1.738***	11.54	1.417***	10.66	1.891***	15.12
L_AgProductivity	0.170***	3.20	0.139***	3.52	0.073***	2.52
IncomeGap	-0.045***	-3.26	-0.081***	-6.60	-0.081***	-7.05
L_TimeHospital	-0.287***	-19.82	-0.246***	-15.76	-0.209***	-13.59
L_DistHighway	-0.057***	-5.45	-0.028***	-2.72	-0.045***	-5.49
D_Railway	0.136***	4.94	0.013	0.58	0.111***	5.33
D_PrimarySchool	0.272***	5.84	0.530***	14.55	0.480***	13.87
D_HighSchool	0.020	0.23	0.490***	11.57	0.636***	17.08
L_Altitude	-0.050***	-3.95	-0.022*	-1.72	-0.009	-0.88
D_Coast	0.383***	7.81	0.295***	6.26	0.170***	4.22
L_DistBigCity	-0.064***	-4.97	-0.063***	-5.00	-0.026**	-2.13
D_City5K	0.125	1.42	0.234***	5.17	0.350***	9.17
Trend	-0.045***	-8.22	-0.039***	-8.57	-0.038***	-9.97
Trend*D_2009	0.005	1.50	0.005*	1.83	0.004*	1.77
R^2	83 %		87 %		91 %	
Observations	1,716		1,716		1,716	

*, **, *** indicate statistical significance at the 10 %, 5 % and 1 % significance levels.

Source: Own elaboration.

[11] Fixed effects were not specified in the empirical model since some of the relevant variables are time–invariant (Altitude, Coast, DistBigCity).

[12] The standard errors of the estimates were computed using White's heteroskedasticity–consistent variance–covariance matrix estimator.

In general, the results of the three models are very similar. The coefficients of most variables are significant (just 5 out of 48 estimated coefficients are nonsignificant at the 10 % significance level) and they all carry the expected sign. The three models show a high goodness of fit in terms of the R^2 statistic, which ranges from 83 % to 91 %. These values are much larger than those typically found in similar studies of rural population.

The economic variables are positive and significant. As expected, a larger share of production in sectors other than agriculture as well as higher agricultural productivity increase rural population. Therefore, population stays in rural areas where the economic situation is favorable. However, Li *et al*. (2019) argue that agriculture only contributes to a very small extent as a driver of rural development in developed countries, suggesting that the future of rural areas depends on the diversification of their economies. The negative sign of IncomeGap, on the other hand, indicates that the higher the difference between local income and income in urban areas (as measured by the income in the capital of the region), the lower the rural population. Merino & Prats (2020) also conclude that depopulation is a consequence of migration in search of new and better salaries and quality of life.

The infrastructure variables also carry the expected sign. Starting with health–related variables, the further the distance to the nearest hospital, the lower the rural population. In fact, hospitals are just a part of the healthcare system, and while they are important, they are used very occasionally by people. Probably a better variable to reflect the importance that people give to having access to health services is the presence of primary healthcare centers. We have data for this variable just after 2006 and for this reason we decided not to include it[13].

The effect of having at least a primary school or a high school in the municipality is positive. This result suggests that the policy of rural school closures has probably had a negative effect on rural population. In Spain, as in many other countries, the continuous decline in rural school enrolment led to a process of closures and amalgamation. Our finding is in line with previous research. For example, Gillies (2013) studied the effect of rural school closure in the Scottish Hebridean island, finding that most students cited further education as the main reason for leaving. However, their analysis suggests that it was lack of suitable employment that kept them away. They conclude that "while the education system is implicated in initial out–migration, it is the economics of employment that is the key, underlying factor". Lehtonen (2021) also finds clear evidence of a negative effect of rural school closures on population.

[13] The estimation of our models using data since 2006 and adding a dummy variable which takes value 1 if there is at least one primary healthcare center in the municipality indicates that this variable is positive and highly significant.

The coefficient of the (shortest) distance to a highway is negative and significant in the three models, indicating that the further away the nearest highway, the lower the rural population. Chi (2012) also found that in rural areas of Wisconsin highway improvement promotes population growth. A similar result was obtained by Alamá–Sabater *et al*. (2019), who study the factors that condition rural depopulation using data at the municipality level in Valencia, finding that lack of accessibility of rural locations is a sufficient condition for high depopulation risk.

The coefficient of the dummy variable for having a train station is positive and significant in two of the models, indicating that railway connectivity helps to fix rural population. Collantes & Pinilla (2004) also include the low endowment of railway infrastructure as one of the factors of the economic and demographic decline of the mountainous areas of Aragón.

With regards to the characteristics of the municipalities, the coefficient of the altitude of the capital is always negative and significant, reflecting the well–known fact that people tend to move away from mountainous areas. The coefficient of the variable that measures the distance to a big city (over 50,000 people) is negative and significant, as expected. This is a very important variable in depopulation studies. Dijkstra & Poelman (2008) found that 'remote rural regions' are the only group with a negative population growth in the EU-27. Johnson & Lichter (2019) analyze the depopulation in rural America and find that more than 46 percent of remote rural counties that are not adjacent to metropolitan areas are depopulating compared to 24 percent that are. Melo *et al*. (2021) suggest that proximity to cities "allow rural people to work in cities but live in nearby rural areas due to lower housing costs and preferences for natural amenities and better environmental quality (e.g., clean air, less noise, and more appealing landscapes)".

An important explanatory variable is the presence in the municipality of a town larger than 5,000 people, which is measured by the binary variable D_CITY5K. The positive coefficient of this variable indicates that these towns help to maintain the population in the countryside.

Finally, it is worth mentioning the negative and significant coefficient of the trend variable. The trend is picking up the effect of time-varying variables (common to all municipalities) not included in the model. It is not easy to guess which relevant effects of this type have been left out. One possibility is the influence of psychological factors. For example, Hoggart & Paniagua (2001) comment that the unwillingness to work in farming can be explained by the fact that some young people may consider the agricultural sector as having a low social status. With the widespread use of social networks, this perception may be increasing overtime. In any case, the negative sign of the trend indicates that even if the variables included in the model do not change, rural population decline will continue.

The interaction of the time trend with the dummy variable for years after 2008 that is intended to account for the economic recession carries a positive sign, indicating that the crisis helped to keep rural population in the countryside. This result was expected due to the enormous effect of the Great Recession on the Spanish economy, which suffered a decrease in GDP, an increase in the unemployment rate, and a decline of real wages. The depth of the economic crisis caused a rise in international emigration while internal movements declined (Melguizo & Royuela, 2017).

4. Summary and Conclusions

We examine the evolution of rural population in Asturias between 1998 and 2019. Rural population was computed using data at the parish level and three different thresholds, four, six, and ten thousand people. The three variables show a decreasing trend during the sample period.

One of our main conclusions has to do with the importance of connectivity. The shorter the distance to hospitals and highways, as well as the presence of a railway station, the higher the rural population. The availability of good communications has important implications for health and safety, particularly for the elderly. Poor local mobility makes residents leave and potential new residents stay away, worsening demographic decline.

Both the presence of a primary school or a high school help to maintain rural population in the countryside. It has been argued that since there is free public transportation to the schools from any settlement, in some sense, this is similar to having the school in the municipality. However, this is not taking into account the increase in commuting time by young scholars which sometimes makes them get up too early to be able to attend school.

In summary, we find that proximity to social and physical infrastructures is an important factor to keep population in rural areas. However, it is not clear whether this result implies that more infrastructures should be built in rural areas. After all, infrastructures are costly and some economists deem the rural exodus as the result of a process of utility maximization by individuals which has been taking place since the Industrial Revolution and that little (if any) should be done to stop it. In conclusion, policymakers should seriously consider if costly investments in infrastructures (hospitals, schools, highways, railway stations…) pay off in order to keep population in the rural areas of the region.

It is important to point out that in recent years migration has been replaced by negative natural growth as the key factor in rural depopulation. Since one of the consequences of depopulation is that rural areas are aging faster, the birth rate decreases and is not enough to compensate for deaths. One solution to this problem is immigration. As an example, Pinilla *et al.* (2008) find that the pace of depopulation has slowed down in the rural areas of Aragon since 2001. In fact, the municipalities with more than 1,000 people have seen positive population growth. The main reason behind population growth is foreign immigration. A similar result was obtained by Collantes *et al*. (2014).

Finally, an important limitation of our paper and, in general, of the literature that uses econometric models to explain rural population change is the geographical scope. For example, in our case we have considered the characteristics (economic, physical…) of the Asturian municipalities as if rural people migrated only within the province. However, rural people move also to other regions or countries. Therefore, the income-gap perceived by rural people in Asturias is not necessarily the gap with the capital of the province but rather with the income of other places (weighted by distance). Despite this limitation, our three models perform rather well in terms of fit and significance of the variables.

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