A gravity model to explain flows of wild edible mushroom picking. A panel data analysis

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Abstract: Picking wild edible mushrooms is becomingly an increasingly widespread activity. Recent research is reporting a change in the way pickers access this resource, particularly in the more developed countries. The latest studies focus on exploring the demand functions of harvesting, with the emphasis shifting away from analyses that address the issue from a commercial standpoint. Yet these studies fail to deal with the topic from a global perspective and provide only partial information that is felt to be insufficient when attempting to manage the resource efficiently. The present work seeks to provide an approach to the problem by applying, for the first time, a gravity model to study the system governing the sale of harvesting permits (www.micocyl.es, Castilla y León-Spain). The main advantage of this application is that, for the first time, three-dimensional panel data are used to link economic variables to climate variables and their interaction to the supply and demand of picking permits. Results show that the method provides key management information. Managing the picking of wild edible mushrooms should aim to focus more on handling the tourist flows it generates.

Key Words: Wild edible mushroom, management, gravity model

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1. Introduction

Collecting wild mushrooms is common the world over and forms an important part of production and recreational activities in many societies (Boa, 2004). These forest resources are put to a wide range of uses and there are many examples in every continent such as Europe (Roman and Boa, 2006; Sita and Floriani, 2008; Turtiainen *et al.*, 2012; Frutos *et al.*; 2012), the Americas (Starbuck *et. al.*, 2004; Montoya *et al.*, 2008; Pérez *et al.*, 2008; *Barron et al.*, 2015), Africa (Dijk, *et al.*, 2003; Buyck, 2008; Tibuhwa, 2013; Nharingo *et al.*, 2015), Asia (Christensen *et al.*, 2008; He *et al.*, 2011; Thatoi and Singdevsachan, 2014) and Oceania (Thomas, 2002; Pauli and Foot, 2015).

Yet despite this worldwide importance, forest resource management plans do not tend to take mushrooms into account. At most, they are considered of secondary importance compared to wood-based products (Aldea *et al.*, 2012). Their complicated ecology (Dighton and White, 2017) coupled with complex organisational factors, which are not included when managing other forest resources (Frutos *et al.*, 2016), have meant that legislation over control of mushrooms remains scarce.

Prominent directives in this area are the regulatory frameworks in place in the United States (McLain, 2008), Spain (Gorriz *et al.*, 2017a), Italy (Secco *et al.*, 2010) or Nepal (Thapa *et al.* 2014), and are based on establishing permits that grant access to mushrooms depending on pickers' particular circumstances. All of the legislation in place is based on complex management systems which need to draw on information related to market conditions, and which does not tend to be available to those responsible for decision making. This might lead to inefficient decisions being taken that could compromise the long-term sustainability of the regulatory model. Moreover, these decisions must be taken bearing in mind the transversality between policies aimed at managing the resource and others, such as nature conservation, public safety or tourist policy. This complicates even further the task facing those who manage said resources, since various levels of administrative control might be involved in decision making.

To date, few studies have provided relevant information to help support management of the collecting areas. Research has tended to focus on the economic value of the wild mushrooms collected (Alexander *et al.*, 2002; Palahi, *et al.*, 2009; Cai *et al.*, 2011; Voces *et al.*, 2012). Yet said information continues to prove inadequate vis-à-vis gaining efficiency when managing the resource in question, since aspects related to the market value of forest resource production are becoming less important. There is now a shift towards a more multifunctional approach to forest management, where recreational aspects are coming to the fore (Sisack *et al.*, 2016). As a result, analyses of the demand functions of harvesting wild edible mushrooms using environmental valuation techniques are gaining in importance (Starbuck *et. al.*, 2004; Frutos *et al.*, 2009; Martínez de Aragón *et al.*, 2011). Arguably, the studies to have provided most information aimed at filling this gap are those published by Frutos *et al.*, 2016 or Gorriz *et al.* (2017b). Whilst the former studies model willingness to pay for permits to collect wild mushrooms in Andalusia (Spain) and the explanatory variables involved, the latter explore the link between collecting, forest ownership and options to control the activity in Catalonia (Spain).

However, the main limitation of these studies is that they are partial models that only explore the drivers of the harvesting demand function, yet overlook other factors that might also have a bearing on pickers' decisions. For instance, they fail to take account of determinants on the supply side of picking such as the physical infrastructure (potential and actual) of the area, or how this may be influenced by external factors, such as the climate, as well as public and private investment aimed at adapting it to their use, or changes in the provision of tourist infrastructure.

Yet where almost all the studies cited do concur is in the importance of approaching picking as an activity that embraces a strong tourist motivation component, with mycotourism being an emerging activity (Büngen, *et al.*, 2017). The use of general distribution models that take account of aspects such as origin and destination are emerging as suitable explanatory tools for describing the flows of individuals (Cesario, 1973). What is required is a model able to explain mushroom pickers' movements based both on the push of the origin and the pull of the collecting areas that are the destination. Gaining an insight into how and why mushroom pickers make their decisions might prove important when implementing key measures that can ensure long-term sustainability.

The use of equilibrium models thus offers valuable information that will go beyond any simple interpretation that may be gained from the demand side. Such models provide for a study of the activity as a whole and, therefore, help when examining links that have thus far remained unexplored with other areas of policy such as tourist, infrastructure or tax related issues.

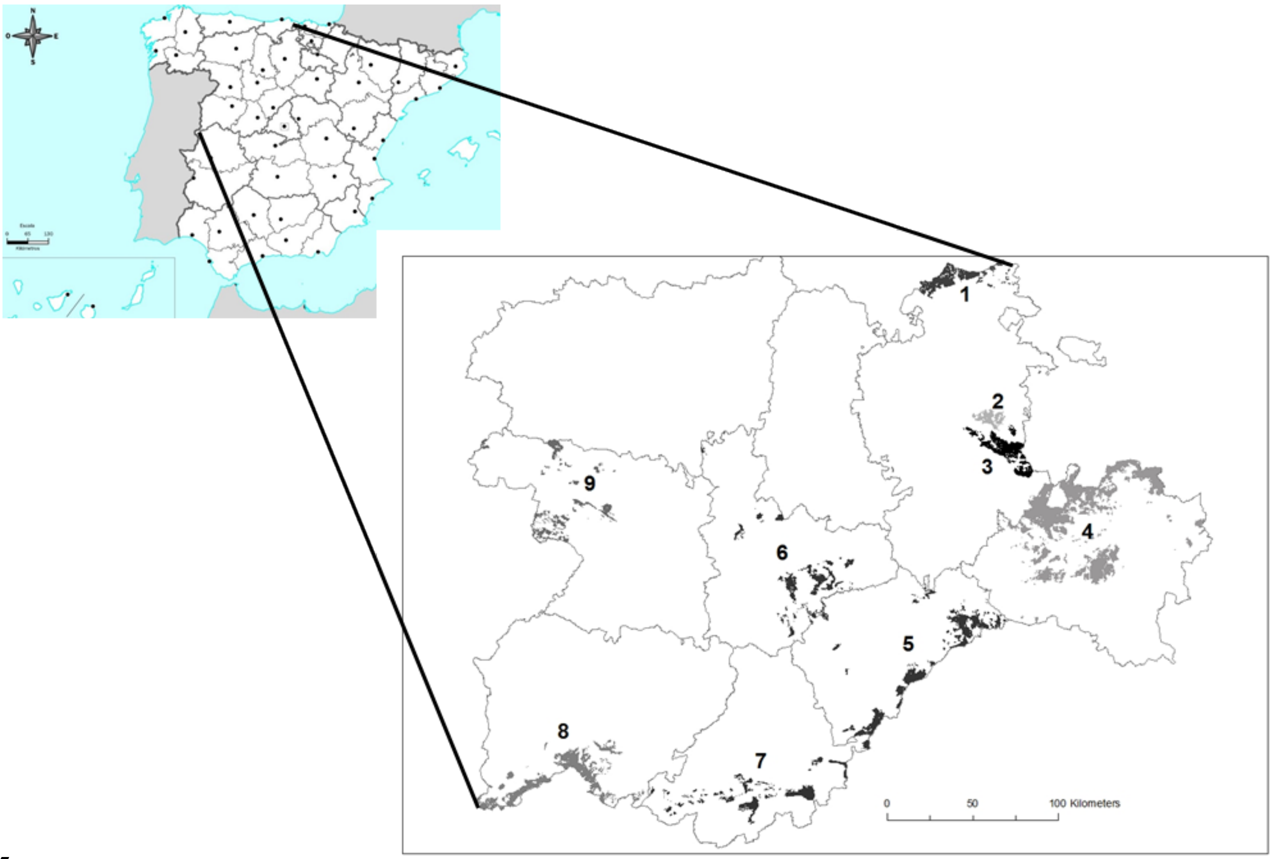
The present research seeks to provide a gravity model at a national scale, Spain in this instance, capable of offering a clear explanation of the relevant variables that determine the picking permits issued in a given collecting area, in this case the www.micocyl.es system run by the Regional Government of Castilla y León (Spain). The research also aims to assess how pickers respond to certain management decisions taken concerning the resource in question by studying the elasticities of the corresponding explanatory variables and by examining possible transversal links with other public policies. One of the principal novelties of the study involves the use of panel data, drawing on information from different mycological management areas over the period 2013-2015. An attempt is thus made to respond to the criticisms levelled at other models like the travel cost method based on the problem of stability of measures estimated using longitudinal data (Cooper and Loomis, 1990; Hellerstein, 1993).

2. Material and methods

2.1 Study site

The Autonomous Community of Castilla y León is located in the centre of Spain (Figure 1). It is the largest region in the country, covering 84,226 km^2 (18.6% of the whole country) and is the third largest European NUT-2 administrative area, being similar in size to countries like Bulgaria, Hungary or Portugal.

Figure 1: Study site



Source: Micocyl
(*) Numbers correspond to locations are listed in table 1

Castilla y León has a wide variety of forest habitats and, consequently, a wide variety of wild mushrooms, estimated at some 2,744 species. The most representative genera are *Agaricales* (42%), *Russulales* (8%), *Polyporales* (6%) and *Boletales* (6%). Of these species, around fifty taxa are of commercial interest due to their high market value. The average gross annual production of wild edible mushrooms, excluding truffles, is 34,000 tons, equivalent to some 80 million euros (Martínez-Peña et al. 2011). The harvesting of a wide range of edible mushroom species, including *Boletus edulis* Bull., *Lactarius deliciosus* (L.) Gray, *Amanita caesarea* (Scop.) Pers and *Cantharellus cibarius* (Fries), has been attracting greater attention among local populations since the 1950s.

The predominant system governing the harvesting of wild mushrooms in the region of Castilla y León (Spain), a system known as Micocyl, has been in place since 2003 (Martinez-Peña*, et al.*, 2017). It is an advanced model for managing the forest use of wild edible mushrooms. This joint bottom-up governance model today includes over 350 public forest owners (mainly local rural municipalities), and covers more than 400,000 regulated hectares belonging to over 700 forest holdings spread throughout the region, split into 225 municipalities (Figure 1 and Table 1). This regulatory system is grouped and organised into nine collecting areas managed with common aims and tools whilst also taking into account the specific features of each area.

Based on sustainability and organisational criteria, the Micocyl system (García *et al.,* 2011) must decide for each collecting area both the total number of harvesting permits that can be issued as well as the type and cost. These decisions are taken depending on aspects such as each area's capacity (maximum number of permits per km^2), the relation between the picker and the municipality that owns the forest where the activity is to be undertaken, why the mushrooms are to be picked (whether for commercial, recreational or research purposes) or the length of time the activity will take place (table 2).

Micocyl has succeeded in bringing together all forest owners in a sophisticated common platform that provides information and online sales of picking permits (www.micocyl.es) connected in real time with the forest agents and security forces responsible for overseeing good practices in the use of the mycological resources the permits provide for. Each collecting area establishes its own sale price for the permits as well as the different types available (table 2). The owners' association, the body governing each collecting area, adjusts the prices intuitively with the social justification of generating a minimum revenue for use of mushrooms, which will enable management of the available mycological resources to be maintained and improved in a sustainable manner. Prices are also established following the criterion of favouring local pickers and mycotourism. To achieve this, symbolic prices ranging between 3 and 10 euros per year are applied for pickers registered as residents in the towns and villages that form part of the Micocyl system. This is coupled with reasonable prices for the majority of mycotourists, ranging between 5-10 euros per day and recreational use.

Table 1. MICOCYL mycological regulatory system: main features (2013-2015)

Collecting area	L[(a)]	Province	Regulated Forest	Number of Owners	Municipalities	Hectares
Las Merindades	1	Burgos	50	27	5	28,400
Montes de Oca [(b)]	2	Burgos	37	27	12	12,314
Demanda - San Millán	3	Burgos	30	15	11	28,645
Montes de Soria	4	Soria	258	86	59	158,320
Montes de Segovia	5	Segovia	101	50	32	47,291
Torozos-Mayorga-Pinares	6	Valladolid	58	32	28	32,486
Norte de Gredos	7	Avila	41	27	27	16,017
Sierras de Francia, Béjar, Quilamas y el Rebollar	8	Salamanca	84	44	36	53,710
Montes de Zamora	9	Zamora	72	45	15	25,710
TOTAL			**731**	**353**	**225**	**402,893**

(a) Location on Figure 1.
(b) Came into being in 2014
Source: own elaboration

Table 2: Sales permits (SP) by types, collecting areas and years (2013-2015)

Collecting area	Season	Recreational				Commercial (all season)			Total
		All season			1-2 days weekend				
		Local	Relating[(a)]	Others		Local	Relating[(a)]	Others	
Las Merindades	2013	375	528	238	890	29	0	1	**2,061**
	2014	348	437	123	1,042	16	0	0	**1,966**
	2015	421	556	212	2,930	27	0	1	**4,147**
	Total	*1,144*	*1,521*	*573*	*4,862*	*72*	*0*	*2*	***8,174***
Montes de Oca	2013	-	-	-	-	-	-	-	-
	2014	442	229	212	734	0	0	0	**1,617**
	2015	429	266	259	437	4	0	0	**1,395**
	Total	*871*	*495*	*471*	*1171*	*4*	*0*	*0*	***3,012***
Demanda - San Millán	2013	30	2	11	106	1	0	0	**150**
	2014	168	154	20	696	166	0	0	**1,204**
	2015	165	219	46	619	149	0	1	**1,199**
	Total	*363*	*375*	*77*	*1,421*	*316*	*0*	*1*	***2,553***
Montes de Soria	2013	14,856	4,526	83	15,904	2,489	45	12	**37,915**
	2014	15,727	5,812	86	29,252	4,109	60	5	**55,051**
	2015	12,232	5,199	68	31,362	4,683	79	4	**53,627**
	Total	*42,815*	*15,537*	*237*	*76,518*	*11,281*	*184*	*21*	***146593***
Montes de Segovia	2013	2,038	646	2	188	377	0	0	**3,251**
	2014	4,307	1,291	568	663	270	1	2	**7,102**
	2015	4,693	1,639	516	478	232	0	0	**7,558**
	Total	*11,038*	*3,576*	*1,086*	*1,329*	*879*	*1*	*2*	***17,911***
Torozos-Mayorga-Pinares	2013	8,830	205	60	199	101	0	0	**9,395**
	2014	9,544	402	289	404	191	0	0	**10,830**
	2015	8,779	463	293	766	189	0	0	**10,490**
	Total	*27,153*	*1,070*	*642*	*1,369*	*481*	*0*	*0*	***30,715***
Norte de Gredos	2013	994	292	226	340	64	1	2	**1,919**
	2014	1,237	447	390	759	153	3	33	**3,022**
	2015	1,174	481	273	942	130	1	12	**3,013**
	Total	*3,405*	*1,220*	*889*	*2,041*	*347*	*5*	*47*	***7,954***
Sierras de Francia, Béjar, Quilamas y el Rebollar	2013	1,116	249	64	269	22	81	1	**1,802**
	2014	1,441	364	140	430	130	1	0	**2,506**
	2015	1,370	397	196	443	100	0	0	**2,506**
	Total	*3,927*	*1,010*	*400*	*1,142*	*252*	*82*	*1*	***6,814***
Montes de Zamora	2013	109	43	50	95	440	0	0	**737**
	2014	64	0	47	248	473	14	0	**846**
	2015	80	0	0	268	339	12	0	**699**
	Total	253	43	97	611	1,252	*26*	*0*	***2,282***

(a): if the picker is in some way linked to the regulated municipalities other than through being a local resident

Source: own elaboration

2.2 Data and model

The model proposed, known as the gravity model or gravity equation model, is based on Newtonian physics. It is based on the force of attraction between two masses, modelled through the universal gravitational equation proposed by the English physicist and mathematician Sir Isaac Newton (1642-1727) in 1687 in his work *Philosophiae Naturalis Principia Mathematica*:

$$F=G*m_1*m_2/d^2 \qquad (1)$$

where G is the universal gravitational constant, m_i the mass of bodies and d the distance separating them.

It was adapted to other disciplines in the late 19th century when Ravenstein (1885) used the gravity equation to explain population migration flows. The forces of push and pull between territories arose because of the differences in living conditions in various areas, where distance acted as a deterrent to migration. This model became widespread in the late 20th and early 21st century in this field (Millinton, 1994, Karemera *et al.*, 2000; Pietrzak *et al.*, 2012; Palmer and Pytliková, 2015).

This tool has also been used to model the movements of other production factors such as international investment flows (Abbott and Vita, 2011; Kersan-Sakabic, 2014) but above all to model commercial bilateral movements between countries (Aitken, 1973; Sapir, 1981; Brada and Mendez, 1985; Yeyati, 2002; Nsiah *et al.*, 2012; Kahouli and Maktouf, 2014). This is where various authors established the sound theoretical microeconomic fundamentals of a market equilibrium model (Anderson, 1979; Bergstrand, 1985). For example, Bergstrand, 1985 develops a general international equilibrium model for trade, resolution of which is based on gravity equation widely used in these empirical studies.

Yet one question that must be borne in mind is whether a well-defined theoretical model to explain commercial movements is able to explain other types of flows such as international tourism (Keum, 2010). Gray (1970) claims that international commercial service transactions may be seen as one specific case within the theory of international trade flows. Said author assumes that the mechanisms governing the goods market at an international scale are the same for the service market, such that the theoretical fundamentals also concur.

Linder's hypothesis (1961) concerning the impact on trade of differences in per capita GDP, as a source of goods trade, would also apply to the trade in services and, therefore, to tourist flows. Such a parallelism led to the general application of the technique in this area to explain both the movement of people for recreational purposes between countries (Socher 1986; Vellas and Becherel 1995; Durbarry, 2000) as well as domestically, as is the case in hand (Eugenio-Martín and Campos-Soria, 2010, Priego *et al.*, 2015). It even holds true for more specific motivations closer to hand such as the topic of the present research, namely rural and nature tourism (Santeramo and Morelli, 2015; Elbeck *et al.*, 2016). In this regard, the strong recreational component of the activity studied evidences the appropriateness of adapting the proposed method to the case study in question. So, only 6.7% of the permits sold in collecting areas in the three years studied were for commercial purposes, with the rest being for recreational purposes.

Moreover, this method has also been used to examine other motivations beyond the tourist and recreational, at both a national and international scale. In research exploring which factors impact on the movements of people, the method has been widely used in areas such as planning transport infrastructure (Wilson, 1967), assessing inflows to shopping centres and malls (Baker, 2000), patient flows between hospitals (Congdon, 2001) or fans attending music concerts (Deichman, 2014).

These distribution models were suggested by Cesario (1973, 1975) to estimate the demand function of natural spaces and the benefits provided to tourists (Cesario and Knetsch, 1976). Drawing on the idea put forward by Hotelling (1949), Cesario developed a model based on the forces of push and pull applied to an open-air recreation system in Pennsylvania (USA) comprising ten counties of origin and five state destination parks. Distance, defined in terms of travel cost and accessibility to the various places, tended to diminish said forces.

Cesario's (1973) adapted distribution model to our setting is structured as follows. Let i denote the nine collecting areas. After purchasing the relevant picking permit, pickers from the 50 Spanish provinces (denoted by j) can access each of them, in a given year t, where t=2013, 2014, 2015. Thus, i represents the collecting areas ("destination" in gravity model terminology), j the picker's province of residence ("origin" in gravity model terminology) and t the collecting season.

In order to model the push forces in each province *j*, we adapt the microeconomic fundamentals of these models posited by Anderson (1979) and Bergstrand (1985). To do this, we consider the population of province *j* in year *t*, measured by the logarithm of the actual number of inhabitants each year ($LNPOP_{jt}$) and per capita income in province *j* in year *t*, calculated based on the logarithm of the gross domestic product in euros per inhabitant ($LNGDPpc_{jt}$). The expected effect of these variables should be positive in line with the theoretical fundamentals of the model and Linder's hypothesis (Anderson, 1979; Bergstrand, 1985). In order to model preferences related to demand for mushroom picking in each province, the number of mycological associations in province *j* in year *t* is also included (MA_{jt}). As with the previous variables, expected sales of permits in a province should be positively related to the provincial preferences towards picking, measured as the number of associations that bring together people with a declared preference for picking that resource (Frutos *et al.,* 2009).

In order to model the pull forces in each collecting area *i*, the initial aspect taken into account is the effect of the expected harvest as a factor which draws pickers to the collecting area in a two-fold sense. The first is the potential production capacity of wild edible mushrooms in a collecting area in each year, measured in terms of yield, in kilograms per hectare, expressed in logarithms ($LNPP_{it}$). A greater expectation of successful picking is assumed to give rise to a greater influx to collecting areas and thus higher sales of permits. The second is the impact of weather conditions in each collecting area *i* on potential production. The fruit-bearing capacity in each mycological season *t* may be influenced by variables such as rainfall in litres per square metre (R_{it}), thermal range between maximum and minimum temperature in degrees centigrade (TD_{it}), mean wind speed in kilometres per hour (WF_{it}) and sub-zero temperatures, measured by the number of days of frost (FD_{it}). As regards the expected signs of the climate variables, rainfall is obviously expected to have a positive impact on fruit-bearing capacity (Büntgen *et al.*, 2015) and, therefore, on the expected harvest and the sale of permits. As for the remaining variables, there is insufficient related literature to predict any given sign, as is commented on in the discussion section.

Each collecting area *i* is also assumed to be able to attract and cater to pickers in terms of providing tourist and hospitality facilities in year *t*, measured by accommodation and restaurants in the year in question (hotels, rural houses, bars, etc.), TE_{it}. Greater provision should attract more pickers, such that there should be a positive relation to the number of permits sold (Frutos *et al.*, 2012).

Finally, in order to model the effect of price as a pull factor on the harvest demand function, the average price of the permits sold, in logarithmic form, in collecting area *i,* in province j, in year *t* (LNP_{ijt}) is taken into account as an explanatory variable. Microeconomics usually predicts a negative relation between price and amount in demand, yet this sign will depend on the type of good or service in question, which might give rise to the corresponding interpretation.

To conclude, another factor taken into consideration is how the distance between the province and the collecting area, measured in kilometres of road from provincial capital j to the main population nucleus in collecting area i, and expressed in logarithms (LND_{ij}), might act as a deterrent on these push and pull forces. In this case, all the related literature predicts a negative relation between distance and inflow and, therefore, the sale of permits.

In order to reflect the possible added effect the collecting area might have on the province in which it is located, a dummy variable taking the value 1 if collecting area i is in province j and zero otherwise ($INCLUSION_{ij}$) has been included. Inclusion would also imply greater inflow to the picking area with the expectation of a positive sign.

Unobserved year-specific effects are controlled by two year dummies for 2014 and 2015. Those variables take value 1 for the corresponding year and 0 otherwise.

As a result, the total amount of harvesting permits sold for collecting area *i* in province *j* during year *t* ($LNSP_{ijt}$), expressed in logarithms, could be modelled following the gravity equation, as follows:

$$LNSP_{ijt} = \beta_0 + \beta_1\, LNPOP_{jt} + \beta_2\, LNGDPpc_{jt} + \beta_3\, MA_{jt} + \beta_4\, LNPP_{it} + \beta_5\, R_{it} + \beta_6\, TD_{it} + \beta_7\, WF_{it} + \beta_8\, FD_{it} + \beta_9\, TE_{it} + \beta_{10}\, LNP_{it} + \beta_{11}\, LND_{ij} + \beta_{12}\, INCLUSION_{ij} + \beta_{13}\, 2014_t + \beta_{14}\, 2015_t + \nu_{ijt}$$

where ν_{ijt} is a composite error term, defined as $\nu_{ijt} = \mu_{ij} + \varepsilon_{ijt}$. μ_{ij} captures the unobserved heterogeneity across collecting areas and provinces, i.e. the collecting area-province specific effects, and ε_{ijt} the idiosyncratic error term. We assume that $\mu_{ij}\sim(0,\sigma_u^2)$ and $\varepsilon_{ijt}\sim(0,\sigma_\varepsilon^2)$.

Various sources of information were taken into account when gathering data. Data concerning the number of permits issued and their price during the period studied (2013-2015) in the different collecting areas were provided by the managing agency (Micocyl), which has a database linked to the online platform that handles the sales of permits and contains information regarding the number, type and payment per harvesting permit, as well as information such as the picker's home town (www.micocyl.es).

Data on mushroom production were provided by MicodataSIG, an expert model based on the analysis and weighting of the presence and abundance of wild edible mushrooms compared to the features of the National Forest Map, Soils Map and Spanish Climate Map (Martínez-Peña *et al.,* 2012).

Weather data were gathered as means of the values recorded at the weather stations in the National Meteorology Agency and located inside the boundaries of the collecting areas. Population and per capita income data were obtained from the National Institute of Statistics. Information concerning tourist facilities was obtained from the Statistics Information System, part of the Regional Government of Castilla y León. The list of mycological associations was obtained by consulting the main web addresses in the sector. Finally, data concerning distance were gathered from the CartoCiudad System ("CityMap System").

The appendix provides the main statistics concerning the variables included in the model. As can be seen, the sample is an unbalanced panel of 607 observations. As mentioned earlier, there are no data available for 2013 corresponding to Montes de Oca because this collecting area came into operation in 2014. In addition, not all the provinces are linked to all the collecting areas and to all the years.

3. Results

The panel data model specified can be estimated by three different methods: pooled ordinary least square (OLS), fixed effects estimator (FE), and random effects (RE) estimator. The fixed effects estimator will not work well for data for which within-cluster variation is minimal or for slow change over time (Wooldridge, 2010) since the key insight is that if the individual unobserved heterogeneity (in our case, the area-province specific effect) does not change over time, then any change in the dependent variable must be due to influences other than these fixed characteristics (Stock and Watson, 2012). One limitation of the fixed effects estimator is also that the time-invariant variables are dropped and their coefficients are not identified. Therefore, we would not be able to estimate the effect of variables whose values do not change over time (Cameron and Trivedi, 2005). In the model, these variables are the distance between the province and the collecting area and the number of mycological associations in each province. For these reasons, we only obtained pooled ordinary least squared and random effects estimates. The results are reported in Table 3. In both regressions, in order to have valid statistical inference, panel-robust standard errors are calculated using the cluster-robust covariance estimator, treating each pair ij as a cluster and without assuming specific functional forms for either serial correlation or heteroskedasticity (Wooldridge, 2010).

Both regressions provide similar results in terms of the estimates found and the goodness of fit indicators (R2 and F/Chi2). To choose between OLS or RE effects regressions, we run the Breusch and Pagan Lagrangian multiplier test (LM). The null hypothesis is that variance across collecting areas and provinces is zero $\left(\sigma_u^2 = 0\right)$. In other words, there is no significant difference across units ($\mu_{ij} = \mu$). The LM statistic [206.8; p-value=0.00] rejects the null hypothesis and concludes that random effects regression is preferred.

Table 3. Panel data regression results for the log of the number of permits issued (2013-2015)

Variable	Pooled Ordinary Least Squared (OLS)		Random Effects (RE)	
	Coefficient	Standard Error[a]	Coefficient	Standard Error[a]
LNPOP	0.778***	0.0524	0.733***	0.0769
LNGDPpc	2.176***	0.2575	1.993***	0.3800
MA	-0.005	0.0108	0.001	0.0180
LNPP	0.496***	0.1316	0.323**	0.1297
R	0.004***	0.0003	0.002***	0.0003
TD	-0.270***	0.06135	-0.207***	0.0588
WF	-0.265***	0.0209	-0.133***	0.0223
FD	0.039***	0.0065	0.024***	0.0045
TE	0.004***	0.0004	0.004***	0.0005
LNP	-0.295**	0.1042	-0.393***	0.0981
LND	-2.112***	0.0882	-1.898***	0.1337
INCLUSION	2.786***	0.2876	2.769***	0.4834
2014	0.470**	0.1544	0.529***	0.0852
2015	0.239*	0.1315	0.455***	0.0892
Constant	-15.314***	2.8427	-15.260***	4.0206
N	607		607	
R2	0.78		0.75	
F/Chi2	166.804 [p-value=0.00]		893.4 [p-value=0.00]	
Rho			0,77	
Breusch-Pagan Test for RE vs Pooled (LM)			206.83 [p-value=0.00]	

(a) Robust standard errors to heteroskedasticity and serial correlation.
(b) * p-value<0.10, ** p-value<0.05, ***p-value<0.001

Turning to the estimates of the coefficients, all the selected variables apart from the number of mycological associations[2] proved significant. Moreover, the vast majority showed significance levels above 99%. In addition, all the economic variables in the model displayed the sign expected by economic theory. Specifically, population, income, productivity, facilities and inclusion evidenced a direct link to the sale of permits. This behaviour can also be seen for the variables related to the unobserved specific annual effects. Contrastingly, the number of permits and distance showed an inverse relation. As regards weather variables, as expected, rainfall displayed a direct link to the sale of permits as did the number of days of frost. In contrast, both thermal range and wind evidenced an inverse relation.

[2] This result is in line with those obtained by Frutos *et al.* (2009). This lack of significance might be related to the quality of the data used. It is the only variable not taken from either the management collecting areas or from official sources. However, there is no alternative source for modelling pickers' preferences by provinces.

Coupled with the model's good overall fit, all of the above indicate that the model proves valid as a means of interpreting the information generated in the terms posited in the following sections.

4. Discussion

With regard to push factors, the most relevant information for the managers of collecting areas concerns the discussion related to values corresponding to demand elasticities[3]. As regards price elasticity (LNP), the demand function for harvesting permits proved to be inelastic, such that the price effect is more important than the effect of the number of permits. This finding is in line with what tends to occur with tourist demand as a whole, the absolute values of which are usually in the range 0.5-1 (Álvarez *et al.*, 2015). The results obtained show even lower values (0.295 and 0.393), which might be related to the small percentage this expenditure represents out of the picker's total final spending. This is very similar to what occurs in other leisure travel sectors that also involve paying an admission price, such as a visit to a museum (O,Hagan, 1995). Thus, although demand may be extremely sensitive to the total amount spent on a trip, it is scarcely noticeable in terms of admission price, or the cost of the harvesting permit in this case (Frey and Meyer, 2006).

As regards income elasticity (LNGDP), its value is positive, reflecting that demand for this activity may be deemed normal. The fact that it is above one indicates that the spending associated to picking increases more than proportionally with the increase in income, such that activities of this nature carry ever-increasing weight in pickers' budgets. Its behaviour would thus be similar to other activities related to leisure that might be deemed luxury goods from the standpoint of economic theory, and which consumers with a medium to high level of income engage in (Heilbrun and Gray, 1993). For instance, values close to 2, estimated in this study, are very similar to those reported by Vicente and Frutos (2011) for visits to a temporary exhibition of ecclesiastical

[3] For log-transformed variables, the estimated coefficient is interpreted as an elasticity, i.e. it indicates the percentage variation in permits sold following a one per cent increase in the explanatory variable, whereas for non-log-transformed variables the estimated coefficient is interpreted as a semi-elasticity, i.e. it indicates the percentage variation in permits sold following a 1-unit increase in the explanatory variable.

art in Spain (1.8). Santeramo and Morelli (2015) also reported income elasticities above one (1.4) in rural tourism flows in Italy.

There is also a positive relation between the size of the markets (LNPOP) and the sale of permits. Nevertheless, the link between the sale of permits and the population of the various provinces proved to be inelastic (0.778 and 0.773). As a result, the sale of permits grows less in percentage terms with regard to the size of the population. Confirmation of this finding is to be found in the work of Priego *et al.* (2015). In their study of domestic tourism flows in Spain at a provincial level and the link to climate change, said authors reported population elasticity values identical to those found in the present study, with values of 0.745 and 0.749 (depending on the specifications). Very similar values can be found in Elbeck *et al.* (2016) in their study of eco-tourism in rural areas of Uzbekistan, with a unitary elasticity demand. This finding might be reflecting different attitudes towards picking between those who live in less densely populated areas and those who live in major cities. Exploring these differences might provide valuable information for managers when interpreting possible changes in the inflow of pickers to collecting areas related to changes in population distribution patterns.

Continuing with the issue of pull factors, the potential productivity of collecting areas (LNPP) emerges as a significant pull factor. Expecting a good harvest influences a picker's decision concerning which collecting area they opt to visit and to buy the permit for. In this case, the demand function for permits also displays a value that is inelastic to productivity. This rigid demand might be related to the fact that the commercial or self-consumption component of mushroom picking is becoming increasingly less important compared to the recreational element (Frutos *et al.*, 2016), such that expectations regarding the harvest have only a limited impact on the sale of permits. As expected, weather variables have a significant effect on the sale of permits since they prove determinant in terms of the fruit-bearing capacity of the wild mushrooms, particularly when it comes to rainfall and temperature (Büntgen *et al.*, 2015, Taye *et al.*, 2016). Changes in climatic conditions have a major bearing on the distribution of species (Root *et al.*, 2003) and, therefore, on harvest yields (Alday *et al.*, 2017). This would explain the positive link between the sale of permits and rainfall (R) in the corresponding season. In contrast, the range between maximum and minimum temperatures (TD) has a negative impact on fruit-bearing capacity. This variation is greatest on clear days (no rainfall) and during anticyclones with strong temperature inversions, which does not favour the fruit-bearing capacity of fungal species (Büntgen *et al.*, 2015).

Interpreting in climate terms the sign of the coefficient on frosty days (FD) proves more complex, since there is a positive relation between the number of days with frost during the season and the sales of permits, which would seem to contradict the above-mentioned relation. The explanation behind this might be more closely linked to the notion of consumer satisfaction. In this case, a frosty autumn evening means a sunny, mild and wind-free following day, thus making the experience of picking mushrooms more pleasant and boosting the sales of permits. The same explanation might be posited between wind speed (WF) and the experience of picking, such that there is a negative relation. Thus, the more unpleasant the weather conditions, measured in terms of wind speed, the less enjoyable the experience and the fewer the number of permits sold.

To conclude the pull factors, the tourist endowments of the collecting areas (TE) also exert a significant and positive influence on the sale of permits. The impact of picking wild edible mushrooms on rural economies, through the activity's ability to drive the tourist sector, has been studied by Frutos *et al.* (2012). Said work posited the key link between the number of overnight stays pickers made and the impact on the economy and employment. Once again, findings show how tourism and mushroom picking are closely linked. This underscores the idea of a shift away from picking for commercial and self-consumption purposes towards picking that is more focused on the notion of tourism and leisure.

The distance variable (LND) also displays elastic behaviour in relation to the sale of permits (2.1 and 1.8). These values are virtually identical to those obtained by Keum (2010) in the gravitational study of tourist flows in Korea (1.97, 1.99 and 2.07, depending on specifications). The sale of permits thus falls in a greater proportion than the kilometres travelled by pickers. This would reflect the fact that mushroom picking in collecting areas follows extremely important proximity patterns. Such a finding is further evidenced by the significance of the INCLUSION variable. Thus, in provinces with collecting areas, the models estimate that almost three times as many permits are sold than in the rest. In this case, having strong ties with the area would be a very important pull factor in the picking of wild edible mushrooms. Another fact to account for this behaviour is the substantial increase in travel costs after a certain distance, related to overnight stays and associated expenses (Vicente and Frutos, 2011)

Finally, the positive values of the seasonal variables (2014 and 2015) indicate that each year substantially more permits are sold in the collecting areas, regardless of the remaining explanatory variables. Thus, for example, and in the eyes of the experts, the 2014 season was deemed exceptional in production terms compared to 2013, which was rated as average, with 2015 also again being deemed average (Alday, *et al.,* 2017). Despite this, the seasonal variables indicate that the sale of permits continues to rise.

5. Conclusions

Using the gravity equation, the present study models, for the first time, the push and pull factors related to picking wild edible mushrooms. Results provide abundant information that might aid the decision making of those responsible for managing the resource. In this vein, the model confirms the results obtained by other authors regarding the changes that are leading to this activity being undertaken less from the quantitative perspective and related to the amount harvested, towards a more qualitative approach, linked to the leisure experience. Consequently, a constant and sustained growth in demand for harvesting is to be expected resulting from changes in pickers' preferences. This might jeopardise the preservation of the species, which would ultimately prove detrimental to the main goal of mycological management, namely the environmental sustainability of mushroom picking. It is therefore necessary to implement models to regulate picking and that set out the limits (maximum number of permits), maximum amounts, and minimum sizes, coupled with close monitoring and strict control.

In the short term, we feel that those responsible have the necessary tools to cope with this greater demand, and which might be offset by increased prices for the permits sold. This would have a two-fold positive effect. Firstly, it would relieve the pressure on harvesting by reducing the number of permits sold.

Secondly, results have shown that, if implemented, the regulatory system might boost total revenue, with the extra revenue being used to improve the forest status, thus making it more sustainable.

This strategy of setting prices is compatible with the system of price discrimination already implemented by managers. Results also show that the sale of permits at different prices depending on the picker's place of origin is the right approach and would continue, if possible, more intensely. It is important to try to balance the often difficult relationship between local and outside pickers. The former, who tend to have more deeply ingrained views regarding ownership rights linked to accessing mushrooms, would be made to feel that the regulatory system is in their best interests. This would help create a favourable climate amongst the local population who would come to see the regulatory system as something that safeguards the long-term conservation of this traditional asset. In this regard, price discrimination, together with additional training and awareness-raising, would help to generate a favourable disposition. Demand inelasticity regarding the size of the destination markets might help maintain such a strategy.

In the long run, the important link between the sale of permits and the productivity of the collecting areas supports the idea that the regulatory system should be grounded on environmental policy. The competent authorities must be able to adopt the measures required to safeguard this productivity by applying the appropriate silviculture management techniques. Should they fail to do so, sales of permits would be affected as would the regulatory system itself. As has been amply highlighted throughout the present research, issues concerning regulatory control of picking and environmental management should not be approached separately. Several authors have shown that careful collection of fungal species fruit bodies (carpophores) need not affect future production (Egli et al., 2006; Parladé et al., 2017). However, in line with the principle of prudence, access and collection limits have been established in many regions, together with awareness-raising campaigns in order to educate society on good collecting practices and reduce the collecting pressure in mushroom-producing forests (Martínez-Peña et al., 2017). It is therefore useful to develop mushroom collecting control models, and other monitoring indicators that provide insights into the future consequences of such activities.

These strategies should go hand in hand with other management policies such as those related to tourism. The link between the provision of infrastructure for general tourist use in rural areas and the sale of permits supports the idea that mushroom picking might help to offset one of the major weaknesses inherent in the sector; namely its seasonality. Thus, the body responsible for managing mycological regulation, the regional government that has official powers over tourist activities, and the professional associations that merge the sector's interests, should work hand in hand to explore the fresh business opportunities to emerge from the growing mycotourism industry. For instance, the results obtained indicate that the supply of tourism in rural areas should increase in line with the sale of permits. Interpreting the value of the semi-elasticity presented might serve as a guide for these groups vis-à-vis planning this development in an organised fashion. As a result, multidisciplinary management should go hand in hand with a system for generating information so as to support efficient decision making.

We should also not overlook other policies that must adapt to the likely increase in this activity such as infrastructure policy for planning controlled and environmentally sustainable access to collecting areas, regional policy and management of European regional development funds such as LEADER, whose scope of action includes these areas. Education policy, in its environmental aspect, is another area to be considered, and indeed certain local action groups have already seen this as an opportunity to raise awareness amongst future generations with regard to mushroom picking that is environmentally sustainable in the long term.

As regards future lines of research, it is necessary to explore in greater depth the changes in pickers' preferences. One limitation of the present research is that it has been unable to model such preferences suitably and, therefore, has failed to provide information that may be interpreted in terms of proposals for management measures. Future lines of research should thus examine which factors impact on the actual harvesting experience. Analysing the profile and motivations of the pickers emerges as a basic tool for devising future management strategies.

Another limitation of the present study is the model's inability to explain factors such as the impact of illegal picking, the opportunity costs of picking in non-regulated areas, the types of species harvested or complementary activities that pickers might engage in when visiting the collecting areas. Creating and including in the model certain variables that reflect surveillance, the percentage of regulated area, etc. also emerge as future lines of research to be taken into account that might help to improve the explanatory capacity of the push and pull factors of the model presented. Finally, the authors are aware that the regulated area of wild edible mushrooms in Castilla y León accounts for approximately a quarter of the total accessible and public production area. The general equilibrium model presented is therefore the best that could be applied given the available data. It might thus prove interesting to explore whether the push and pull factors modelled in the present research would behave in the same manner were the whole of the area susceptible to regulation to be taken into consideration.

In sum, improvements in both the quantity as well as quality of the existing information would help to enhance the explanatory power of the model presented, since no other no substantial restrictions have been found in the method related to other issues. The authors thus feel that this method could be adapted to explore other areas related to the use and enjoyment of natural resources in the case of wild edible mushrooms.

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Appendix

Table A1. Descriptive Statistics of dependent and independent variables of the panel data model[(a)]

Variable		Mean	Std. Dev.	Min	Max	Observations
LNSP	overall	2.45	2.35	0.00	10.03	N = 607
	between		2.19	0.00	9.92	n = 286
	within		0.45	0.18	3.99	T = 2.12
LNPOP	overall	13.35	0.99	11.35	15.69	N = 607
	between		0.98	11.35	15.68	n = 286
	within		0.05	12.40	13.84	T = 2.12
LNGDPpc	overall	9.98	0.21	9.63	10.41	N = 607
	between		0.20	9.63	10.41	n = 286
	within		0.01	9.93	10.09	T = 2.12
MA	overall	6.15	5.99	0.00	28.00	N = 607
	between		5.51	0.00	28.00	n = 286
	within		0.00	6.15	6.15	T = 2.12
LNPP	overall	1.32	0.65	0.45	2.16	N = 607
	between		0.62	0.45	2.16	n = 286
	within		0.06	1.04	1.54	T = 2.12
R	overall	625.19	213.68	280.75	1023.20	N = 607
	between		196.53	280.75	1023.20	n = 286
	within		106.84	371.39	819.09	T = 2.12
TD	overall	12.33	1.43	8.14	14.13	N = 607
	between		1.51	8.14	14.13	n = 286
	within		0.27	11.78	12.94	T = 2.12
WF	overall	20.05	2.93	16.99	28.29	N = 607
	between		2.79	16.99	27.20	n = 286
	within		1.07	15.81	25.66	T = 2.12
FD	overall	67.57	16.55	26.00	88.00	N = 607
	between		16.59	26.00	88.00	n = 286
	within		6.56	53.57	80.90	T = 2.12
TE	overall	276.05	177.22	14.00	488.00	N = 607
	between		175.29	14.00	477.67	n = 286
	within		6.03	259.39	291.39	T = 2.12
LNP	overall	2.21	0.61	1.10	5.52	N = 607
	between		0.60	1.10	5.52	n = 286
	within		0.21	1.31	3.66	T = 2.12
LND	overall	5.70	0.74	3.30	7.57	N = 607
	between		0.71	3.30	7.57	n = 286
	within		0.00	5.70	5.70	T = 2.12
INCLUSION	overall	0.04	0.21	0.00	1.00	N = 607
	between		0.18	0.00	1.00	n = 286
	within		0.03	-0.29	0.71	T = 2.12
2014	overall	0.38	0.48	0.00	1.00	N = 607
	between		0.31	0.00	1.00	n = 286
	within		0.43	-0.12	1.04	T = 2.12
2015	overall	0.36	0.48	0.00	1.00	N = 607
	between		0.30	0.00	1.00	n = 286
	within		0.43	-0.14	1.03	T = 2.12

[(a)] Each variable (X_{ijt}) is decomposed into a between ($\overline{X}_{ij}$) and within (X_{ijt}-$\overline{X}_{ij}$+$\overline{\overline{X}}$). The overall and within statistics are calculated over 607 collecting area-province-year observations and the between statistics are calculated over 286 collecting area-province observations, with 2.12 being the average number of years that a combination of collecting area-province is observed.