The impact of pharmacy deregulation process on market competition and customers' accessibility. Insights from the case of Navarre Region in Spain.

Ilaria Barbarisi[1], Javier Elizalde Blasco[2], Giuseppe Bruno[1], Antonio Diglio[1], Carmela Piccolo[1]*

[1] Department of Industrial Engineering (DII),
Università degli Studi di Napoli Federico II,
Piazzale Tecchio, 80
80125 Naples, Italy

[2] Facultad de Ciencias Económicas y Empresariales.
Universidad de Navarra

*Corresponding author

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1. Introduction

In most European countries the retail pharmacy market is regulated with the aim of guaranteeing some objectives of accessibility, equity, efficiency and quality of services. Regulations, which widely differ across countries, usually regard conditions for opening a pharmacy (entry barriers), the location of the stores, the ownership, the possibility of vertical integration between wholesale pharmaceutical companies and drugstores and the distribution of pharmaceuticals in other typologies of shops.

In many cases, the regulation for the establishment of new pharmacies combines demographic (e.g. maximum number of pharmacies per inhabitants) and geographic (e.g. minimum distance among pharmacies) criteria, with the aim of guaranteeing accessibility to medicine products for the entire population, while preserving at the same time adequate market niches to the pharmacists. In the last years, many countries started to adopt, at different levels, policies aimed at promoting the competition in the sector. In this context, the restrictions for the release of licences for new openings were progressively relaxed, with the consequence of a significant increase in the number of facilities.

In Italy, the Law Decree n.1/2012 introduced several novelties in this field. In particular, it reduced to 200 meters the minimum distance among pharmacies and made less restrictive also the demographic constraints. Indeed, the old limit of one pharmacy per 5000 and 4000 inhabitants for rural and urban areas, respectively, passed to one pharmacy per 3300 inhabitants. Moreover, it was left to regional authorities also the possibility to open further stores in high attractive venues (e.g. train stations, airports, shopping malls), up to a maximum of 5% of the total number of ordinary facilities (Garattini et al., 2012).

In the case of Spain, the restrictions first introduced in 1941 were modified in June 17th1996, through the Decree-Law 11/1996. It established general geographic and demographic rules valid at national level (i.e., minimum distance of 250 meters among pharmacies and one pharmacy per 2800 inhabitants) but it transferred the right to the Autonomous Communities to modify such rules in order to take better into account the specific conditions of their territories. After such measures, the most relevant deregulation episode took place in the Community of Navarre, through the Ley Foral 12/2000 de Atención Farmacéutica. The law reduced the minimum distance among drugstores to 150 meters and the population rule to one pharmacy per 700 inhabitants in the whole autonomous community. This new rule induced a dramatic entry process, almost doubling the overall number of pharmacies in Navarre. In Pamplona, the capital of the region, it passed from 119 in 2000 to 206 in 2017 (Elizalde et al., 2015).

In this work, we analyze how the deregulation process that took place in Spain, affected the accessibility of users and the competition in the market. In particular, we assess, through the use of quantitative and spatial analysis, the entry process of new drugstores, which took place in Pamplona in the time span 2001—2017. Then, we propose alternative strategies, based on the use of a mathematical model, for the regulation of the market, aimed at guaranteeing accessibility and equity for users but at same time at containing the potential cannibalization effect among competing drugstores.

2. Methodology and contribution

The debate on the potential effects of deregulation in the pharmaceutical sector on users' accessibility is attracting a growing attention, both in the scientific and civil community. Using comparative case studies among three highly liberalized (Ireland, Netherlands and Norway) and three highly regulated European countries (Austria, Finland and Spain), ÖBIG (2006)'s report "comes to the conclusion that deregulation […] has not met the expectations", arguing that increasing competition and cost-containment are not observed in the deregulated markets while deregulation has increased clustering of pharmacies in urban centers with disregard for rural areas. Then, urgent policies are required to avoid under provision in remote areas to avoid a decline in public health in those areas.

Almarsdóttir et al. (2000, b) and Anell (2005) analysed the main consequences of the liberalization process in Iceland and Norway, that in 1996 and 2001 relaxed restrictions on ownerships of drugstores and competition. While in Norway an increased accessibility was experienced by a large part of the population, in Iceland it was mainly restricted to Reykjavik and, by contrast, most of rural areas were interested by a reduction in the accessibility to retail pharmacy services. On the basis of users' perception after the reform, also Almarsdóttir et al. (2000, a) confirmed that the liberalization in Iceland increased inequalities between rural and urban areas.

Through a comparative analysis of the highly regulated market in Spain and the much less restricted system in the UK, Lluch and Kanavos (2010) concluded that the goal of efficiency is better obtained through a less regulated system (with ownership liberalization and OTC price freedom) while the goals of equity and accessibility are better obtained through a more regulated market, where conditions to open new pharmacies are based on geographic, demographic and needs-based criteria.

Vogler et al. (2014) extended the comparison of the pharmacy systems to 9 European countries (less and more regulated), on the basis of data collected by literature reviews, a questionnaire survey and interviews. They confirm that access to pharmacies usually increases after a deregulation but it is likely to favor urban populations. They reccomend policy makers to take actions to take actions to ensure equitable accessibility and sustainable competition in a more deregulated environment.

Most of the papers proposed in literature confirm that liberalization of the pharmaceutical markets has not produced the expected results, in terms of users' accessibility, and that in many cases it has exacerbated the differences among and rural areas. Moreover, there is also a general consensus on the complexity of managing reforms in this sector, due to the need of combining conflicting objectives (efficiency vs accessibility). However, few studies have provided insights and practical indications to policy makers on alternative mechanisms to regulate the sector.

In this work, we focus on the regulation criteria related to the establishment of new pharmacies and we show, through a real case study, how their relaxation and the consequent increase of drugstores may produce undesirable effects, both on users and on the competition. In particular, we propose a mathematical model that optimally locates new drugstores in a given location space, according to some requirements defined by a central decision maker (the regulator), with the objective of guaranteeing a more equitable access of users to the service and, at same time, of mitigating the cannibalization effect. This way, we aim at testifying that a deeper spatial analysis of the area under analysis and the use of appropriate methodologies may help policy makers in defining more effective regulation mechanisms and in producing more equitable scenarios.

In order to formulate the model, we refer to the class of *Facility Location Models* (FLMs), that is traditionally used to address problems related to the territorial organization of private and public services (Laporte et al., 2014). A FLM is aimed at identifying the best position to assign to one or more structures (facilities), in a given location space, in order to satisfy a demand (actual or potential), according to some objectives to be optimized and constraints to be satisfied. In literature, a wide range of application areas have been identified, both in the context of public and private sector. In the applications related to public sector, the main issue is to combine efficiency goals with the need of guaranteeing a good and equitable access of users to the provided services (Marianov et al., 2002; Barbati and Piccolo, 2016; Bruno et al., 2016). While in the context of private sector, models explicitly incorporate the fact that other facilities are already (or will be) present in the market and that the new facilities will have to compete with them for their market share (Plastria, 2001). In the case under analysis, the model should have to combine characteristics of both classes of models, as the competition among drugstores is mitigated by the rules fixed by a centralized decision maker, that has to guarantee equity and accessibility objectives, similarly to what happens in the public sector.

3. The effects of the deregulation process in Spain

3.1 The Regulation of the pharmaceutical sector in Spain

In 1996, the Decree-Law 11/1996 introduced new geographic and demographic criteria for the opening of new pharmacies in Spain (i.e., minimum distance of 250 meters among pharmacies and one pharmacy per 2800 inhabitants). The criteria were valid at national level, but the right of modifying such rules was left to the Autonomous Communities, in order to better take into account specific geographical and demographical conditions. In Table 1, the values fixed by each Spanish Autonomous Community for the demographic and geographic criteria are reported.

Autonomous Communities of Spain	**Capital**	**Population**	**Area**	**Minimum Population per Drugstore**	**Minimum Distance Among Drugstores**
		(Inhabitants) (a)	**(km^2) (b)**	**(Inhabitants) (c)**	**(m) (d)**
Andalusia	Seville	8.388.107	87,3	2.800*	250*
Aragon	Zaragoza	1.308.563	47,7	2.600	250*
Asturias	Oviedo	1.042.608	10,6	600	250*
Balearic Islands	Palma	1.107.220	5,0	2.800*	250*
Canary Islands	Santa Cruz de Tenerife and Las Palmas	2.101.924	7,4	2.800*	250*
Cantabria	Santander	582.206	5,3	2.800*	250*
Castile and Leòn	Valladolid	2.447.519	94,2	2.500	250*
Castilla-La Mancha	Toledo	2.041.631	79,5	1.800	250*
Catalonia	Barcelona	7.522.596	32,1	4.000	250*
Community of Madrid	Madrid	6.466.996	8,0	2.800*	250*
Estremadura	Mérida	1.087.778	41,6	500	250*
Galicia	Santiago de Compostela	2.718.525	29,6	2.800*	400
La Rioja	Logroño	315.794	5,0	2.800*	250*
Navarra	Pamplona	640.647	10,4	700	150
Region of Murcia	Murcia	1.464.847	11,3	2.800*	250*
Basque Country	Vitoria-Gasteiz	2.189.534	7,2	3.200	250*
Valencian community	Valencia	4.959.968	23,3	2.800*	250*
***communities that have receipied the criteria fixed at national level**					

Table 1 – Territorial Organization Requirements for the activation of a new drugstores for each Autonomous Community

It can be noticed that while some communities (highlighted in grey) have just implemented the indications fixed at national level, some others introduced different threshold values. Among these latter, the Navarre Region represents the most representative case, as it reduced the minimum distance among drugstores to 150 meters and the population rule to one pharmacy per 700 inhabitants. This new rule induced a dramatic entry process, almost doubling the overall number of pharmacies in Navarre, as indicated in Figure 1. In Pamplona, the capital of the region, it passed from 119 in 2000 to 202 in 2017 (Elizalde et al., 2015).

As opposed, the case of Catalonia appears to be one of the most regulated, as it implemented the dispersion requirement fixed at national level (i.e. a minimum distance of 250 meters among drugstores) but it increased the demographic criteria from 2800 to 4000 inhabitants. By comparing Pamplona with the city of Sabadell in Catalonia, that has approximately the same population (197.604 vs 206.556 respectively) and extension (23,55 vs 38,00 km^2), we can notice how the number of active drugstores in 2017 is remarkably different, 202 against 68 (Figure 2).

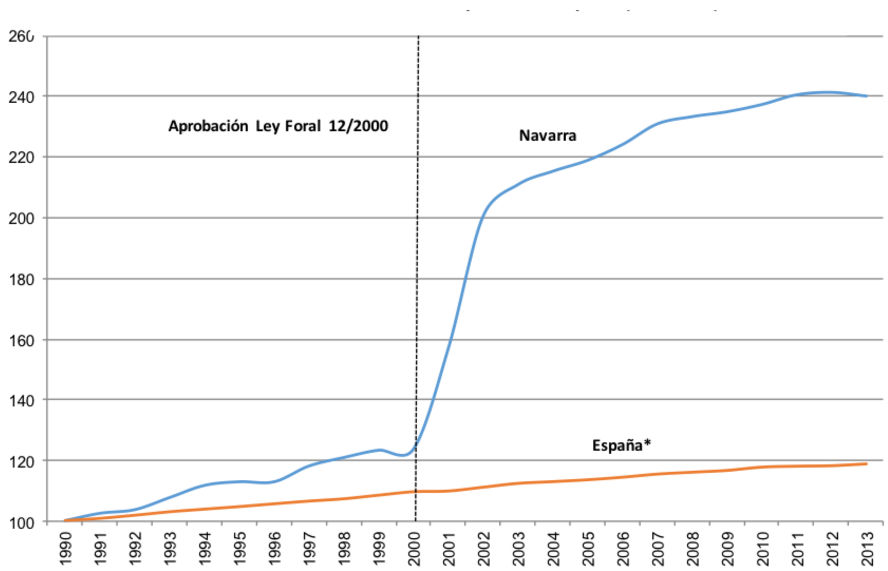
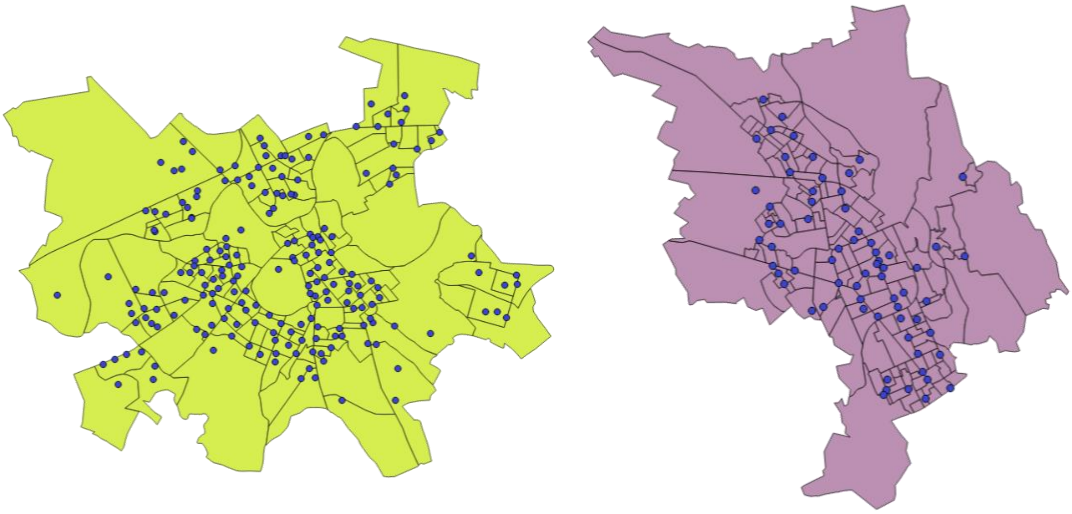


Figure 1 – Trend of drugstore numbers in Navarre Region and Spain (1990-2013)



Number of drugstores = 202 **Number of drugstores = 68**

(a) Pamplona (Navarre) **(b) Sabadell (Catalonia)**

Figure 2 – Drugstore Locations in two cities belonging to different Spanish Autonomous Communities (2017)

2.2 The case of the city of Pamplona

In this section, we analyze how the deregulation process above described affected the accessibility of users to the services provided by drugstores and the competition in the market, in terms of cannibalization of potential customers.

At this aim, we focused on the case of the Community of Navarre, as in this area the deregulation process took place with a stronger pace compared with the others. In particular, we analysed the case of its capital, the city of Pamplona, which counts 197.604 inhabitants and an area of 23,55 km^2(INE, 2017). From an administrative point of view, the city is partitioned in 8 districts, in turn subdivided in 137 census tracts (Figure 5a).

The entry process, which took place in the time span 2000—2017, was first analysed by considering the sets of open drugstores J_t at the end of each year t (t ∈ $\{2000, \dots, 2017\}$). Figure 4 shows the evolution of the overall number of drugstores in the considered time span ($|J_t|$) while Figure 5 shows the locations of pharmacies in the last year, by distinguishing among the ones already located in 2000 and the new ones.

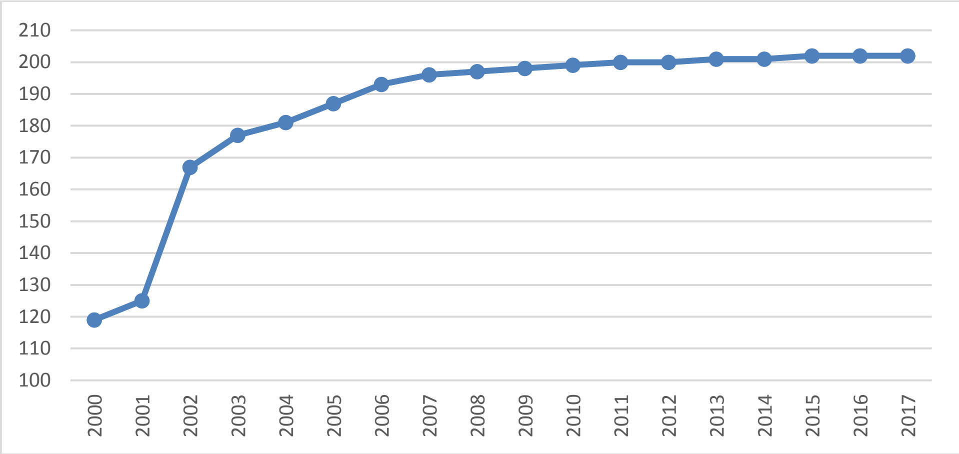


Figure 3 – Number of drugstores in the time span 2000-2017

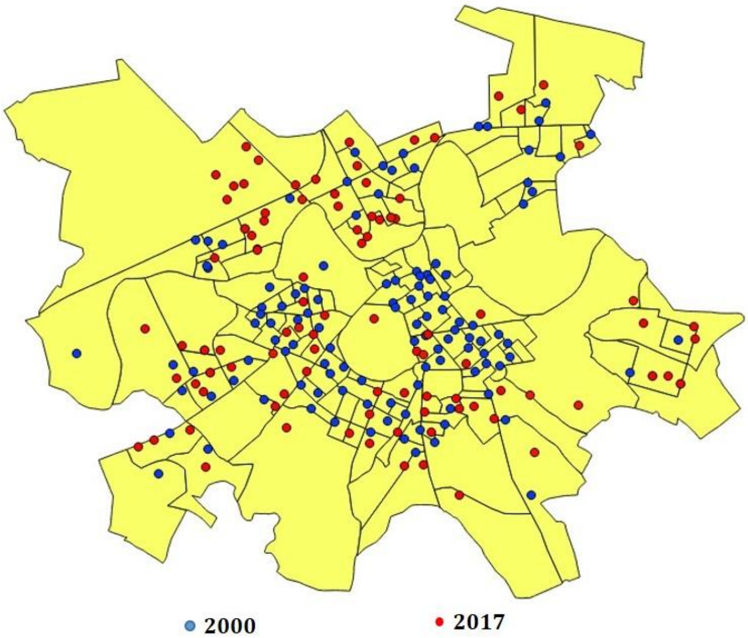
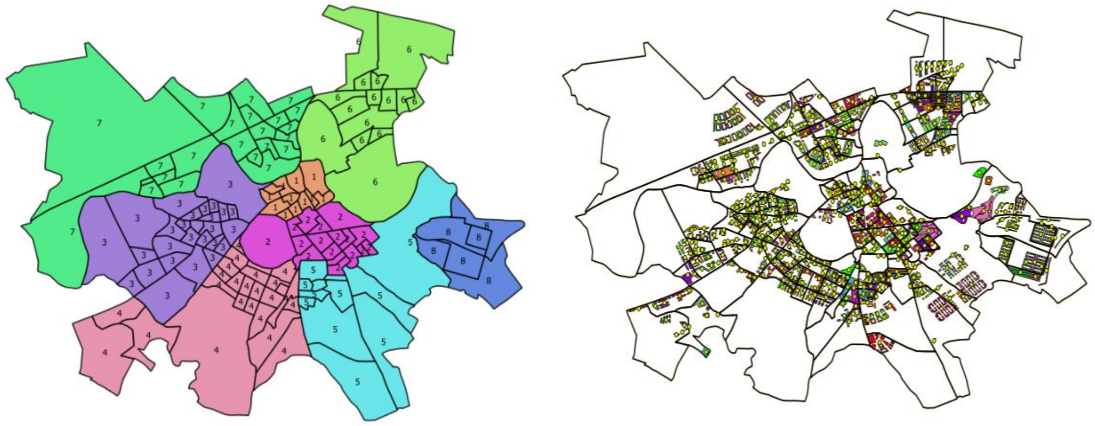


Figure 4 – Locations of drugstores in Pamplona

In order to effectively represent demand distribution, we referred to Municipal Plan of the Pamplona City Council (Ayuntamiento de Pamplona, 2017 - https://sig.pamplona.es/), that reports the information related to the urban land classification of the city. In particular, we first selected the residential elementary areas throughout the city (4828) and, then, we aggregated them in 497 territorial units, according to a specific methodology that takes into account their geographic proximity and their belonging census tract. We finally assumed that all the population living within each unit $i \in I$ ($I = \{1, \dots, 497\}$) is concentrated in its centroid (Figure 5b).



a) Census Tracts and Districts **b) Territorial Residential Units**

Figure 5 – Pamplona city

In order to analyse the interaction of such facilities with potential customers, we assumed that all pharmacies are indistinguishable to consumers in terms of attractiveness and perceived quality. Therefore, we may reasonably assume that users patronize their closest facility and we adopt the minimum distance as a proxy of their accessibility. This means that, by denoting with d_{ij} the distance between the centroid $i \in I$ and the generic drugstore location $j \in \bigcup_t J_t$, in terms of shortest pedestrian path on the road network, the accessibility of a generic customer i to the drugstore network in period t is given by $d_{it}^{min} = \min_{j \in J_t}\{d_{ij}\}$. In Figure 6, the cumulative distributions of such minimum distances $\{d_{it}^{min}\}$ in the years 2000 and 2017 are shown and compared. In particular, for each year t, the percentage of the population α_t having a distance from the closest facility not exceeding d_i^{min} has been reported ($\alpha_t = F^{-1}(d_{it}^{min})$). As expected, the accessibility condition of users in 2017 results significantly improved if compared with the situation in the base year 2000, as the line in red moved on the left side with reference to the blue one. However, it is worthy to underline that the situation improved especially for those consumers already characterized by a good accessibility. Indeed, while the percentage of population within 200m from the closest drugstore passed from an initial value of 63% to a final one equal to 83%, the fraction of population characterized by a distance over 600m slightly decreased and the maximum distance remained the same, equal to 1560m.

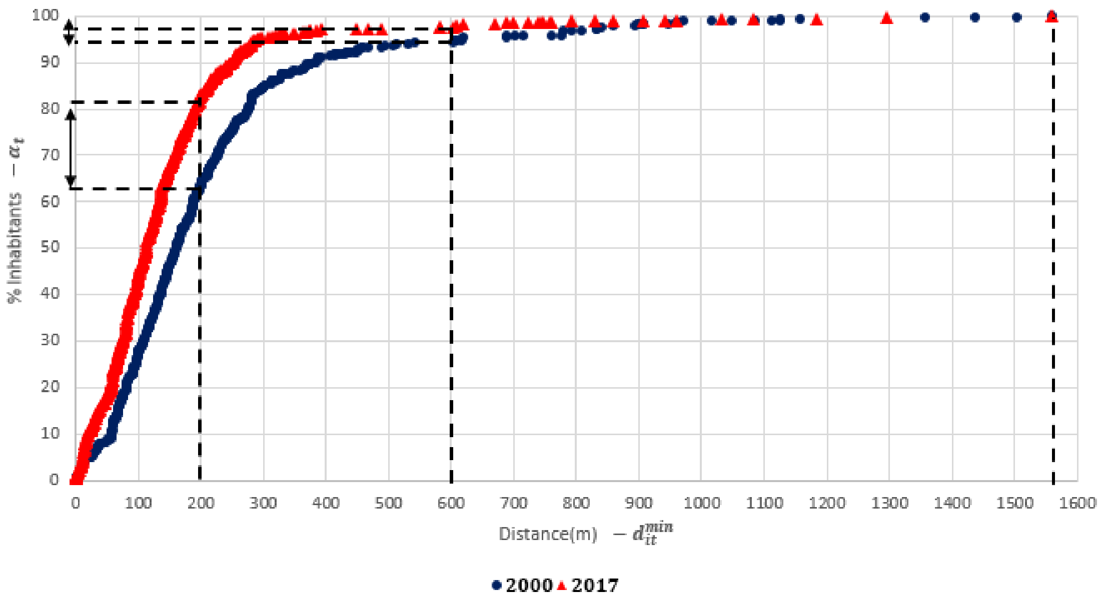


Figure 6 – Distribution of the population by distance from the closest facility

On the basis of the above introduced allocation mechanism, we determined also the market shares captured by each drugstore in each period ($MS_{jt},\ t \in T, j \in J_t$). In Figure 7, the market shares gained in 2000 and 2017 are compared for all those pharmacies already located in 2000 ($j \in J_{2000}$). This way, points on the line that bisect the first quadrant represent drugstores that have lost no market share ($MS_{j2000} = MS_{j2017}$), while points under that line represent drugstores that have been cannibalized. Of course, the higher is the distance from that line the higher is the lost market share. Figure 7 highlights that there is a significant number of pharmacies that have been completely cannibalized by new entrances, being their new market share equal to zero.

The analysis of the entry process in the city of Pamplona shows that the regulation of the market, mainly based on the definition of demographic conditions and mutual distances among pharmacies, has produced some negative effects that should be better addressed. On one side, the location of new drugstores has produced an overall improvement of accessibility, but it has not contributed to make the access more equitable, by improving the situation of consumers in the worst condition. On the other side, the cannibalization effect has produced unbalanced situations, in which old pharmacies have not been able to maintain an adequate market niche.

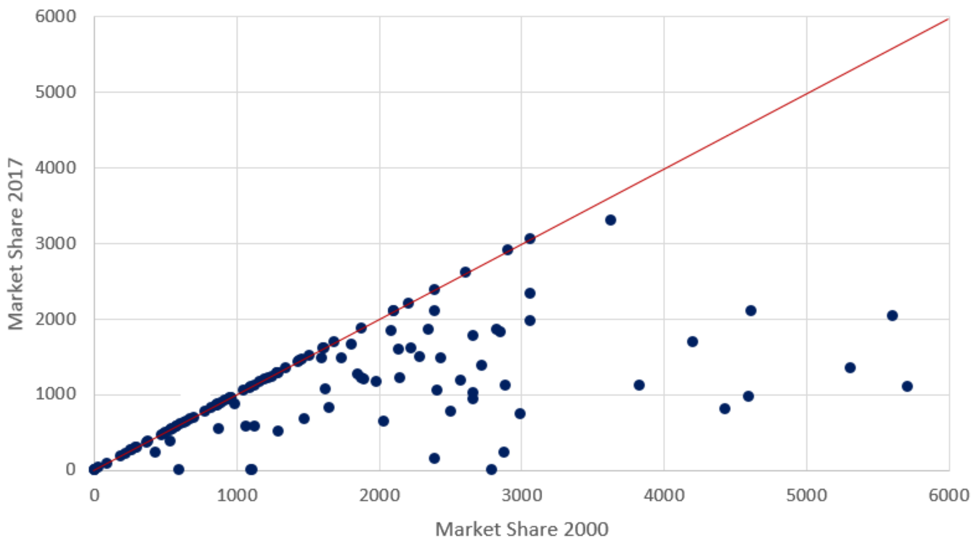


Figure 7 – Cannibalization effect on the existing drugstores in 2000

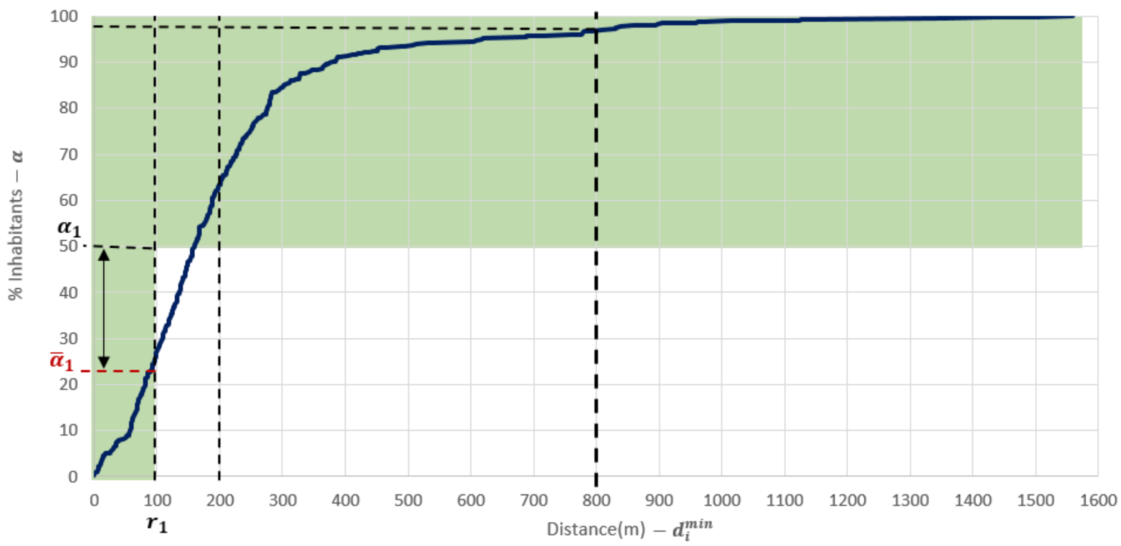
In this context, policy-makers are recommended to take actions in order to define new regulation mechanisms able to ensure equitable accessibility and sustainable competition in a more liberalized environment. At this aim, we show how a deeper spatial analysis of the regions under analysis is needed to effectively drive the process and how the use of optimization tool can be useful in order to define possible alternative scenarios.

4. A mathematical model for the location of new drugstores

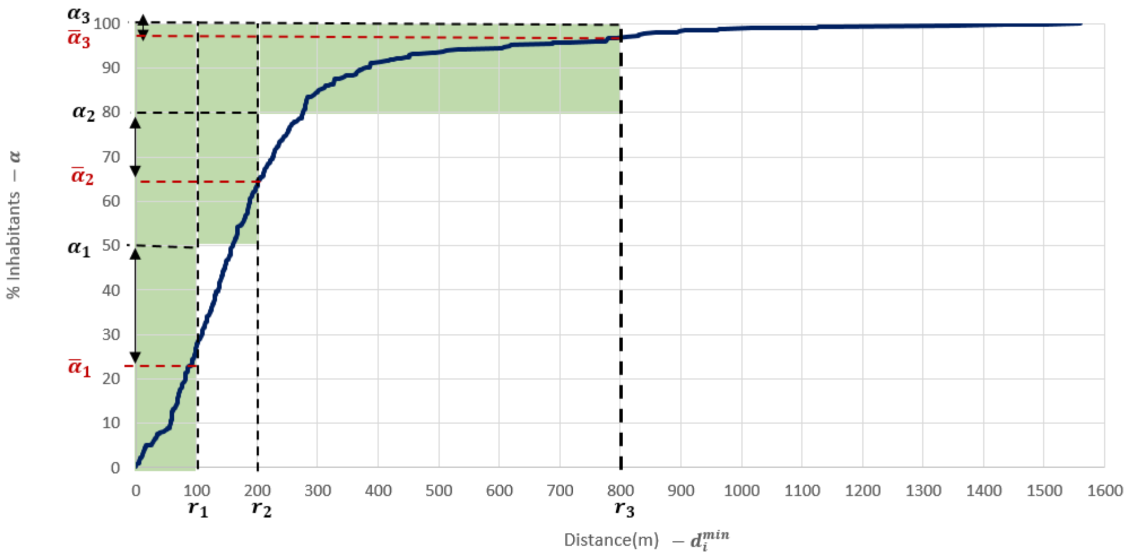
4.1 Model Assumptions

With reference to a given region, we consider a set I of discrete nodes where potential customers for pharmaceutical products and services are located and we denote with p_i the total population living in each of them. Moreover, we suppose the presence of a set J^E of existing drugstores, already located in the region, and a set J^N of nodes where new drugstores may be potentially located. The distance between any demand node $i \in I$ and any $j \in (J^E \cup J^N)$ is denoted by d_{ij}. By assuming that all pharmacies are indistinguishable to consumers in terms of attractiveness and perceived quality, we may reasonably assume that users patronize their closest facility. Hence, by adopting the *minimum distance* as a proxy of their accessibility condition, we may assume that each user is characterized by an initial accessibility condition given by $d_i^{min} = \min_{j \in J^E}\{d_{ij}\}$. In principle, the opening of new pharmacies should positively affect users, in terms of accessibility; indeed, each customer $i \in I$ may select, if available, a new drugstore, closer than d_i^{min}, to patronize.

We assume that the decision maker (in this case the *regulator*) may drive the location process, by fixing some *service level requirements*, in terms of expected improvement of users' accessibility. In particular, by fixing a given radius r_k, we assumed that the decision maker is interested in increasing the percentage of population covered within r_k, from an actual value $\bar{\alpha}_k$ ($\bar{\alpha}_k = \sum_{i \in I: d_i^{min} \leq r_k} p_i \,/\, \sum_{i \in I} p_i$) to a target value α_k (with $\alpha_k > \bar{\alpha}_k$). The introduced regulation mechanism may be generalized by fixing $|K|$ different covering radii r_k ($with\ r_1 < r_2 <\ldots< r_{|K|}$) and $|K|$ corresponding coverage levels α_k ($with\ \alpha_1 < \alpha_2 <\ldots< \alpha_{|K|} \leq 1.0$). Of course, the calibration of parameters r_k and α_k is crucial for the regulation of the process. Indeed, through them, the decision maker may impact at different levels the final shape of the accesibility curve. In Figure 8, we report two different examples of calibration, in which the initial accessibility curve of the case under analysis is represented in blue and the feasibility region for the accessibility curve in the final configuration is highlighted in green. In particular, Figure 8(a) reports the case in which the decision maker requires that the percentage of users covered within 100 m increases up to a level of 50% (starting from an initial value $\bar{\alpha}_1$ equal to 23%), while Figure 8(b) reports the case in which the decision maker requires that the 50% of population is covered within 100m, the 80% within 200m and the 100% within 800. Of course, in the first case the decision maker is interested in improving the condition of users, regardless of their initial condition, while in the second case, he aims at improving also the accessibility of those users that are currently in the worst condition



(a) $\boldsymbol{r_1 = 100m;\ \alpha_1 = 0.50}$



$(\mathbf{b})(r_1, r_2, r_3) = (100, 200, 800)\ m;\ (\alpha_1, \alpha_2, \alpha_3) = (0.5, 0.8, 1.0)$

Figure 8 – Feasibility region for the accessibility curve by varying calibration parameters α_k and r_k

Given the regulation mechanism described above, the model aims at minimizing the total number of new drugstores to be located. This way, it will tend at providing a trade-off solution between the need of guaranteeing a good and equitable access of users to the market and the need of controlling cannibalization effect among drugstores. At this aim, also the dispersion requirement among drugstores is taken into account.

4.2 Model Formulation

In order to formulate the model, we introduce the following notation:

I	set of demand nodes, indexed by i;
J^E	set of nodes where existing drugstores are located;
J^N	set of nodes where new drugstores may be potentially located;
K	set of service or coverage levels;
p_i	population associated to the generic node $i \in I$
d_{ij}	distance between any node $i \in I$ and $j \in (J^E \cup J^N)$;
d_{jt}	distance between any pair of potential drugstores $j, t \in J^N$;
d_i^{min}	current accessibility condition of users in $i \in I$, i.e. their distance from the closest existing drugstores $j \in J^E$ $(d_i^{min} = \min_{j \in J^E}\{d_{ij}\})$;
$\bar{d}$	minimum required distance among active drugstores;
r_k	covering radius associated to the $k - th$ service level $(r_1 < r_2 <\ldots< r_k)$;

$\alpha_k = \alpha\ (r_k)$ percentage of population that have to be covered within the radius r_k ($\alpha_1 < \alpha_2 <\ldots< \alpha_k$);

F_i^k set of existing or potential drugstore locations that cover the demand node $i \in I$ within the covering radius r^k ($F_i^k = \{ j \in J^E \cup J^N : d_{ij} \leq r_k \}$.

and the following set of decision variables:

y_j binary decision variable equal to 1 if and only if a new drugstore is open in the node $j \in J^N$;

x_{ij} binary decision variable equal to 1 if and only if the demand node $i \in I$ is assigned to drugstore $j \in (J^E \cup J^N)$;

Then, the Integer (Binary) Programming model is formulated as follows:

$$\min z = \sum_{j \in J^N} y_j \qquad (1)$$

$$\sum_{j \in (J^E \cup J^N)} x_{ij} = 1 \qquad \forall\ i \in I \qquad (2)$$

$$x_{ij} \leq y_j \qquad \forall\ i \in I, \forall\ j \in J^N \qquad (3)$$

$$\sum_{t \in J^N} d_{it} x_{it} + (M - d_{ij}) * y_j \leq M \qquad \forall\ i \in I, \forall\ j \in J^N \qquad (4)$$

$$\sum_{t \in J^E} d_{it} x_{it} \leq d_i^{min} \qquad \forall\ i \in I \qquad (5)$$

$$\sum_{i \in I} \sum_{j \in F_i^k} p_i * x_{ij} \geq \alpha_k * \sum_{i \in I} p_i \qquad \forall\ k \in K \qquad (6)$$

$$(d_{jt} - \bar{d})\ y_j\ y_t \geq 0 \qquad \forall\ j, t \in J^N : j \neq t \qquad (7)$$

$$y_j \epsilon \{0/1\} \qquad \forall\ j \in J^N \qquad (8)$$

$$x_{ij}\ \epsilon \{0/1\} \qquad \forall\ i \in I, \forall j \in (J^E \cup J^N) \qquad (9)$$

The objective function (1), to be minimized, is defined as the total number of new drugstores to be located. Constraints (2) impose that each demand node $i \in I$ is assigned to a single facility $j \in (J^E \cup J^N)$ while constraints (3) guarantee that, besides the old drugstores $j \in J^O$, each demand node $i \in I$ may be assigned only to those nodes $j \in J^N$ where a drugstore is activated in the final configuration (y_j =1). Constraints (4-5) guarantee that each node $i \in I$ is allocated to its closest active drugstore (old or new). In particular, constraints (4) impose that, among the new potential locations $j \in J^N$, each node $i \in I$ may be assigned only to the closest active drugstore. Indeed, by setting $M = \max_{i \in I, j \in J^N} \{d_{ij}\}$, conditions (4) become redundant for all those nodes $j \in J^N$ in which no facility is located ($y_j = 0$); while, in relation to active drugstores ($y_j = 1$), they are satisfied only by assigning each node i to the node t at the minimum distance. On the other side, constraints (5) impose that, among the existing drugstore $j \in J^E$, each node $i \in I$ may be assigned only to the node at the distance d_i^{min}. Then, by intersecting conditions (4) and (5), each node i is assigned to the closest drugstore among the closest existing one and the closest new one. Conditions (6) impose different coverage levels within each covering radius r_k. In particular, the population covered within each radius r_k ($\sum_{i \in I} \sum_{j \in F_i^k} p_i * x_{ij}$) has to be higher than a given percentage α_k of the total population. Of course, the higher the radius is, the higher is the percentage of population to be covered within it. Constraints (7) guarantee a minimum dispersion among drugstores; in other words, they impose that distance between any pair (j, t) of new active drugstores has to be higher than a given threshold value $\bar{d}$. Finally, constraints (8-9) define the nature of the introduced decision variables.

The model (1–9) is not linear, due to the presence of constraints (7). In order to linearize them, we introduced a new set of binary decision variables z_{jt} ($z_{jt} = y_j * y_t$) and the following set of constraints, that guarantee that the new binary variable z_{jt} is equal to 1 if and only if two drugstores are simultaneously open in j and $t \in J^N$ ($y_j = y_t = 1$):

$$z_{jt} \geq y_j + y_t - 1 \qquad \forall\, j, t \in J^N \quad (10)$$

$$z_{jt} \leq y_j \qquad \forall\, j, t \in J^N \quad (11)$$

$$z_{jt} \leq y_t \qquad \forall\, j, t \in J^N \quad (12)$$

This way the model may be formulated as follows:

min (1)

subject to:

$(2-6), (8-12)$

$$(d_{jt} - \bar{d}) * z_{jt} \geq 0 \qquad \forall\, j, t \in J^N : j \neq t \quad (7')$$

$$z_{jt} \in \{0/1\} \qquad \forall\, j, t \in J^N \quad (13)$$

In the next section, we analyse the application of the model to the case study of Pamplona.

5. Preliminary Results

As introduced above, we apply the proposed model to the city of Pamplona, in order to show different feasible scenarios, that could have been implemented as alternative to the real entry patterns observed after the year 2000, as a consequence of the relaxation of the geographic and demographic criteria by the regulator.

In order to apply the model to the selected case study, we refer to the discretization of the study area introduced in Section 2.2 and we consider the set of existing drugstores J^E coinciding with the set of drugstores at the end of year 2000 (J_{2000}). As concerns the set of potential locations, we refer to the 4752 commercial areas included in the Municipal Plan of the city of Pamplona (Ayuntamiento de Pamplona, 2017 - https://sig.pamplona.es/), which were in turn aggregated in 397 nodes.

The distances between each demand node and each drugstore (existing and potential), as well as between any pair of potential drugstores, were determined as pedestrian shortest paths on the road network (through customized requests to the service Distance Matrix API, provided by Google, that were automatically generated thanks to a Matlab script).

Each model has been solved using CPLEX 12.4.

First of all, we solved the model with the aim of identifying the number and the location of drugstores required to reproduce an accessibility curve similar to current one (Figure 6, line blue). At this aim, we set $(r_1, r_2, r_3) = (100, 150, 250)$ and $(\alpha_1, \alpha_2, \alpha_3) = (0.5, 0.7, 0.9)$. The model opens 34 new drugstores against the 83 ones registered in the real case. In Figure 9, the acessibility curve produced by our model is reported and compared with those representative of the initial and final conditions in the real case study. It is possible to notice that the accessibility in the scenario produced by the model is very similar to the real scenario in 2017; this means that such condition could be reached by activating a number of new drugstore significantly lower than the real one. Of course, this had a good impact also in terms of competition among drugstores. Indeed, the total market share gained by the new drugstores is equal to 53.935 (27,3%) against the 70.054 (35,5%) related to the real case. In order to evaluate the distribution of market shares among active drugstores, in terms of total attracted population ($MS_j = \sum_{i \in I} p_i x_{ij}$), we report in Figure 10 the Lorenz curve. It represents the relationship between the cumulative percentage of drugstores (X axis) and the cumulative percentage of gained market share (Y axis). If the p% of drugstores cover the p% of the customers (or population), the distribution may be considered perfectly equitable and the Lorenz curve coincides with the bisector of the first and third quadrant. When the market shares are not equally distributed among drugstores, the Lorenz curve drops below the straight equity line, to an extent that will be greater when the distribution become more unequal. The Gini coefficient measures the area between the two curves. From Figure 10, it can be noticed that the solution provided by our model (line in green) is characterized by a more eqitable distribution of market shares among dugstores, if compared with the initial and the final scenarios observed in 2000 and 2017 (lines in blue and red, respectively). This result is encouraging; indeed, even if we did not explicitly considered in the model a mechanism to control the competition among drugstores, the model automatically produce more equitable solutions. This is mainly due to the fact that, by minimizing the total number of new activations, the model will tend to create not overlapping market areas, with the consequence of mitigating cannibalization effect.

Figure 9 – Scenario 1: Accessibility curve

$(r_1, r_2, r_3) = (100, 150, 250); (\alpha_1, \alpha_2, \alpha_3) = (0.5, 0.7, 0.9)$

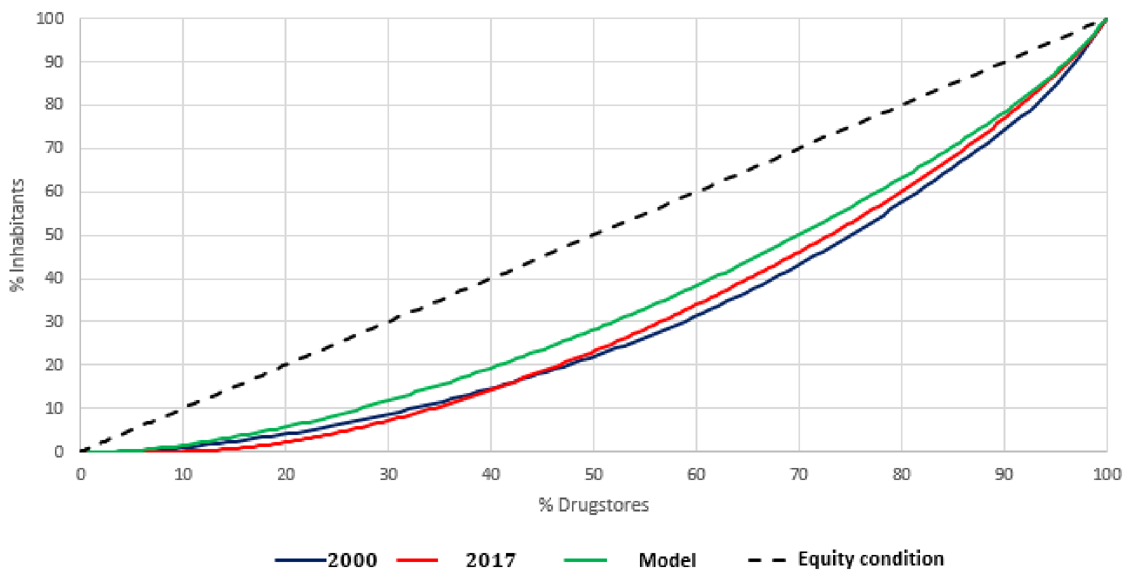


Figure 10 – Scenario 1: Distribution of Market share by drugstores (Lorenz curve)

$(r_1, r_2, r_3) = (100, 150, 250); (\alpha_1, \alpha_2, \alpha_3) = (0.5, 0.7, 0.9)$

Given that in the Scenario 1, the accessibility of users in the worst condition has not improved (i.e. the maximum distance from the closest drugstores remained equal to 1560m), we produced alternative scenarios aimed at improving accessibility condition of more disadvantage users. At this aim, we run the model by imposing that in the new scenario the 100% of the population is covered within a new radius r_4, that was varied according to the following rule:

$$r_4 = 1500 - k * 100 \quad \forall k = 0, \dots, 5$$

In Table 1, all the produced solutions are compared in terms of total number of active drugstores, users' accessibility (average and maximum distance of users from their closest drugstore) and distribution of gained market shares (minimum, maximum and Gini coefficient). It can be noticed that, in any case, the scenarios provided by our model are characterized by a lower number of active pharmacies than the real scenario of 2017. Of course, by decreasing the maximum distance r_4, the number of drugstores increases. Moreover, the model is able of mitigating the cannibalization effect, as the produced scenario are always characterized by a range between the maximum and the minimum market share lower than the existing one and a lower value of Gini coefficient.

	Active facilities	d_{max}	$\bar{d}$	MS_{min}	MS_{max}	**Gini coefficient**
		[m]		**[inhabitants]**		
Real Scenario Year 2000	**119**	**1560**	**237**	**31**	**5714**	**0,377**
Real Scenario Year 2017	**197**	**1560**	**169**	**0**	**3300**	**0,368**
$(r_1, \cdots, r_3) = (100,150,250)$ $(\alpha_1, \dots, \alpha_3) = (0.5, 0.7, 0.9)$	**153**	**1560**	**173**	**29**	**3690**	**0,299**
$(r_1, \dots, r_4) = (100,150,250,1500)$ $(\alpha_1, \dots, \alpha_4) = (0.5, 0.7, 0.9, 1.0)$	**154**	**1356**	**169**	**29**	**3690**	**0,297**
$(r_1, \dots, r_4) = (100,150,250,1400)$ $(\alpha_1, \dots, \alpha_4) = (0.5, 0.7, 0.9, 1.0)$	**154**	**1356**	**168**	**29**	**3690**	**0,297**
$(r_1, \dots, r_4) = (100,150,250,1300)$ $(\alpha_1, \dots, \alpha_4) = (0.5, 0.7, 0.9, 1.0)$	**155**	**1117**	**167**	**29**	**3690**	**0,299**
$(r_1, \dots, r_4) = (114,160,252,1200)$ $(\alpha_1, \dots, \alpha_4) = (0.5, 0.7, 0.9,1.0)$	**155**	**1117**	**166**	**29**	**3690**	**0,299**
$(r_1, \dots, r_4) = (114,160,252,1100)$ $(\alpha_1, \dots, \alpha_4) = (0.5, 0.7, 0.9,1.0)$	**155**	**1087**	**172**	**0**	**3690**	**0,310**

Table 2 – Scenarios comparison

6. Conclusions

In most European countries the retail pharmacy market is regulated with the aim of guaranteeing some objectives of accessibility, equity, efficiency and quality of services. Usually, the regulation for the establishment of new pharmacies is based on demographic and geographic criteria. In the last years, in a general deregulation trend, these criteria have been progressively relaxed in several countries, with the result of a general increase of competitors in the market. Nevertheless, in many cases this phenomenon did not produce the expected results, in terms of users' accessibility and quality of services, but it has exacerbated the differences among urban and rural areas, with a higher concentration of drugstores in high density populated areas.

In this context, policy-makers are recommended to take actions in order to define new regulation mechanisms able to ensure equitable accessibility and sustainable competition in a more liberalized environment.

In this work, we propose a mathematical model that optimally locates new drugstores in a given location space, according to some requirements defined by a central decision maker (the regulator), with the objective of guaranteeing a more equitable access of users to the service and, at same time, of mitigating the cannibalization effect. This way, we aim at testifying that a deeper spatial analysis of the area under analysis and the use of appropriate methodologies may help policy makers in defining more effective regulation mechanisms and in producing more equitable scenarios.

References

Almarsdóttir, A. B., Morgall, J. M., & Björnsdóttir, I. (2000). A question of emphasis efficiency or equality in the provision of pharmaceuticals. *The International journal of health planning and management*, 15(2), 149-161.

Almarsdóttir, A. B., Morgall, J. M., & Grímsson, A. (2000). Cost containment of pharmaceutical use in Iceland: the impact of liberalisation and user charges. *Journal of Health Services Research & Policy*, 5(2), 109-113.

Anell, A. (2005). Deregulating the pharmacy market: the case of Iceland and Norway. *Health Policy*, 75(1), 9-17.

Barbati, M., & Piccolo, C. (2016). Equality measures properties for location problems. *Optimization Letters*, 10(5), 903-920.

Bruno, G., Genovese, A., & Piccolo, C. (2016). Capacity management in public service facility networks: a model, computational tests and a case study. *Optimization Letters*, 10(5), 975-995.

Elizalde, J., Kinateder, M., & Rodríguez-Carreño, I. (2015). Entry regulation, firm's behaviour and social welfare. *European Journal of Law and Economics*, 40(1), 13-31.

Garattini, L., van de Vooren, K., & Curto, A. (2012). Will the reform of community pharmacies in Italy be of benefit to patients or the Italian National Health Service*?*. *Drugs & Therapy Perspectives*, 28(11), 23-26.

Laporte G., Nickel S., Saldanha-Da-Gama F. (Eds) (2014). *Location Science*. Springer Berlin.

Lluch, M., & Kanavos, P. (2010). Impact of regulation of Community Pharmacies on efficiency, access and equity. Evidence from the UK and Spain. *Health Policy*, 95(2-3), 245-254.

Marianov, V., & Serra, D. (2002). Location problems in the public sector. *Facility location: applications and theory*, 1, 119-150.

ÖBIG (2006), Community Pharmacy in Europe, Vienna: Austrian Health Institute (commissioned by PGEU – Pharmaceutical Group of European Union).

Plastria, F. (2001). Static competitive facility location: an overview of optimisation approaches. *European Journal of Operational Research*, 129(3), 461-470.

Vogler, S., Habimana, K., & Arts, D. (2014). Does deregulation in community pharmacy impact accessibility of medicines, quality of pharmacy services and costs? Evidence from nine European countries. *Health policy*, 117(3), 311-327.