

EVIDENCE BASED RELATIONSHIP BETWEEN HEALTHCARE INFRASTRUCTURE AND NOSOCOMIAL INFECTIONS IN ROMANIA

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Abstract

We investigate the regional dynamic of nosocomial infections in Romanian hospitals, and find potential predictors. Our data covers 13 years, and refer to the incidence of nosocomial infections for each of the 42 Romanian administrative units every year. A preliminary cluster analysis reveals that there is heterogeneity across counties both in terms of average, and variability of nosocomial infections incidence. The heterogeneity can be explained to an important degree by the local level of healthcare infrastructure, urbanization rate and economic development. Supporting programs and clear standards for quality assurance must accompany the investment in health infrastructure, and the development of new out – care units should be prioritized

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1. Introduction

In the last decades, significant efforts aimed to adapt the efficiency paradigm to different public domains (Afonso et al., 2010). The process continues to be intricately difficult with respect to finding the relevant methods and indicators to assess efficiency, and the case of health care systems is on top among those particularly challenging ones (Jacobs et al., 2006; Mills, 1995).

In between the gap of problematic health system issues diverging from developed to developing countries, the case of transition economies remains somewhat unclassified and poses specific efficiency concerns. Looking through the filter of internationally acknowledged metrics, most of these healthcare systems underperform (Mirmirani et al., 2008), by comparison to their Western counterparts, but not necessarily in a systematic way, proving also some underestimated and underexplored strengths (Asandului et al., 2014).

Romania does not make an exception. A recent analysis of average efficiency scores by health outcome (e.g. life expectancy at birth/at age 65, healthy life expectancy at birth/at age 65, amenable mortality etc.), employing data envelopment analysis (DEA) models, reveals that Romania ranks 22 among 28 European countries, with a score below the 25th percentile (Medeiros and Schwierz, 2015). At an internal level, a high level of opacity characterizes the system, opacity heighten also by the last global financial crisis and its negative impact on population health (Carausu et al., 2017). While various public policy makers often claim that a partnership with academia is desirable, this remains only a declarative statement since the principal means to achieve it – access to reliable and internationally comparable statistical data – are heavily ignored. Thus, there is no surprise that the dynamic of health economics as a field is a sluggish one (Tamba et al., 2016), providing an insufficient amount of solid quantitative findings to support a scientific fundament for policy making.

This is by no means the equivalent of a stable system but at the contrary, of a system marked by frequent and not always coherent reforms (Healy and McKee, 2002). As it was the case for other Eastern European countries, the Romanian health system was massively centered on hospitals (Ho and Ali-Zade, n.d.), making them the focus of much reorganization. Radu and Haraga (Radu and Haraga, 2008) point out that even if there are signs of an increase in transparency, there are many improvements to be made in terms of connecting patient data with other health service providers, in equitable allocating hospital funds or in generating realistic incentives for technical efficiency.

A crucial topic on hospital agendas in both developed (Stone, 2009) and developing countries (Allegranzi et al., 2011) for many years now, but marginally treated in Romania is

that of nosocomial infections or healthcare associated infections. By definition, these infections usually appear in the process of hospitalization and, in consequence, may potentially lead to longer stays (generating at their turn long term disabilities, increased antimicrobial resistance, increased mortality rates) and an increase of financial costs (Khan et al., 2017). Jarvis (Jarvis, 1996) points out the extensive socioeconomic implications in terms of morbidity, mortality, costs and prevention, with some precise estimation for the case of US, while for Europe the literature mostly accounts for the prevalence of such infections in different types of medical care units (Vincent et al., 1995). An important aspect to mention refers to the increased impact noticed for countries employing payment systems based on diagnosis-related groups, such as Romania, impact expressed through bigger prospective losses for hospitals (Jarvis, 1996).

According to the WHO (2010), the overall prevalence of nosocomial infections in developed countries is postulated between 5 and 9%, while for developing countries the value rises to 10 -12%. For Romania, to this date, there is only one official report (Popescu et al., 2014) focused on antibiotics consumption and the associated resistance that also includes the results of a 2012 European study on 10 Romanian hospitals (2417 patients). The data reveals a 5.5% prevalence of nosocomial infections, but the small value is discussed in the larger context characterized by a constant tendency of underreporting and under-diagnose for such infections. This is partially explained by the fear of sanctions, from hospital managers, and partially by the lack of specialized controllers. Within this framework it is not surprising that nosocomial infections in Romania are not the object of public policies interventions. There are indeed a couple of papers discussing particular cases - preventing nosocomial tuberculosis infections (Turusbekova et al., 2016) Clostridium difficile infections (Laza et al., 2015) or Pseudomonas antibiotic resistant strains (Junie et al., 2010) – but not an integrated strategy at the level of the entire health care system.

Such an approach is even more ineffective if we consider the expert opinions assessing that at least 20% of nosocomial infections are preventable (Harbarth et al., 2003). The wider explanation for ignoring such facts can be identifying in the perception that preventing nosocomial infections is not a priority because it is mostly an activity that may help reduce costs but not also generate some revenues (Haley, 1991).

Our paper aims to fill this gap and investigate the dynamic of nosocomial infections in Romania, over a period of 13 years. In the first stage, we opted for a preliminary exploratory analysis, aimed to reveal that there is a high level of heterogeneity in the incidence of nosocomial infections across Romanian counties. Secondly, we relied on regression analysis to identify factors responsible with the specificities. To our knowledge, this is the first

exploration of nosocomial infections data in Romania, and we hope that our contribution will trigger other future studies in the field.

The remaining of the paper is organized as follows: after introducing the data, section 2 presents a hierarchical cluster analysis that illustrates the similarities between counties in terms of nosocomial infections incidence. Considering the differences identified between groups, we further use panel data modelling to capture associations between nosocomial infections incidence and two categories of factors: healthcare-related infrastructure and local level of economic development. Section 3 summarizes the main findings, informs possible interventions, and presents the limitations of the study along with future directions of research.

2. Data and method

2.1. Data

Data covers 13 years, from 2002 until 2014, and refer to the main variable of interest, namely the incidence of nosocomial infections, in absolute value, reported by The National Institute of Public Health in relation to each of the 42 Romanian administrative units (41 counties and the Bucharest municipality) every year. Our analysis was therefore based on a total of 494 observations. The Romanian Institute of Statistics provided the variables aimed to explain the relationship between nosocomial infection incidence and healthcare infrastructure. A detailed list of the variables used through the paper, along with their definitions, is included in Annex 1.

The two graphs included in Annex 2 present the dynamic of nosocomial by county and across time, in two cases. Figure 1a and b shows the case when all 42 administrative units are included, which reveals that Bucharest Municipality and Iasi are significant outliers. The result is not surprising, since both are important university centres around which an important number of patients, and difficult cases gravitate all the time. What is rather surprising is that some other university centers like Timis and Cluj do not display a similar level of incidence in nosocomial infections, although they also attract a large number of patients with difficult conditions. As it will be seen in the next subsection, our cluster analysis confirms indeed that Bucharest Municipality and Iasi are part of a specific group. Figure 2a and b in the same Annex 2 presents the nosocomial infections dynamic by county and across time after removing these two outliers.

Table 1 below presents some descriptive statistics related to our variables of interest. This time, we address the overall data.

Table 1. Descriptive statistics – overall

Variable	Min	Median	Mean	Max	Standard deviation
Infections	0	0.1877	0.438	6.481	0.754
Hospitals	0.744	1.792	1.885	5.290	0.668
Out-care	0.186	1.370	1.443	2.720	0.526
Nurses	226.9	499.8	510.6	885.5	116.511
Physicians	52.61	121.02	149.83	434.36	75.181
Urbanization	0.109	0.491	0.5003	0.765	0.124
Average net wage	15.19	29.41	29.16	56.87	7.119

Next step will be to explore our data in terms of potential groups of counties displaying similar patterns in what concerns the evolution of nosocomial infections incidence over the 13 years under analysis.

2.2. Cluster analysis

Cluster analysis is an unsupervised learning method used to find groups in data. While grouping objects using cluster analysis, the aim is to find objects that are similar within groups, and dissimilar across groups. Our departure point in this stage was to look into the distribution of the nosocomial infections for each administrative unit, and explore similarities in terms of average and coefficient of variations. Figure 1 displays the relationship between the two (average on the vertical axis and coefficient of variation on the horizontal axis), each dot on the graph corresponding to a county, or to the Bucharest Municipality. In light of the results that we get from our cluster analysis, we assigned different colours to the administrative units assigned to different groups.

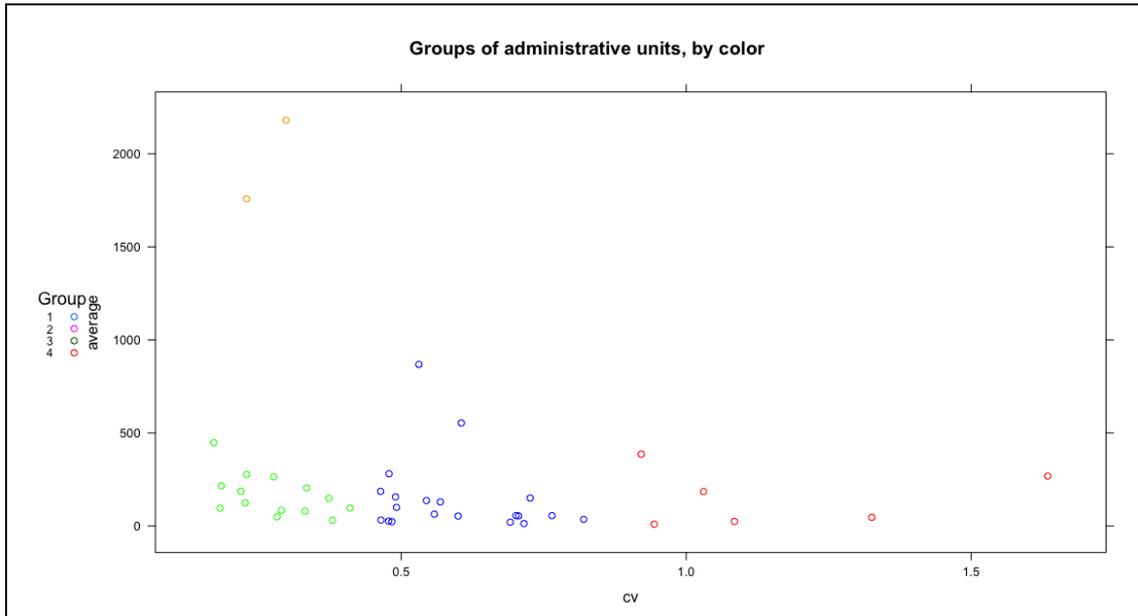


Figure 1. Several interesting groups

Figure 1 suggests that there are counties that share high average values of nosocomial infections incidence and low variability, while other counties, despite their low average level of incidence, display high values of their coefficient of variation. A hierarchical clustering applied to our data set results in the dendrogram presented in Figure 2, and to the output included in Table 2.

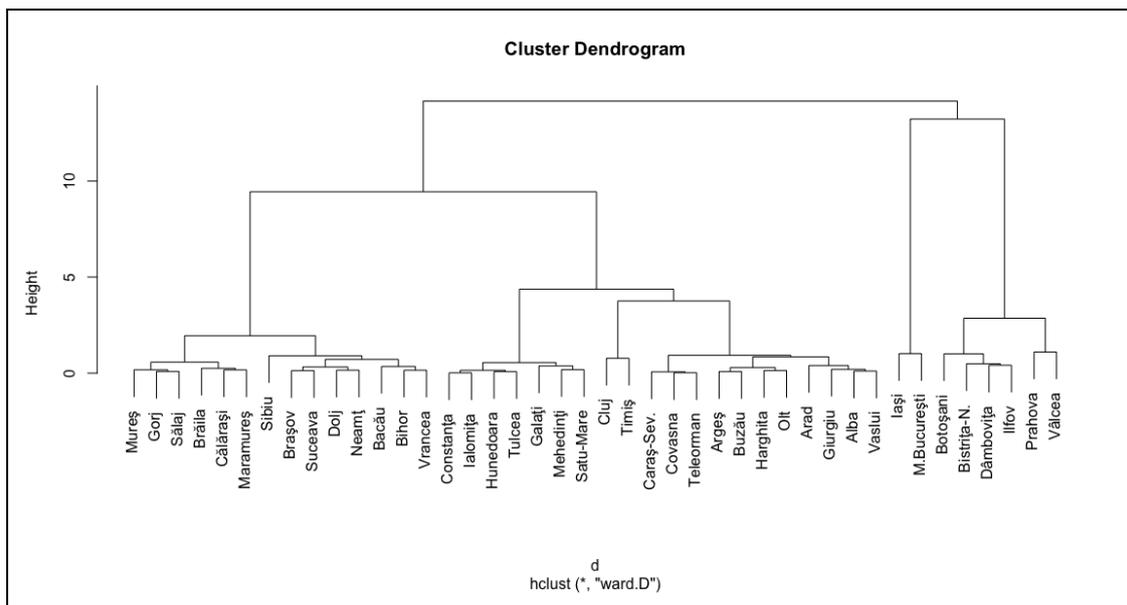


Figure 2. The dendrogram: we choose 4 groups

Table 2 shows that the first group identified in our exploration contains nearly half of the counties (47.6%) and is characterized by lowest average incidence of 149 new cases per year, and rather moderate variability, of 0.594. Unlike this group, the second one is characterized by a little higher average incidence, 164 cases per year, but half of the previous coefficient of variation: 0.278. This second group comprises of 14 counties (33.3% of the total). The third group deserves a special attention: the average incidence is lower than in case of the second group, but coefficient of variation is high, which places the counties among the sources of high risks. This third group contains 6 counties that, at a first glance, seem to be geographically placed in the neighbourhood of the counties where the main university centres are in Romania: Bucharest, Cluj, Iasi and Timis.

Table 2. The groups resulted from the hierarchical cluster analysis

Group	Average	Coefficient of variation	Proportion	Administrative units
1	149.400	0.594	0.476	Alba, Arad, Argeş, Buzău, Caraş-Sev., Cluj, Constanţa, Covasna, Galaţi, Giurgiu, Harghita, Hunedoara, Ialomiţa, Mehedinţi, Olt, Satu-Mare, Teleorman, Timiş, Tulcea, Vaslui
2	164.308	0.278	0.333	Bacău, Bihor, Braşov, Brăila, Călăraşi, Dolj, Gorj, Maramureş, Mureş, Neamţ, Sălaj, Sibiu, Suceava, Vrancea
3	153.013	1.157	0.143	Bistriţa-N., Botoşani, Dâmboviţa, Ilfov, Prahova, Vâlcea
4	1969.116	0.263	0.048	Iaşi, and Bucharest Municipality

Last, but not least, our cluster analysis identified Iasi and Bucharest Municipality as a separate group 4, characterized by a huge average number of infections, but with variability comparable with group 3. Considering that both Iasi and Bucharest are university centers, having strong medical schools, we can easily explain the high average incidence in terms of patient attendance. In fact, Figure 1 in Annex 2 clearly shows that both Iasi and Bucharest display peaks compared to the rest of the counties. On the other hand, Cluj and Timis counties, both of them having also strong medical schools, are assigned to the first group, characterized by the lowest average incidence, but rather high variability.

Our preliminary cluster analysis reveals that the 42 Romanian administrative units cluster in groups displaying different behavior in terms of average and variability of the incidence of nosocomial infections. While in some cases, like for example Bucharest Municipality and Iasi, we can find clear explanations based on patient attendance, a deeper exploration of

specific factors that may be responsible for this behavior will be presented in the next subsection.

2.3. Panel data modeling

The first observation that can be derived from our preliminary analysis points toward the fact that the problems in each group need to be approached specifically. Group 1 is characterized by low average incidence, but high variability: the intervention should focus on identifying the source of this variability, and mitigate the risks. Unlike this case, the second group displays a higher average and low coefficient of variation, which points toward the fact that the incidence of nosocomial infections may be high due to systematic causes, and not to contextual events. Group 3 seems to embody the features of both group 2 and 3, in the sense that we have high average and also significant variability.

In this subsection, we intent to use a simple panel regression model to explain the variations in the incidence of nosocomial infections across Romania. Two dimensions characterize our data: the cross – sectional one, accounting for 42 statistical units (counties and Bucharest municipality, as well as the time dimension, as each variable has been measured over 13 years. As a consequence, we will rely on panel data models, a field that gained in interest in recent years not only because the advantages of this type of analysis over other method, but also in response to the increasing computational power and advances of the theoretical econometric background (Hsiao, 2007). In our case, there are two main reasons why we prefer to rely on panel data models: on the one side, this type of models allows to control for the impact of omitted variables. Given extensive data unavailability in Romania, we found that this particular methodology may compensate at least to a certain extent the lack of other predictors that might have proved useful. On a different level, the analysis that we conducted in the previous section revealed that there are specificities that group together the Romanian counties in four groups with clear characteristics. Since panel data analysis allows capturing heterogeneity across the units under analysis, we found this methodology useful to check whether or not the specificities remain, after controlling for several variables.

The simplest approach in working with panel data is the pooled OLS model, a model that assumes that all the data is treated as cross – sectional. Subsequently, such a regression model will employ the exact same coefficients for all the analyzed units, thus the counties in our study, deliberately neglecting the repetition of the same county in our sample, at different moments in time. Type of generality can be very useful, but typically overlooks heterogeneity and serial correlation, making this models to be suitable only in cases when the statistical units under analysis do not display specific characteristics that should be captured separately.

If heterogeneity is present, more accurate predictions are performed when considering the existence of individual specificities for each county, through the means of fixed and random effects models. In both cases, the standard procedure consists in eliminating those characteristics that do not vary temporally and then simply reassess the effect of the predictors on the dependent variable. Next, a new assumption comes in place regarding the correlation between the county-specific factors, expressed through the intercepts, and the regressors. A fixed effect model accounts for the correlation, while a random effect model states that the observed differences across intercepts are rather due to random influences.

Finally, deciding upon models is made with the help of two statistical tests: Lagrange Multiplier and Hausman. The first contributes in choosing between the OLS pooled model and the models characterized by individual specificities. If the pooled model is rejected, the Hausman test makes a ruling between a fixed or random effects model, according to the basic panel data econometrics principles explained by Baltagi (Baltagi, 2008).

After removing the two outliers detected as Group 4, namely Bucharest Municipality and Iasi county from the data (see Figure 1.a. and 1.b. in Annex 2), we will work with the dependent variable “infections”, defined as the number of nosocomial infections per 100,000 inhabitants. Our attempt is to explain this variable as a function of the independent variables presented in Annex 1. An extensive list of these predictors, along with their correlation matrix is included in Annex 3.

The set of explanatory variables employed in the final model (presented and defined in Annex 2) is in line with the common determinants of nosocomial infections incidence discussed in the literature, and with the constraints regarding data availability for this level of aggregation. We ended up with the following model specification:

$$\text{Nosocomial infections incidence} = \beta_0 + \beta_1 \text{Number of hospitals} + \beta_2 \text{Number of out-care units} + \beta_3 \text{Number of nurses} + \beta_4 \text{Number of physicians} + \beta_5 \text{Urbanization rate} + \beta_6 \text{Average net wage} + e \quad (1)$$

The estimated coefficients of the predictors are presented in Table 3, where the Arrelano correction for heteroscedasticity and serial correlation has been considered.

Table 3. The estimated coefficients corrected for heteroscedasticity and serial correlation

Variables	Nosocomial infections incidence (Pooled model)
Intercept	0.886*** (<2e-16)

Hospitals	0.301*** ($<2e-16$)
Out-care	-0.132** (0.005)
Nurses	0.001* (0.011)
Physicians	0.001* (0.026)
Urbanization	-0.741*** ($<2e-16$)
Average net wage (in log)	-0.285*** ($<2e-16$)
R - Squared	21.82%
Adjusted R – Squared	20.90%
F - statistic	23.859, on 6 and 513 DF ($< 2.22e-16$)

In terms of model choice and diagnostic, an important aspect that has to be discussed is that, according to the econometric theory, we run all three models pertaining a panel data analysis: the pooled, fixed and random effects model. The lm test for poolability, testing for fixed effects, or cross – sectional specificities, indicated that there are no significant effects that should be considered. Therefore, a first conclusion that can be derived is that, although the cluster analysis revealed several clusters, after controlling for our predictors there is no significant heterogeneity left. Another aspect that deserves to be mentioned is that both the Breusch-Pagan LM test of independence and the Pasaran test for cross-sectional dependence indicate that the residuals across entities are not correlated. Table 4 presents the results of the main tests conducted in order to choose the right model and to run the model diagnostic.

The only test that warns for possible problems is the Breusch–Godfrey Test for serial correlations in idiosyncratic errors. Unlike the Durbin Watson test, it shows that there is serial correlation: to address the problem, we used the Arrelano correction of the coefficients, as mentioned in Table 3. With the estimated coefficients adjusted with this correction, we found several interesting results that will be discussed in the next section.

Table 4: Model selection and diagnostic

Test	Null hypothesis	P - value	Decision
LM test for poolability	There are not fixed effects	0.5945	Fail to reject the null
Breusch-Pagan LM test	There is no cross – sectional correlation	0.3443	Fail to reject the null
Pasaran CD test	There is no cross – sectional correlation	0.08072	Fail to reject the null
Durbin-Watson	There is no serial correlation in	0.273	Fail to reject the

test	errors		null
Breusch–Godfrey Test	There is no serial correlation in errors	1.338e-05	Reject the null

3. Conclusions, discussions and future work

A preliminary exploration of the county-level data for the incidence of the nosocomial infections across Romania revealed a number of groups displaying specific patterns of either high incidence and low variability, or the other way around. Such patterns were obtained by leaving aside the somewhat natural group formed in this case, composed of two strong university centers - Iasi and Bucharest. Their association is legitimate and unsurprising since, given their resources and expertise, they act as attractors for a significant number of patients with serious diseases. This typically leads to advanced interventions, a fact that explains the huge nosocomial infections incidence and the rather low variability around it.

When explaining the variations in incidence of the nosocomial infections using several healthcare infrastructure variables, like number of hospitals, nurses, physicians and out-care units, we found that the heterogeneity across units is removed, which means that the specificities can be explained to an important extend by specific variables that describe the regional healthcare infrastructure, urbanization and level of economic development.

Of the healthcare related variables, only the number of out-care units is negatively related with the incidence of nosocomial infections. The rest of the variables, like number of hospitals, nurses and physicians, have a positive impact, leading thus to a strong counterintuitive assessment of what may constitute first concern interventions. In other words, at this stage, increasing healthcare infrastructure in Romania, a energetically acclaimed objective, does not come only with the good expected results of improving health care access and utilization. It has a complementary side that would be dangerous to ignore: it generates an increase in the degree of patient density and therefore an increase of the risk for further nosocomial infections. This positive paradoxical association points toward the fact that the infrastructure is underdeveloped, and that further improvement will provide, at least for a certain period of time, increased access to medical services, but not necessarily better conditions. This is by no means a pledge for not investing in this crucial development of infrastructure but for not to do idealistically and if possible, to accompany it with other supporting programs, targeted directly at the reduction of nosocomial infections.

Furthermore, urbanization rate is negatively associated with the incidence of nosocomial infections, suggesting far-extending implications in the sense that urbanizations is not only correlated with better healthcare conditions, but also with better conditions in terms of education and prevention. This conclusion is supported by the negative relationship between

the nosocomial infections incidence and the average net wage: better living standards provide ground for healthier behaviors, given the same level of healthcare infrastructure.

Of the factors that have been found as reducing the incidence of nosocomial infections, none can be supported without public interventions and proper funding. While increasing the number of out-care units can have an immediate impact on reducing the undesirable incidence, developing a proper infrastructure of the healthcare system is a must that will result in positive effects in many other strategic directions of the Romanians health.

One of the main limitations of our work resides in limited data availability. The academic literature abounds in contributions discussing determinants of hospital – acquired infections, most of them grounded in analysis conducted on micro data. While accepting that our paper lacks data of a similar precision, we reached some conclusions that cannot be overlooked by policymakers. Given the fact that this is the first ecological study pertaining nosocomial infections in Romania, we hope that it will kindle the interest of other academics as well.

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