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# *Assessing health care infrastructure at the regional level: a statistical approach*

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In this paper we construct a set of infrastructure and health-need synthetic indices for the Spanish Autonomous Communities out of a wide range of representative variables by means of the statistical technique of principal components. The combination of both infrastructure and need indices yields a final index of relative coverage which proxies the access to publicly insured health care conditions of Spanish citizens in different regions.

## I. INTRODUCTION AND MOTIVATION

Our main objective in this research consists of carrying out a measurement of regional infrastructures for the Spanish health system (which is mainly publicly funded but has mixed public/private provision), from the point of view of both stocks and potential needs. Thus, an approximation to the access conditions for each region will be obtained out of the interplay between the stocks of infrastructure and need indices. This index of *relative coverage* permits one to obtain a proxy measure of relative excess demand (stock deficit) of health care services in each region, in contrast to the information gained from the two components in isolation (e.g. similar stock indices do not indicate that citizens in two regions have the same probability of access unless inequalities in potential need are considered).

Spain has undergone a rapid process of federalization in the recent past. A growing number of responsibilities, among which public health provision stands out as the destination of a large share of the public budget, have been (or are being) transferred to the Comunidades Autonomas.[1] Given that the process of transfer of responsibilities and the fiscal autonomy to finance them do not advance simultaneously, the analysis of differences in need for public health care provision across Comunidades Autonomas (CA hereafter) has become a core issue in the current research agenda. Current financing mechanisms in decentralized health services are based nearly exclusively on population and past expenditure history. However, the need for health care infrastructure can reasonably be expected to depend upon a much wider range of variables and, ultimately, these needs will have to be weighted against the existing resources before they become a meaningful argument in the funding debate.[2] Notice, in particular, that although the extreme egalitarian per capita distribution of resources among CAs would tend to eliminate regional differences in the long run (since regions with low current stocks could converge toward the mean level gradually), this principle of distribution contradicts the more reasonable needs-based criterion.[3] In these circumstances, the availability of an index of coverage is relevant in order to evaluate the short-run effects of resource allocations on regional equality of treatment when needs are similar. In parallel, such an indicator would also be useful as a guideline for the policy actions required to compensate asymmetries in initial conditions through an interregional fund.[4] Meanwhile, there exist few studies that address this issue in the literature on health infrastructure in European countries (see Bielh, 1986; Figueras *et al.*, 1992 and Culyer and Wagstaff, 1993). With this research, we intend to provide fresh evidence from a more complete set of information.

[1] The Spanish State is divided into 17 Comunidades Autonomas with different degrees of self-government.
[2] The Spanish Ley General de Sanidad (Health Act) establishes as an objective equal access to public health services and therefore the correction of regional inequalities.
[3] Unless needs are homogeneous across regions, that is. Notice also that to argue that the need-based criterion is more adequate implicitly assumes that worse health status deserve more resources (see Culyer and Wagstaff (1993) for a detailed conceptual analysis of the different equity interpretations that may be adopted).
[4] Financing schemes for the Exchequers of CAs include a compensation fund linked to EU development funds such as FEDER.

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## II. FRAMEWORK FOR THE ANALYSIS

The production of publicly financed health services ($y_j$) for each region $j$ can be represented by a function of three arguments such as

$$y_j = F_j\,(n_j, k_j, M_j) \qquad (1)$$

where $n_j$ is an indicator of need for health care, $k_j$ is an indicator of infrastructure endowments and $M_j$ are cash resources devoted to current expenditure.

The index $n_j$ may be interpreted as the cumulated effect of factors such as environmental hazards or population structure on the need for health care. Heterogeneity in $n_j$ requires different levels of both $k_j$ and $M_j$ in order to grant equal access. On the other hand, heterogeneity in $k_j$ is likely to be a result of asymmetries of past investments in infrastructures and the different proportions of the latter that are publicly available across regions.

From Equation 1, we may define

$$v_j = n_j \,/\, k_j \qquad (2)$$

The index $v_j$ is a coefficient of need relative to endowment. That is, it relates the need for health care at $CA_j$ with the degree to which such need may be covered by services available for public use. Notice also that $v_j$ could be interpreted as a parameter measuring difficulty in access to public health services in the utility function of the representative agent for $CA_j$ (see Herrero and Villar, 1991).

## III. METHOD AND DATA

Given the lack of a firm theoretical foundation for the choice of a particular variable to proxy relative needs, it is difficult to avoid a somehow arbitrary choice of variables and their degree of substitutability within the production function. Thus, stocks of infrastructures are usually measured through synthetic and/or cash equivalent public capital indicators. Likewise, health care needs are measured through socio-demographic indicators, disability, mortality and morbidity rates, risk factors, or consensus methods such as DELPHI, etc. All these variables could, in principle, be summarized by means of some kind of aggregation function (e.g. a translogarithmic or a Divisia index). As mentioned before, however, the functional form and weights for such aggregator remain unknown. Hence our strategy consists in, first, selecting a range of variables that may be associated to either $n_j$ or $k_j$ on the basis of previous literature and statistical availability.[5] Secondly, we estimate the weight with which each of these variables should contribute to the overall index by means of the statistical technique of principal components.

A principal component is a linear combination of the original variables corresponding to an underlying characteristic of the data which is 'pure' in the sense that it is not correlated to the rest of the characteristics represented by other principal components (see Manly, 1986 for instance). Given our variables,[6] we expected to obtain a principal component associated to need and another associated to stock and our results are supportive of this assumption. In fact, the largest share of the total variance in both sets of variables are explained by the 'need' and 'stock' principal components for which all included variables have a positive contribution. These contributions permit the calculation of the 'score' of each CA in terms of the two characteristics and therefore a relative ranking is easily obtainable.

With respect to the previous transformation of original variables, the following points are noteworthy. First, there is a heterogeneous level of private demand across CAs and total resources must be adjusted accordingly. Under the assumption that private demand is determined exogenously by the preferences of citizens, the stock of resources available for public use are calculated as total stocks minus stocks taken up to cover private demand.[7] Second, in line with the degree of consensus in the literature about the necessity to adjust per capita expenditure to account for the influence of the age and sex structure of the population (see Sheldon, 1994), we reweight the original stock variables by a demographic index with a view to purge them from the induced effect of sex and age differences so that the rest of relevant factors can be identified independently.[8] Therefore, our final set of stock indicators consists of resources adjusted by age and sex available for public use.

## IV. RESULTS

Concerning health care needs, the first principal component can account for 25.1 % of the variance[9] in original variables. The largest contributors, as Table 1 shows, are the adjusted rate of mortality by cardiovascular diseases (33.2%) and the rates of mortality by ischaemic diseases, followed by malignant tumours, cerebro-vascular diseases, the rate of potential life years lost and the rate of mortality by accidents and poisonings. In total, these variables account for 69.9% of the variation in the score of the component.

Turning now to endowment of infrastructures, the first principal

[5] See the Data appendix for our choice of need and infrastructure variables. (Available from authors on request).
[6] Stocks are measured by 18 variables ranging from doctors per capita to hospital beds per capita. Needs are measured by 51 variables that contain rates of mortality by main diseases, life expectancies, etc. The full set of variables are available from the authors.
[7] As a proxy for available supply, we have taken the share of publicly financed hospital cases out of total hospital cases.
[8] In particular, we compute an index of differences with respect to mean per capita expenditure by age and sex group for each CA. Thus, the effect on consumption caused directly by different population compositions is easily obtainable and can be used as a weight for the rest of the variables.
[9] The complete set of results is available from the authors on request.

Table 1. *Relative indices of need and infrastructure endowments*[a]

| Comunidad autonoma | Stock index | Rank order | Need index | Rank order | Ratio need to endowment | Rank order |
|---|---|---|---|---|---|---|
| Andalusia | 1.82172 | 6 | 1.97684 | 3 | 92.15 | 6 |
| Aragon | 1.76990 | 7 | 1.02986 | 14 | 171.85 | 15 |
| Asturias | 1.85644 | 5 | 1.93630 | 4 | 95.88 | 8 |
| Balearic I. | 1.33824 | 14 | 1.99774 | 2 | 66.99 | 1 |
| Canary I. | 1.99288 | 1 | 1.99951 | 1 | 99.67 | 9 |
| Cantabria | 1.48413 | 9 | 1.05676 | 12 | 140.44 | 12 |
| Castile-leon | 1.47184 | 10 | 1.04111 | 13 | 141.37 | 13 |
| Castile-La Mancha | 1.04878 | 16 | 1.02199 | 15 | 102.62 | 10 |
| Catalonia | 1.40813 | 13 | 1.53355 | 9 | 91.82 | 5 |
| Valencia | 1.45632 | 11 | 1.77009 | 7 | 82.27 | 4 |
| Extremadura | 1.13243 | 15 | 1.56330 | 8 | 72.44 | 2 |
| Galicia | 1.42453 | 12 | 1.93128 | 5 | 73.76 | 3 |
| Madrid | 1.98036 | 3 | 1.01236 | 16 | 195.62 | 16 |
| Murcia | 1.98396 | 2 | 1.92887 | 6 | 102.86 | 11 |
| Navarra | 1.97335 | 4 | 1.00650 | 17 | 196.06 | 17 |
| Basque C. | 1.65979 | 8 | 1.06590 | 11 | 155.71 | 14 |
| Rioja, La | 1.03779 | 17 | 1.09128 | 10 | 95.10 | 7 |

[a] The values of the indices have been scaled to lay between 1 and 2.

component of the original variables explains 32% of their variance, and the variables that contribute most are the per capita numbers of ATS (nursing professionals), doctors and surgery and internal medicine beds. Nearly 90% of the variation in the score of this component is explained by these variables, where the number of per capita staff (both doctors and nursing professionals) account for the largest share.

In Table 1 we present the ranking of CAs according to the ratio $n_j/k_j$ as well as their position with respect to need and stock separately.[10] It is noteworthy that a CA with one of the highest per capita incomes in Spain, the Balearic Islands, lies at the bottom of the stock ranking. This seems to result from the low proportion of health infrastructure available for public use, 60%, in comparison to other CAs. This effect is present for the cases of Madrid and Catalonia too and it suggests that this may be an important variable to take into account when financing schemes are debated. Valencia and Castile-La Mancha are the least endowed CAs of all. The case of the latter may be partly explained by the closeness of Madrid, which may have biased investment in infrastructures in the past. Valencia, however, contains an important volume of population and is not as close to any potential absorption of investment point, so other reasons for its underendowment need to be sought. The ranking of column 5 shows both the Balearic and Canary Islands and Andalusia as the more needy. Concerning the index of coverage, Navarra appears as the most favoured CA, followed by Madrid, Aragon and Basque Country. The other end is occupied by the Balearic Islands, Extremadura, Galicia and Comunidad Valenciana.

Correlation coefficients of the calculated indices with some of the relevant variables have also been calculated and we note that the need index is negatively (and significantly at the 1% level) correlated with the coverage index. This suggests that higher needs are, on average, not compensated with a higher stock of infrastructures. Finally, we have computed the correlation of the indices with several other measures in order to check the robustness of our results. We find, first, that the Bielh (1986) index,[11] which despite its methodological simplicity is widely used to assess inequality in infrastructure endowments, presents no significant correlation with our index. However, life expectancy and discapacity-free life expectancy at birth are positively correlated with the stock and coverage index and negatively correlated with the need index. This finding seems to lend support to our methodology.

## V. DISCUSSION

The regional pattern of health infrastructures and health needs in Spain responds to differences in past investments and geographic and socioeconomic factors. The ranking provided in Table 1 summarizes the information provided by a series of variables which the literature associates with health outcomes and infrastructure into single indices. Per capita numbers of doctors and nurses, and medical and surgical beds against potential life years lost and cancer and heart related mortality mainly determine the position of CAs along the need and infrastructure endowments axes. These results can contribute to the political debate over financing schemes but would be misused if only a myopic attitude of claiming more hospitals and doctors was adopted, for they suggest that the differences in need among regions can be explained by a very specific and limited number

[10] The scores of the components for each CA have been monotonically transformed in order to obtain positive figures rather than deviations from means values.

[11] We have used the following variables: physicians, nursing professionals and beds in use.

of factors and it may be more cost-effective to attack the root of the problem through adequate education policies than to expand care supply *ad infinitum*. This may be a core policy action area for CA health ministries.

Turning now to some possible refinements in the methodology adopted, the following points are relevant. First, the value of the indices provides only a relative ranking. Secondly, the selection of variables cannot be considered totally free from a certain degree of subjectivity, even if the results have appeared to be consistent with alternative configurations. Thirdly, we have implicitly assumed that the production function for health depends only on health services, and finally, some of the selected need variables may be *contaminated* by supply itself. These issues are being considered in our current research.

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