Investigating the Determinants of Beds for High-Care Specialties in the Italian Regions in the Environmental, Social and Governance Model

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Abstract

In the following article, it is presented an investigation of the determinants of Beds for High-Care Specialties-BHCS in the Italian regions in the context of Environmental, Social and Governance-ESG approach. Data from ISTAT-BES for 20 countries in the period 2004-2021 are been used. Different econometric techniques have been applied i.e.: Pooled Ordinary Least Squares, Panel Data with Fixed Effects, Panel Data with Random Effects, Dynamic Panel at 1 stage. Furthermore, a cluster analysis performed with a k-Means algorithm optimized with the Silhouette Coefficient indicated the presence of three clusters. Finally, eight different machine-learning algorithms are analysed to predict the future value of BHCS. The results show that the Artificial Neural Network-ANN algorithm is the best algorithm. The future value of BHSC is expected to growth on average of 4.88% for the analysed regions.

Keywords: *Analysis of Health Care Markets, Health Behaviors, Health Insurance, Public and Private, Health and Inequality, Health and Economic Development, Government Policy, Regulation, Public Health.*

JEL CODE: *I11, I12, I13, I14, I15, I18*

1) Introduction-Research Question

In this article, we present an analysis of the distribution of highly specialized medical beds within the Italian regions in the period between 2004 and 2021. The data analysed were acquired from the ISTAT-BES database [1]. The analysis of highly specialized beds is particularly relevant for the need to offer adequate care to the population. The issue is particularly serious in the Italian regions due to the chronic lack of medical personnel for both primary care and specialist care [2]. Furthermore, the trend of Italian public health spending as a percentage of GDP tends to be declining also due to the financial difficulties of the State burdened by public debt. This leads to the need to find solutions to the issue of the supply of highly specialized beds, especially to meet the needs of a population that is subjected to a significant rate of aging [3]. Furthermore, regional disparities often push the population to migrate for health reasons. That is, many patients, in order to access specialist care, have to change region with the growth of both public and private healthcare costs, as well as the reduction in the quality of life of patients and their families. Furthermore, it is very likely that the presence of highly

specialized beds is due more to the ability of medical personnel to put pressure on the policy maker rather than to the true needs of the population on a socio-demographic basis. The efficient health organization of highly specialized care requires a reorganization of the cooperation structures between primary care and specialist care, a significant intervention in the reduction of waiting lists for hospitals, and a hospital management that is oriented towards following social trends - demographics of the population. Furthermore, in the Italian case there is a further issue that can complicate the resolution of the problem of the adequate supply of highly specialized beds: the socio-economic gap between the Italian regions.

The article continues as follows: the second paragraph presents a brief analysis of the scientific literature on the topic to introduce the topic, the third paragraph contains the results of the econometric analysis, the fourth paragraph shows the results of the clustering using the k-Menas algorithm optimized with the Silhouette coefficient, the fifth paragraph presents the machine learning analysis for prediction, the sixth chapter concludes.

2) Literature Review

In the following part we present a brief analysis of the literature relating to the management of highly specialized beds, with attention also to the questions related to the Intensive Care Units-ICU and the High Care Units-HCU.

The management of hospital beds. Extending patient stays in hospital emergency departments for more than 12 hours increases healthcare costs, comorbidity and mortality rates [4].

High care specialties and Covid19. The Covid 19 pandemic has made the condition of patients who require specialist care, such as in the case of hand pathologies, very complex [5]. The lack of cooperation between medical staff employed in primary and secondary care worsened the hospital response during Covid 19 in Lombardy [6].

The management of Intensive Care Units-ICU and High Intense Care Units-HCU. Intensive care units that have strict staff selection criteria experience low levels of in-hospital patient mortality in Japan [7]. Patients who are ventilated outside of ICUs are at risk of higher mortality rates [8]. The insufficient presence of ICUs has reduced the efficiency of the healthcare response during the Covid 19 pandemic in South Africa [9]. The insufficiency of ICU and HCL in Japan during seismic events poses significant questions relating to the care of people requiring specialized care and assistance [10]. The lack of adequate financial resources and supplies makes healthcare complex even in ICUs in South Africa [11].

The management of specialist care. It is necessary to develop methodologies for specialized healthcare for population cohorts, as in the case of asthma in the childhood population in Denmark [12]. The lack of specialist care is evident in the case of asthma patients in the UK [13]. Improving management practices can lead to a significant reduction in the time needed to receive specialist care, as is the case in Sweden [14]. Access to specialty care has been significantly hindered by the Covid 19 pandemic crisis in Canada. To solve the problem of access to specialist care, a system of collaboration between general practitioners and specialist doctors has been developed [15]. Waiting lists and the lack of organizational efficiency at healthcare management level limit patients' access to care, as in the case of migraine treatment [16]. The technological and organizational innovations introduced at a therapeutic level have made it possible to modify the assistance and treatment systems, moving from interventions by specialists to interventions by non-specialists also thanks to secondary prevention [17]. The use of risk-based healthcare systems could increase the ability to distinguish patients between primary and secondary care while also managing to identify patients who require

more specialized care, as in the case of nephrology in the UK [18]. The existence of barriers to entry and long hospitalization times prevent increasing access to specialist care for people with asthma, as demonstrated in the case of Canada [19].

3) Econometric Model for the Estimation of the Determinants of the BHCS

The analysis of the value of BHCS took place through the analysis of various econometric techniques, namely: Pooled Ordinary Least Squares-OLS, Panel Data with Fixed Effects, Panel Data with Random Effects, 1 Step Dynamic Panel. The data is acquired from the ISTAT-BES dataset for the period 2004-2021 for the Italian regions. We have estimated the following equation:

$$\boldsymbol{BHCS_{it} = \alpha + \beta_1(RI)_{it} + \beta_2(SP)_{it} + \beta_3(EPWH)_{it} + \beta_4(RUP)_{it} + \beta_5(SSC) + \beta_6(DWL)_{it} + \beta_7(RIU)_{it} + \beta_8(ILS)_{it} + \beta_9(CPP)_{it}}$$

Where i=20 and t=[2004-2021]. The list of variable is shown in Table 1.

List of Variables			
Label	**Variable**	**Acronym**	**Description**
A7	Inadequate literacy skills	ILS	Percentage of students in classes III of lower secondary school who do not reach a sufficient level of alphabetic competence.
A22	Employed people working from home	EPWH	Percentage of employed people who carried out their work from home in the last 4 weeks out of total employed people.
A36	Social participation	SP	Persons aged 14 and over who have carried out at least one in the last 12 months social participation activities out of the total people aged 14 and over. The activities considered are: participating in meetings or initiatives (cultural, sports, recreational, spiritual) created or promoted by parishes, congregations or religious groups or spiritual; participate in association meetings cultural, recreational or other; participate in meetings of ecological associations, for civil rights, for peace; participate in meetings of trade union organizations; participate in association meetings professional or category; attend meetings of political parties; carry out free activities for a match; pay a monthly or periodic fee for a sports club/club.
A37	Civic and political participation	CPP	Percentage of people aged 14 and over who carry out at least one civic and political participation activity out of the total number of people aged 14 and over. The activities considered are: talking about politics at least once a week; inform yourself about the facts of Italian politics at least once a week; participate online in consultations or votes on social (civic) or political problems (e.g. urban planning, signing a petition) at least once in the 3 months preceding the interview; express opinions on social or political issues through websites or social media at least once in the 3 months preceding the interview.
A77	Dissatisfaction with the landscape of the living place	DWL	Percentage of people aged 14 and over who declare that the landscape of the place they live is affected by evident degradation out of the total number of people aged 14 and over.
A87	Swimming sea coasts	SSC	Percentage of authorized bathing coasts out of the total coastal line in accordance with current regulations.
A97	Research intensity	RI	Percentage of spending on intramural research and development activities carried out by companies, public institutions, universities (public and private) and the non-profit sector on GDP. Expenditure and GDP are considered in millions of current euros.
A103	Regular internet users	RIU	Percentage of people aged 11 and over who used the Internet at least once a week in the 3 months preceding the interview.
A113	Regular users of public transport	RUP	Percentage of people aged 14 and over who use public transport several times a week (buses, trolleybuses, trams within their own municipality; coaches or coaches connecting different municipalities; train)
A117	Beds for high-care specialties	BHCS	Beds in high-care specialties in ordinary hospitalization in public and private healthcare institutions per 10,000 inhabitants.

Table 1. List of Variables.

The econometric results i.e. Pooled Ordinary Least Squares-OLS, Panel Data with Random Effects, Panel Data with Fixed Effects, and 1-Step Dynamic Panel are shown in Table 2. In the same table are indicated the values of coefficients, standard errors and p-value. Finally, Table 2 shows the average value of the coefficient for each variable for the proposed econometric models.

Econometric Results for the Estimation of the Value of BHCS in the ESG Model in the Italian Regions						
		Pooled OLS	**Fixed Effects**	**Random Effects**	**1-step dynamic panel**	

const	Variable	Coefficient	Standard Error	p-Value	Coefficient	Standard Error	p-Value	Coefficient	Standard Error	p-Value	Coefficient	Standard Error	p-Value	Average
	Constant	3,43304	0,139232	***	3,27393	0,12761	***	3,29024	0,17012	***				2,4993
A7	Inadequate literacy skills	-0,0315883	0,00458027	***	-0,030415	0,00363	***	-0,0306	0,00353	***	-0,028	0,00299	***	-0,0302
A22	Employed people working from home	0,0601662	0,0131186	***	0,0608181	0,01025	***	0,06127	0,01001	***	0,06824	0,00699	***	0,06262
A36	Social participation	0,0748522	0,0117799	***	0,0681201	0,00968	***	0,06871	0,00943	***	0,09636	0,0195	***	0,07701
A37	Civic and political participation	-0,0432891	0,00575662	***	-0,0404057	0,00458	***	-0,0407	0,00447	***	-0,0468	0,00848	***	-0,0428
A77	Dissatisfaction with the landscape of the living place	-0,0150843	0,00584559	**	-0,0152209	0,00428	***	-0,0152	0,00425	***	-0,0133	0,00401	***	-0,0147
A87	Swimming sea coasts	0,0089835	0,00161377	***	0,00996947	0,00136	***	0,00999	0,00133	***	0,00687	0,00116	***	0,00895
A97	Research intensity	0,747539	0,0877077	***	0,873115	0,10752	***	0,86062	0,10108	***	0,50903	0,15996	***	0,74758
A103	Regular internet users	-0,0233691	0,00445658	***	-0,0248467	0,00333	***	-0,0249	0,00328	***	-0,0344	0,00541	***	-0,0269
A113	Regular users of public transport	0,0139629	0,00530796	***	0,0187885	0,00492	***	0,01869	0,00476	***	0,0151	0,00668	**	0,01664
A117 (-1)	Beds for High-Care Specialties										0,2323	0,04826	***	0,05807

Table 2. Econometric Results for the Estimation of the Value of BHCS in the ESG Model in the Italian Regions

The analysis shows that the level of BHCS is positively associated to the following variables:

- *RI*: i.e. research intensity is a variable that represents the percentage of spending on research and development activities carried out by companies, public institutions, universities and the non-profit sector. There is a positive relationship between the value of BHCS and the value of RI. That is, the regions in which the value of RI increases also tends to increase the value of BHCS. For example, if we consider the average values of BHCS and RI between 2004 and 2020 and compare them we can see that many regions that have a high RI value also have a high BHCS value. In particular, this proposition is true for Piedmont which has an RI value equal to 1.97 and BHCS equal to 3.94, Lazio with 1.63 and 3.58, Emilia Romagna with 1.61 and 3.47, Friuli Venezia Giulia with 1.48 and 2.86, Liguria with 1.32 and 3.84, Tuscany with 1.27 and 3.41, Lombardy with 1.23 and 3.4 and Campania with 1.2 and 3, 06. Since research intensity tends to grow with gross domestic product, we can see that regions that have greater research intensity also have greater resources to provide for the growth of BHCS. We also note that the regions indicated are almost all in the centre-north with the sole exception of Campania.

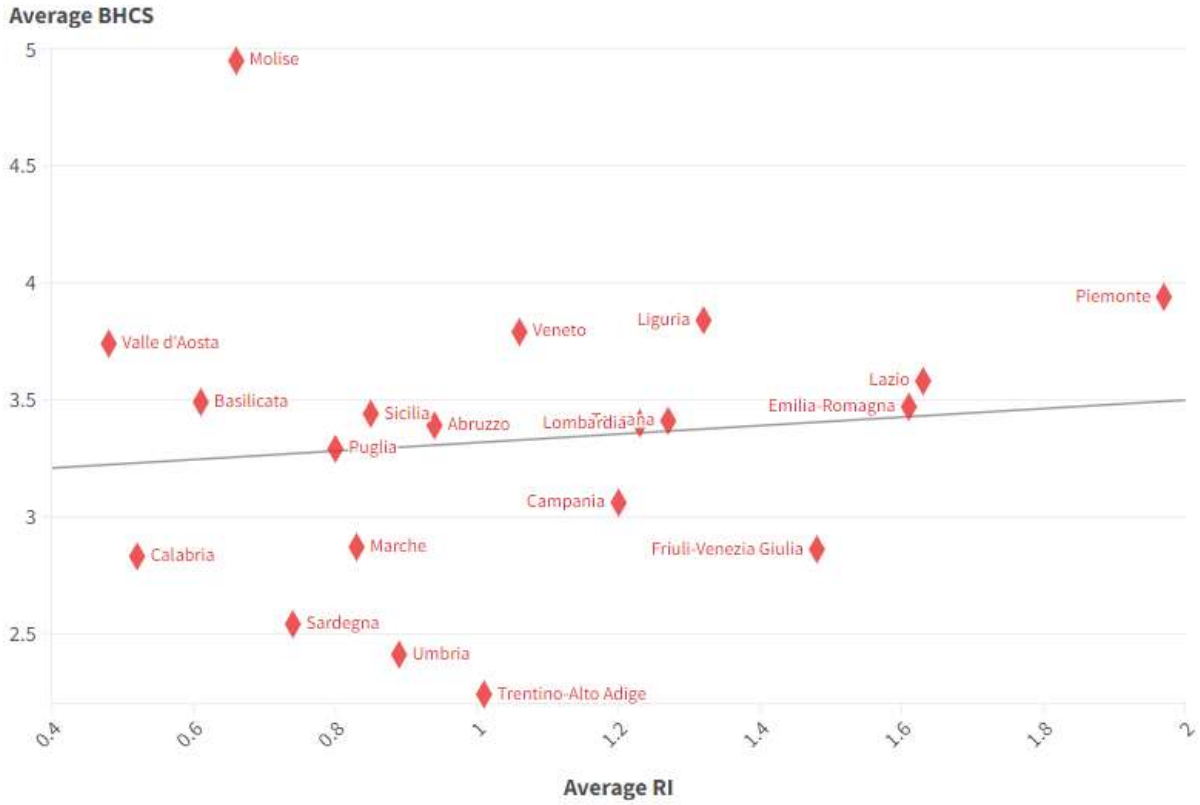

Figure 1. Relationship between average BHCS and average RI. The level of BHCS tends to growth in connection with the level of RI.

- *SP*: i.e. social participation. It is a variable that represents people aged 14 and over who have carried out at least one in the last 12 months social participation activities on the total of people aged 14 and over. The activities considered are: participation in meetings or initiatives (cultural, sporting, recreational, spiritual) conceived or promoted by parishes, congregations or religious or spiritual groups; participate in cultural, recreational or other associative meetings; participate in meetings of ecological, civil rights and peace associations; participate in trade union meetings; participate in professional or trade association meetings; participate in political party meetings; carry out free activities in preparation for a match; pay a monthly or periodic fee for a sports club/club. If we consider the value of SP and BHCS in 2020 we can see that there are many regions that have higher than average values in both variables. For example, Molise has an SP value of 27.1 and a BHCS value of 4.6, Valle d'Aosta with an SP value of 30.8 and a BHCS value of 4, Veneto with 35.5 and 3.9, Liguria with 29.8 and 3.5, Lombardy with 32.7 and 3.3, Puglia with 27.8 and 3.2, Sicily with 22.5 and 3.2, Piedmont 29.5 and 3.1, Tuscany with 29.8 and 3.1. We can note that among the regions that have high levels of BHSC and SP there are both southern regions such as Puglia and Sicily and regions in the Centre-North.

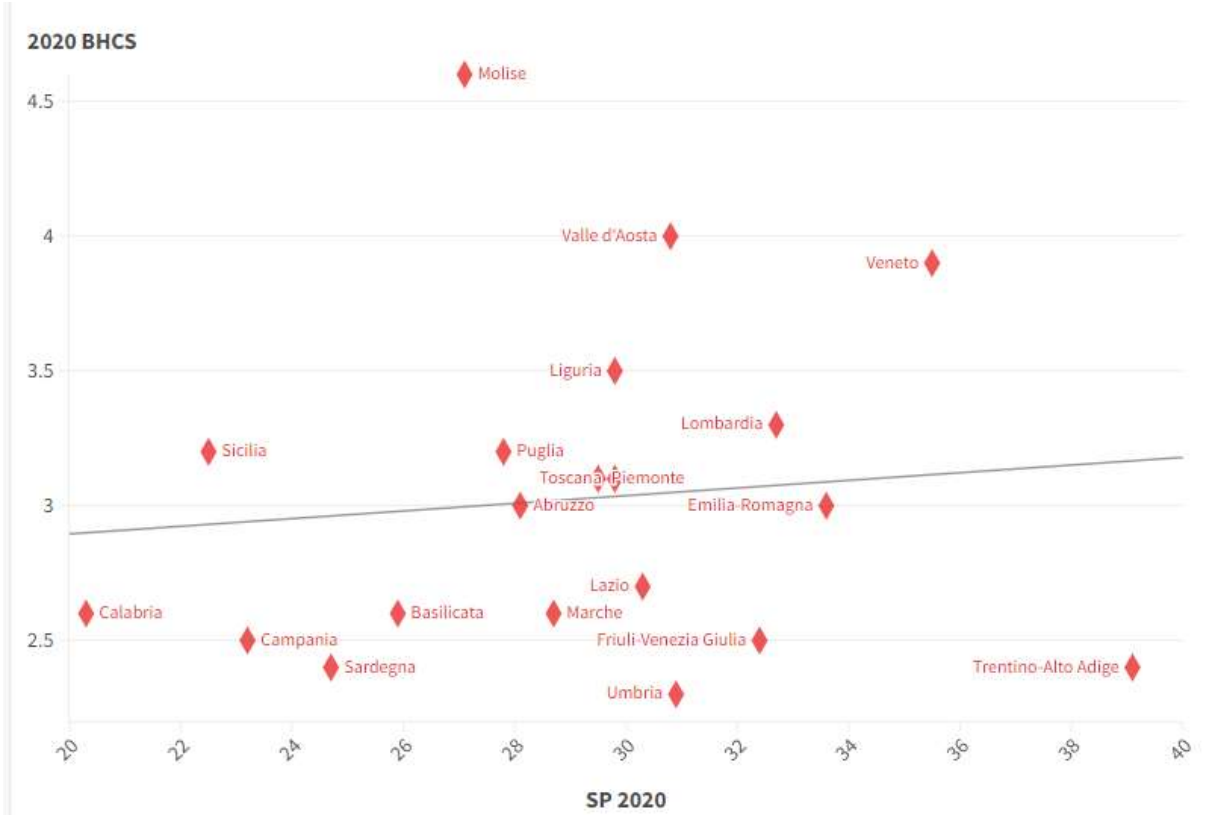

Figure 2. Relationship between BHCS and SP in 2020. The growth in the value of BHCS is positively associated with the growth in the value of social participation.

- *EPWH*: it is a variable that considers the percentage of employed people who have carried out their work from home in the last 4 weeks out of the total number of employed people. There is a positive relationship between the value of EPWH and the value of BHCS. If we consider the average value of EPWH and BHCS we can see that there are many regions that have a value higher than the average for the period. The average EPWH value detected in the period is equal to 7.26 and the BHCS value is equal to 3.33. These regions are Lazio with an average EPWH value equal to 10.07 and BHCS equal to 3.58 , Liguria with an EPWH value equal to 9.53 and BHCS equal to 3.84, Lombardy with an EPWH value equal to 8.97 and BHCS equal to 3.4, Emilia Romagna with an EPWH value equal to amount of 8.73 and a BHCS value equal to 3.47, Piedmont with an EPWH value equal to 8.43 units and BHCS equal to 3.94, Tuscany with an EPWH value equal to 8.17 and BHCS equal at 3.41, Veneto with an EPWH value of 7.3 and a BHCS value of 3.79. We can see that in the regions where the EPWH value is higher the BHCS value is also higher. However, none of the southern regions have high EPWH and BHCS values.
- *RUP*: is a variable that considers the value of the percentage of people aged 14 and over who use public transport several times a week (buses, trolleybuses, trams within their own municipality; coaches or coaches connecting different municipalities; train). There is a positive relationship between the value of RUP and the value of BHCS. For example, if we take into consideration the average values of RUP and BHCS in the period 2005-2020 we can note that there are many regions that have RUP and BHCS values higher than the average, namely: Liguria with an RUP value of 26.54 and a BHCS value equal to 3.83 units, Lazio with a RUP value equal to 24.78 and a BHCS value equal to a value of 3.47, Lombardy with a RUP value equal to 18.29 and a value of 3.37 units, Piedmont with a RUP value equal to

18.06 and a BHCS value equal to an amount of 3.87 units. We can therefore conclude from the analysis carried out that in the regions in which there is greater use of public transport there is also a greater orientation towards making highly specialized hospital health services available to the population (Figure 3).

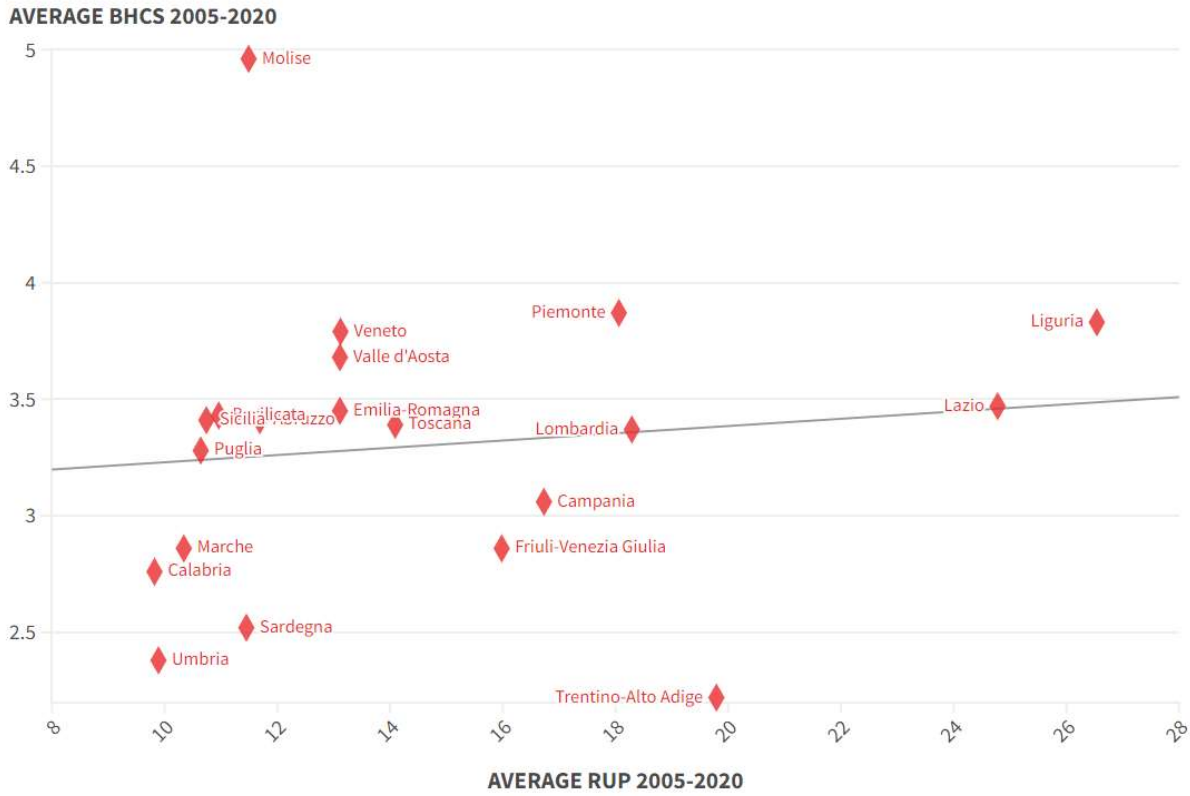

Figure 3. The positive relationship between the average of BHCS in the period 2005-2020 and the average of RUP in the same period.

- SSC: is a variable that considers the Percentage of authorized bathing coasts out of the total coastal line in accordance with current regulations. There is a positive relationship between the value of SSC and the value of BHCS. Specifically we can note that by averaging the respective SSC and BHCS values between 2013 and 2019 there are many regions that have high levels in both variables. For example, Basilicata has an SSC value equal to 191.51 and a BHCS value equal to an amount of 3.07 units, Molise has an SSC value equal to 78.07 units and a BHCS value equal to 4 .95 units, Puglia with a value of SSC with a value of 74.67 units and a value of BHCS equal to an amount of 3.17, Tuscany with a value of SSC equal to 72.27 units and a value of BHCS equal to 3.12, Veneto with an SSC value equal to 64.20 units and a BHCS value equal to 3.74, Emilia Romagna with an SSC value equal to 61.11 units and a BHCS value equal to 3.22, Liguria with an SSC value equal to an amount of 58.60 units and a BHCS value equal to 3.50, Sicily with an SSC value equal to 56.33 units and a BHCS value equal to 3 ,50 units. It should be considered that among the regions considered there is only one southern region while the other regions are in the centre-north (Figure 4).

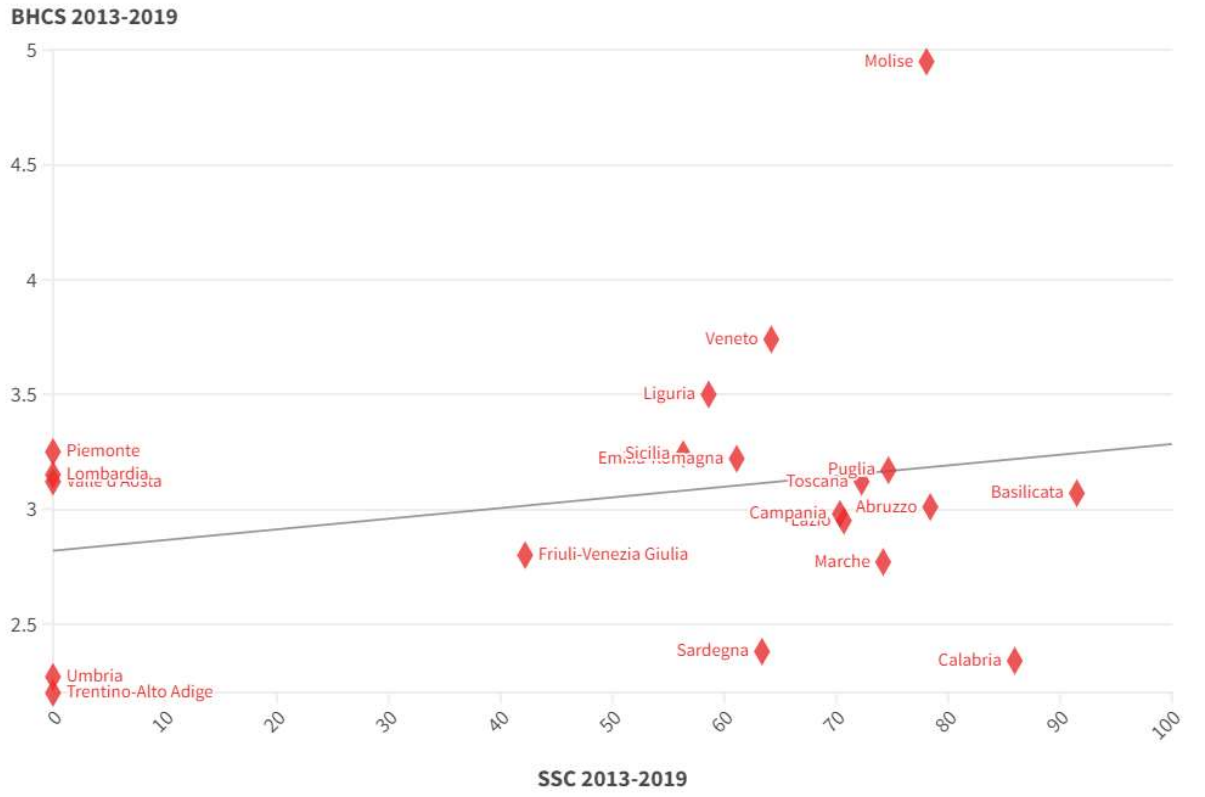

Figure 4. The positive relationship between BHCS and SSC as average value in the period 2013-2019.

The econometric results also show that the level of BHCS is negatively associated to the following variables:

- DWL: it is a variable defined as the percentage of people aged 14 and over reporting that the landscape of the living place is affected by obvious degradation on the total number of people aged 14 and over. There is a negative relationship between the value of BHCS and the value of DWL. In fact, if we consider 2020 we can notice that there are a set of regions that have BHCS and DWL values below the average. That is, Umbria with a BHCS value of 2.3 and a DWL value of 13.4, Trentino Alto Adige with a BHCS value of 2.4 and a DWL value of 7.5 units, Friuli Venezia Giulia with a BHCS value equal to 2.5 units and a DWL value equal to 10.2 units, Marche with a BHCS value equal to 2.6 units and a DWL value equal to 10.7 units, Abruzzo with a BHCS value of 3 and a DWL value of 14.2 units, Emilia Romagna with a BHCS value of 3 and a DWL value of 13.7 units. We can therefore see that regions that have lower levels of satisfaction with the landscape have higher levels of highly specialized beds (Figure 5).

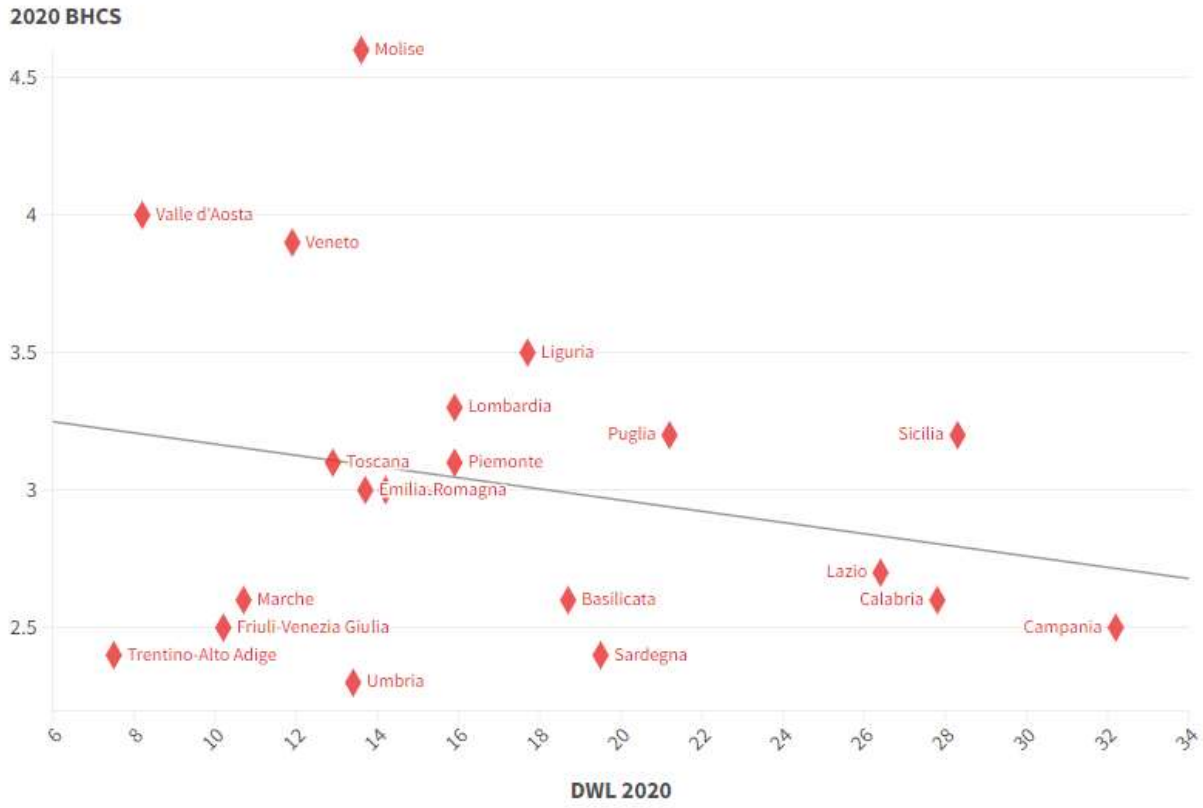

Figure 5. Negative relationship between the value of BHCS and the value of DWL in 2020 in the Italian regions.

- RIU: it is a variable that considers the percentage of people aged 11 and over who used the Internet at least once a week in the 3 months preceding the interview. There is a negative relationship between the value of RIU and the value of BHCS. Specifically, if we consider 2020 we can see that many countries that have a high level of RIU also have a low level of BHCS. For example, Trentino Alto Adige has a RIU value of 75.1 and a BHCS value of 2.4 units, Emilia Romagna has a RIU value of 74.3 units and a BHCS value of 3, Lazio with an RIU value equal to 73.4 units and a BHCS value equal to 2.7 units, Friuli Venezia Giulia with a RIU value equal to 71.2 units and BHCS equal to 2.5, and Umbria with a RIU value equal to 69.3 and a BHCS value equal to 2.3. Therefore, regions that have high levels of internet users also have very low levels of beds for highly specialized care. Obviously, there are also exceptions, i.e. regions that have high levels of both RIU and BHCS such as Lombardy, Tuscany, Piedmont and Liguria. In fact, if we look at the numerical values we can see that the average value of RIU compared to BHCS is equal to -0.0269, which is a negative value, however very small and close to zero (Figure 6).

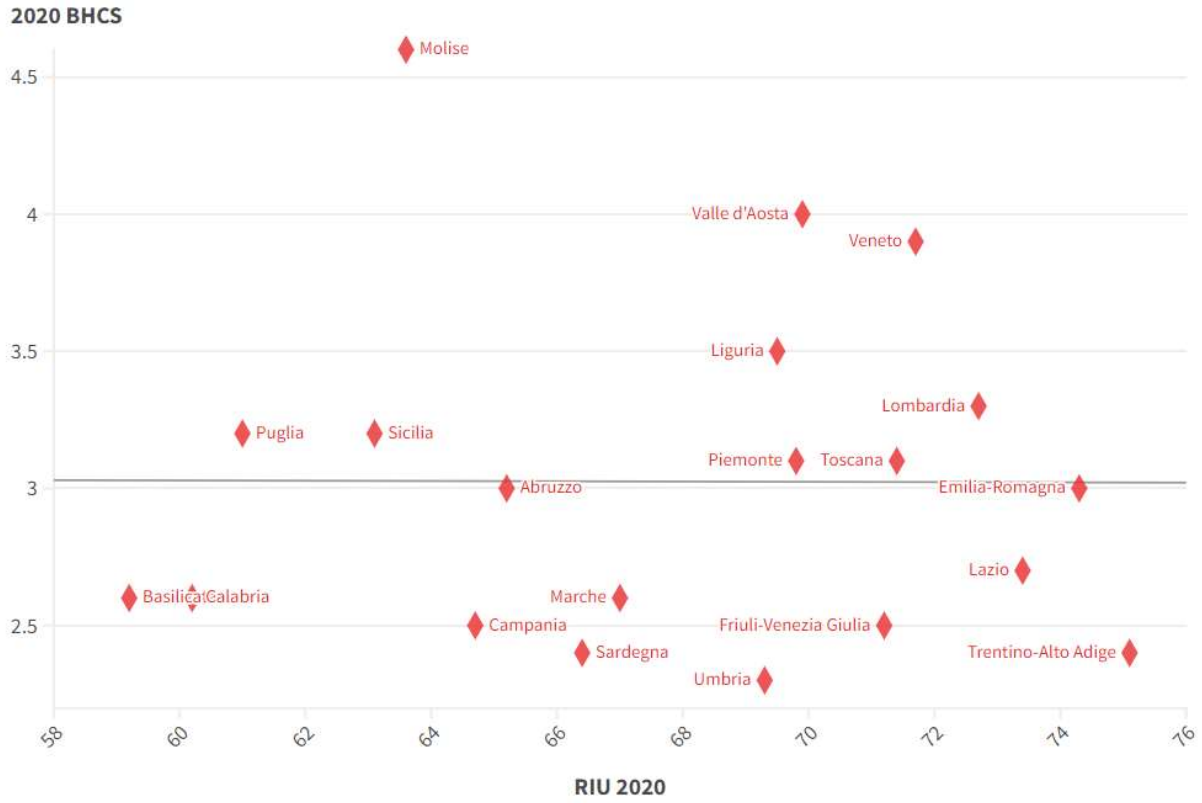

Figure 6. Negative relationship between BHCS and RIU. The value is negative even if it is closer to zero.

- ILS: is a variable that considers the percentage of students in classes III of lower secondary school who do not reach a sufficient level of alphabetic competence. There is a negative relationship between the value of BHCS and the value of ILS. Specifically, if we take 2019 into consideration we can see that there are various regions that have a BHCS value above the average and at the same time an ILS value below the average. For example, Molise has a BHCS value of 4.3 and an ILS value of 34.1 units, followed by Veneto with a BHCS value of 3.8 units and an ILS value of 29.6 units, Liguria with BHCS equal to 3.5 units and ILS equal to 32.4 units, Emilia Romagna with BHCS equal to 3.2 units and ILS equal to 31.7 units, Piedmont with BHCS equal to 3.1 units and ILS equal at 31.8 units, Lombardy with BHCS equal to 3.1 units and ILS equal to 29.1 units, Tuscany with BHCS equal to 3 and ILS equal to 32.5 units, Abruzzo with BHCS equal to 3 and ILS equal to 33 That is, in the Italian regions where there is a high level of highly specialized beds there is also a reduced value of basic alphabetic ability (Figure 7).

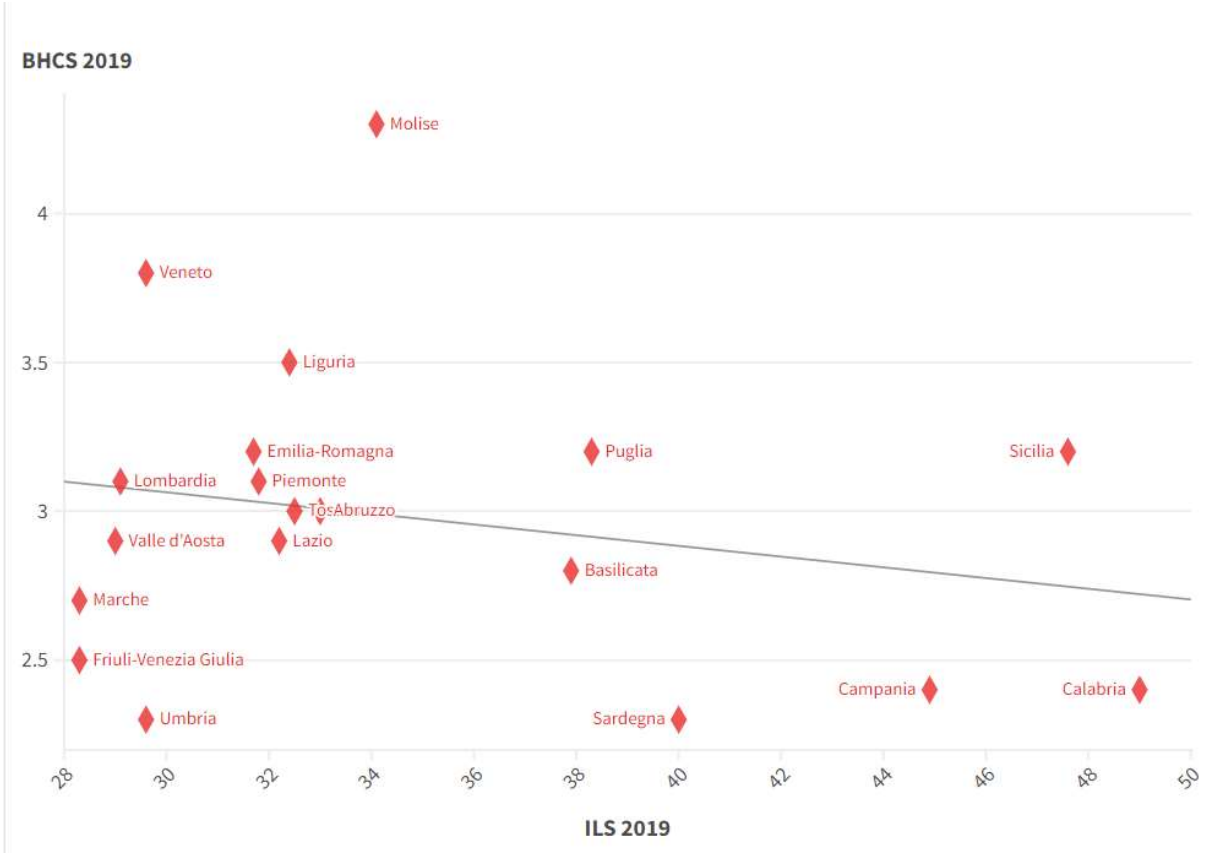

Figure 7. Negative relationship between the value of BHCS and the value of ILS in 2019.

- CPP: it is a variable that considers the percentage of people aged 14 and over who carry out at least one civic and political participation activity out of the total number of people aged 14 and over. The activities considered are: talking about politics at least once a week; inform yourself about the facts of Italian politics at least once a week; participate online in consultations or votes on social (civic) or political problems (e.g. urban planning, signing a petition) at least once in the 3 months preceding the interview; express opinions on social or political issues through websites or social media at least once in the 3 months preceding the interview. There is a negative relationship between the CPP value and the BHCS value. If we take into consideration the average value of CPP and BHCS between 2011 and 2020. We can therefore see that there are many regions that have a CPP value above the average and at the same time a BHCS value below the average. For example, Friuli Venezia Giulia has a CPP value of 70.41 units and a BHCS value of 2.8, Umbria with a CPP value of 68.03 and a BHCS value of 2, 27, Trentino Alto Adige with a CPP value equal to 67.71 and a BHCS value equal to 2.22 units, Sardinia with a CPP value equal to 66.73 units and BHCS equal to 2.43, Lazio with CPP equal to 66.72 units and BHCS equal to 2.98 units, Marche with a CPP value equal to 66.08 units and BHCS equal to 2.8 units. It therefore follows that the regions in which there is an increasing value of civic and political participation have a decreasing value of the availability of beds for specialist care (Figure 8).

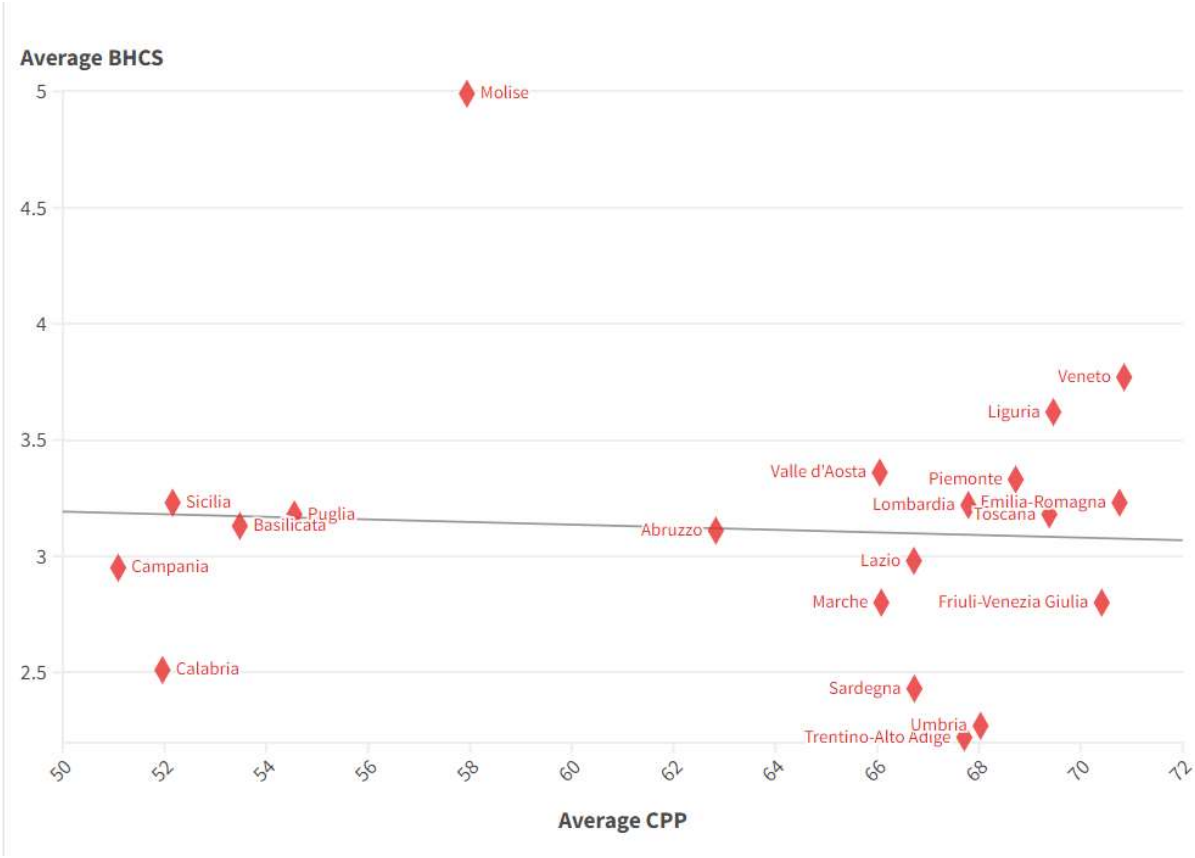

Figure 8. Negative relationship between the BHCS value and the CPP value, both considered as trail averages for 2011 and 2020.

The strange case of Molise as an outlier. In the analysis carried out, the outlier condition of Molise is evident as showed in Figure 1-8. In fact, if we consider the historical series of the BHCS value we can note that Molise has values that are structurally above the average in the period between 2004 and 2020. However, even if this value may certainly appear unusual we can note that from an absolute point of view the Molise's BHCS values are not excessively high. In fact, since Molise has approximately 305,617 inhabitants, and since the BHCS variable is calculated as a value per 10,000.00 inhabitants, since the average value of BHCS between 2004 and 2020 is equal to a value of 4.94, then it appears that the value of highly specialized beds is equal to 305,617/10,000.00*4.94 or equal to 150.97 units. An absolute value that is actually very small when compared to other regions that, having a larger population, also have much more significant absolute values of BHCS.

3.1) A Reclassification of the Determinants of the Estimated Econometric Models in the Sense of ESG Model

Below we propose a reclassification of the econometric model proposed based on the Environment, Social and Governance-ESG logic. The ESG dynamics tends to create synthetic indicators that allow us to evaluate to what extent a certain economic policy, or a certain management model, is sustainable in terms of the environment, society and governance. In the case analysed, after having estimated the variables with the econometric models has showed in the previous paragraph, we can propose a reclassification of the variables to first draw indicators of the E-Environment, S-Social and G-Governance type and then a synthetic ESG-type indicator.

The E-Environment Determinants on the BHCS variable. If we take into consideration the impact of the E-Environment group variables on the BHCS variable, we can see that the result is positive. In

particular, in the reclassification process, three variables were identified that capture the E-Environment element, namely DWL, SSC and RUP. The following analysis therefore derives:

$$BHCS_E = \frac{DWL_{PooledOLS} + DWL_{RandomEffects} + DWL_{FixedEffects} + DWL_{DynamicPanel}}{4} + \frac{SSC_{PooledOLS} + SSC_{RandomEffects} + SSC_{FixedEffects} + SSC_{DynamicPanel}}{4} + \frac{RUP_{PooledOLS} + RUP_{RandomEffecets} + RUP_{FixedEffects} + RUP_{DynamicPanel}}{4} = -0{,}015 + 0{,}009 + 0{,}017 = 0{,}011$$

It therefore follows that the relationship between the BHCS variable and the E-Environment variables is positive with a value equal to 0.011 units. However, we can note that if on the one hand the value of BHCS increases with the use of public transport and with swimming sea coasts, on the other hand the value of BHCS is negatively correlated with the value of dissatisfaction with the quality of the landscape. However, even if the overall relationship between BHCS and the E-Environment variables is positive, we cannot fail to notice that it is still a value very close to zero. In any case, this relationship allows us to establish that there is a positive relationship between the value of BHCS and the value of the E-Environment component within the estimated econometric model.

The S-Social Determinants on the BHCS variable. In the reclassification of the econometric model estimated within the ESG context, we considered the following variables as representative of the S-Social component, namely: EPWH and SP. We therefore calculated the existing relationship between BHCS and the S-Social component considered as an aggregate of EPWH and SP that is:

$$BHCS_S = \frac{EPWH_{PooledOLS} + EPWH_{RandomEffects} + EPWH_{FixedEffects} + EPWH_{DynamicPanel}}{4} + \frac{SP_{PooledOLS} + SP_{RandomEffects} + SP_{FixedEffects} + SP_{DynamicPanel}}{4} = 0{,}063 + 0{,}077 = 0{,}140$$

It follows that there is a positive relationship between the value of BHCS and the value of the S-Social component within the ESG context constituted as the sum of EPWH and SP. Specifically, the component that is most important is social participation. It is therefore possible to state that in the Italian regions in which the value of social participation is growing and the number of employees who work remotely is also growing, the value of BHCS is also growing. It is therefore possible that the regions that pay more attention to the social condition are also more attentive, from a political and value point of view, to offering adequate healthcare solutions to citizens. There is therefore a social determinant positively connected with the efficiency of healthcare provision on a regional basis.

The G-Governance Determinants on the BHCS variable. Below we take into consideration the relationship between BHCS and the variables associated with the G-Governance component within the ESG model. In particular, among the variables of the estimated econometric model, 4 variables relating to the G-Governance component were identified, namely: ILS, CPP, RI and RIU. We can therefore calculate the relationship between BHCS and the variables of the estimated econometric model attributed to the G-Governance component in the ESG model, that is:

$$BHCS_G = \frac{ILS_{PooledOLS} + ILS_{RandomEffects} + ILS_{FixedEffects} + ILS_{DynamicPanel}}{4} + \frac{CPP_{PooledOLS} + CPP_{RandomEffects} + CPP_{FixedEffects} + CPP_{DynamicPanel}}{4} + \frac{RI_{PooledOLS} + RI_{RandomEffects} + RI_{FixedEffects} + RI_{DynamicPanel}}{4} + \frac{RIU_{PooledOLS} + RIU_{RandomEffects} + RIU_{FixedEffects} + RIU_{DynamicPanel}}{4} = -0{,}030 - 0{,}043 + 0{,}748 - 0{,}027 = 0{,}648$$

It follows that there is a positive relationship between the value of BHCS and the variables calculated as belonging to the G component within the estimated econometric model. However, we can note that the positivity of the RI variable cancels out the negative effects of the ILS, CPP and RIU variables. It therefore follows that the most relevant variable within the G-Governance component is RI. That is, in the Italian regions in which the value of spending on research and development is growing, the supply of BHCS is also growing. It is likely that the relationship is because the regions that provide highly specialized medical beds are themselves financed and supported, at least in part, by research and development projects. Obviously, the presence of healthcare facilities, including university ones, equipped with adequate financial resources can also allow for the development of an adequate supply of highly specialized beds. Regarding ILS, CPP and RIU we note that each of these variables is negatively connected to BHCS. This result is counterfactual with regard to CPP and RIU and is instead quite understandable in the case of ILS. In fact, CPP and RIU should be positively connected to the value of BHCS as generally in regions where there is greater political and social participation and where there are greater internet users there is a growth in sensitivity towards health policy issues such as those connected to the BHCS offer. On the contrary, the relationship between ILS and BHCS can be easily explained by considering that regions that have a low level of literacy skills also have low sensitivity in putting pressure on the policy maker in order to increase the provision of BHCS.

Overall, we can see that the overall value of the ESG component on the BHCS variable is positive, that is:

$$BHCS_{ESG} = BHCS_E + BHCS_S + BHCS_G = 0{,}011 + 0{,}140 + 0{,}648 = 0{,}798$$

It follows that the regions in which the E-Environment, S-Social, and G-Governance components are growing also tend to increase the presence of highly specialized medical beds. That is, the quality and efficiency of the healthcare system at a regional level are essentially connected to the presence of economic policy interventions positively inspired to the ESG model.

4) Clusterization with k-Means Algorithm Optimized with the Silhouette Coefficient

Below we apply the k-Means machine learning algorithm to analyze the performance of the Italian regions in terms of BHCS. However, since the k-Means algorithm is an unsupervised machine learning algorithm, then it is necessary to introduce an optimization tool to identify the optimal number of k, i.e. Clusters. The analysis shows the presence of three clusters:

- *Cluster 1*: Sardinia, Umbria, Trentino Alto Adige, Marche, Friuli Venezia Giulia, Calabria, Campania;
- *Cluster 2*: Molise;
- *Cluster 3*: Liguria, Basilicata, Emilia Romagna, Sicily, Valle d'Aosta, Tuscany, Veneto, Piedmont, Lombardy, Lazio, Abruzzo, Puglia.

From the point of view of clustering it appears that the first cluster is made up of Cluster 2, followed by cluster 3 and then by Cluster 1. The following ordering of the clusters therefore derives: C2>C3>C1. We can see that cluster 2 is made up of a single region, namely Molise. This region showed very high levels in terms of BHCS in the observation period, i.e. between 2004 and 2020. Therefore, it represents an outlier within the context of the Italian regions in terms of BHCS value. Cluster 3, made up of a set of very heterogeneous and economically and geographically varied regions, follows this. Finally, in last place in terms of BHCS value is cluster 1, also in this case made up of very different regions from a geographical point of view and also from the point of view of per capita income. Therefore, if we look at the composition of the clusters within the Italian regions we can notice a substantial heterogeneity with regions that have significant socio-economic differences despite being part of the same clusters (Figure 9).

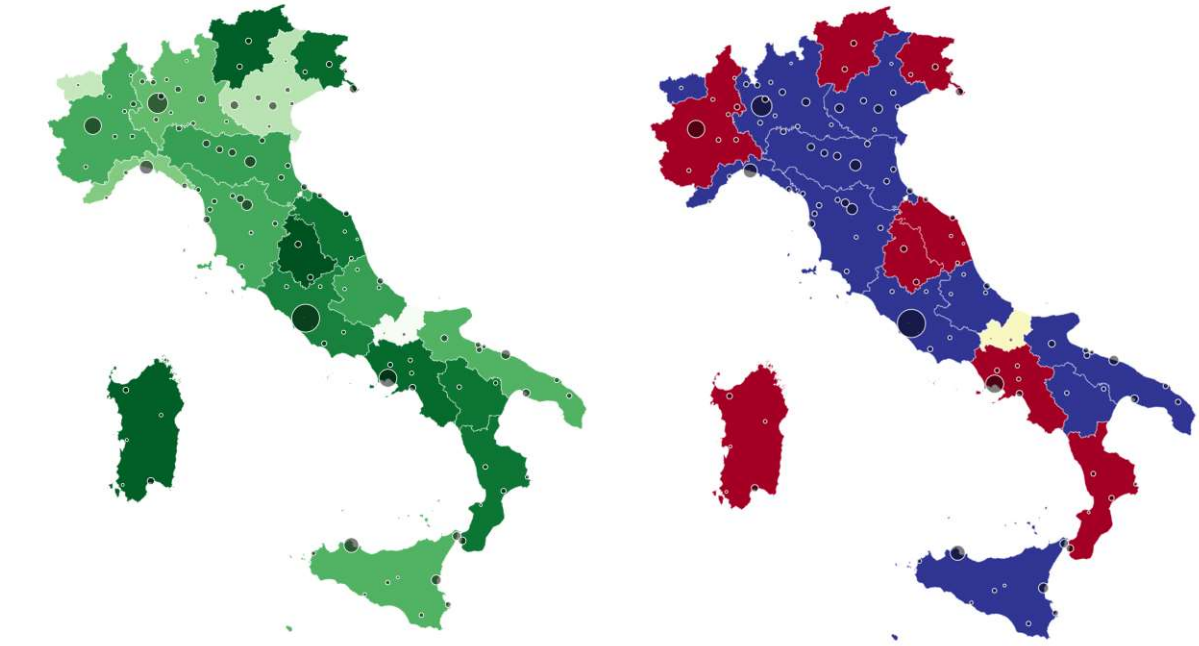

Figure 9. On the left, the Italian regions by BHCS value in 2020 and on the right the clustering of the regions with the k-Means algorithm optimized with the Silhouette coefficient.

If we consider the value of BHCS in 2020, we can see that Molise is in first place with a value of 4.6 units, followed by Valle d'Aosta with an amount of 4.00 units, and Veneto with 3.9 units. In the middle of the table are Tuscany with a value of 3.1 units followed by Emilia Romagna and Abruzzo with a value of 3 units. Trentino Alto Adige and Sardinia close the ranking with a value of 2.4 units and Umbria with a value of 2.3 units. If we take into consideration, the variation between 2004 and 2020 we can note that the value of BHCS has grown significantly in Veneto, going from an amount of 3.8 in 2004 to 3.9 in 2020, i.e. a variation equal to 2.63%. . In all other regions, the percentage change in the BHCS value is negative between 2004 and 2020. The situation is particularly serious in the following regions: Umbria with a change of -23.33% between 2004 and 2020, Calabria with -33.33%, Piedmont with -39.22%, Basilicata with -42.22%, and Lazio with -50.00%. On average, the value of BHCS in the Italian regions between 2004 and 2020 decreased from an amount of 3.79 units to 3.025 units, i.e. a variation of -20.18% (Figure 10). The data therefore highlights a general decline in the value of BHCS between 2004 and 2020. A significant reduction, which affected both southern and northern regions and which also, involved some rich regions of Northern Italy such as Friuli Venezia Giulia and Trentino Alto Adige.

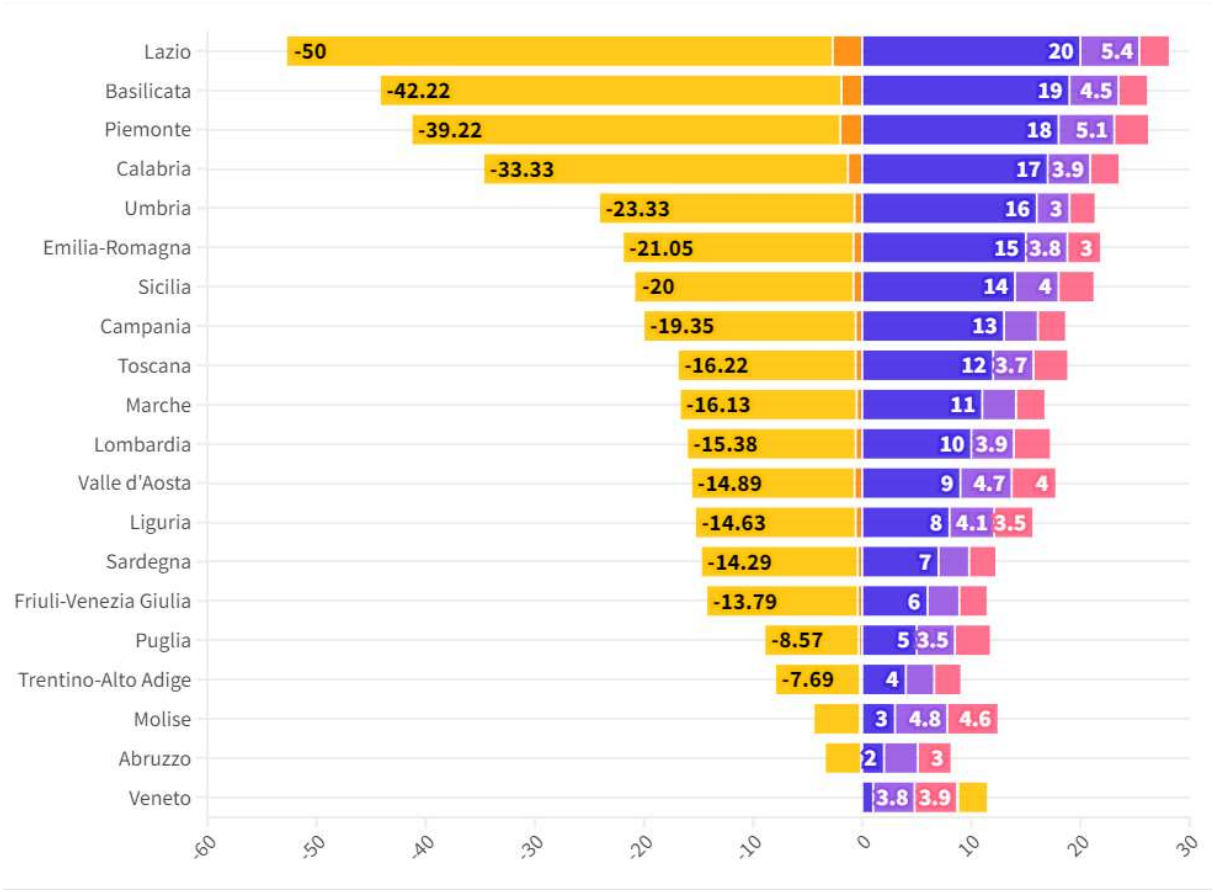

Figure 10. Percentage and absolute change in BHCS value in Italian regions between 2004 and 2022. Most regions experienced a reduction in BHSC value. Veneto was the only region with a positive change in the BHSC value between 2004 and 2020.

5) Machine Learning for the Prediction of the Future Value of BHCS

Below we consider a comparison of eight machine-learning algorithms for predicting the future value of BHCS. The algorithms were trained with 70% of the available data. The algorithms are compared on the basis of their ability to minimize R-squared and maximize the value of statistical errors i.e. MAE-Mean Absolute Error, MSE-Mean Squared Error, RMSE-Root Mean Squared Error (Figure 11).

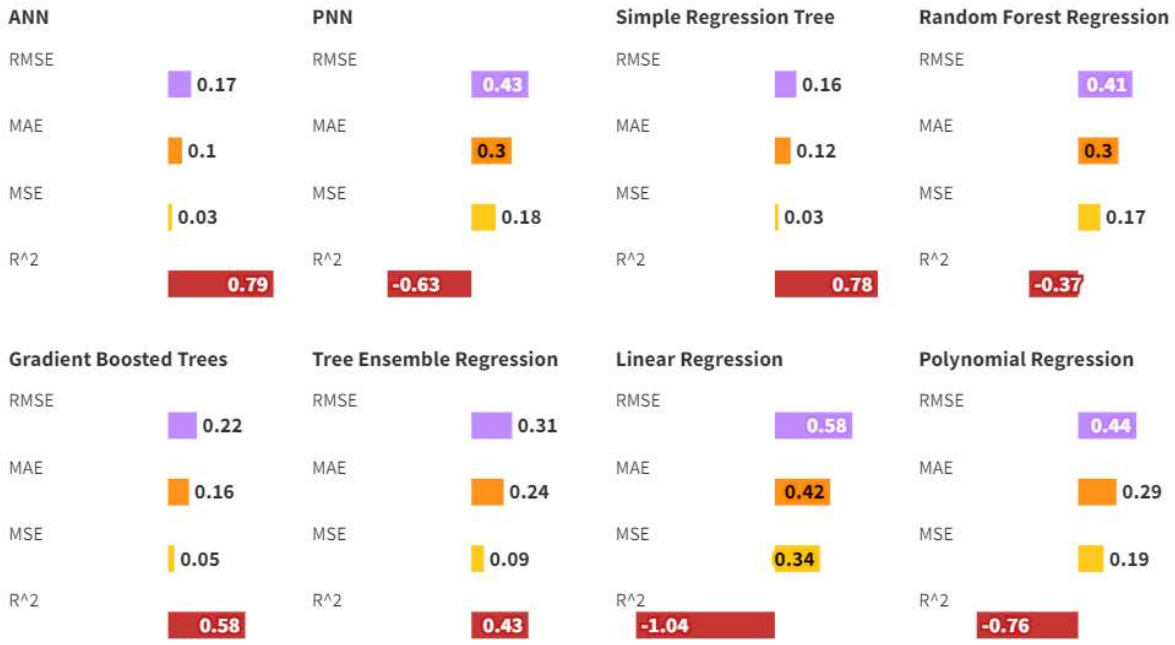

Figure. 11. R-squared, MSE, MAE and RMSE for the machine learning algorithms.

We therefore obtain the following ordering of the algorithms:

- ANN-Artificial Neural Network and Simple Regression Tree with a payoff value of 6
- Gradient Boosted Trees with a payoff value of 12;
- Tree Ensemble Regression with a payoff value of 16;
- Random Forest Regression with a payoff value of 22;
- PNN-Probabilistic Neural Network with a payoff value of 24
- Polynomial Regression with a payoff value of 26;
- Linear Regression with a payoff value of 32.

The analysis shows that the best performing algorithms are the ANN and the Simple Regression Tree. However, between the two algorithms we prefer to choose ANN over Simple Regression Tree as ANN has a higher R-squared value than Simple Regression Tree. Therefore by applying the ANN algorithm it is possible to predict the future value of BHCS. It is possible to divide the regions into three groups, i.e. regions for which a growth in the future value of BHCS is predicted, i.e. winner regions, regions for which a decreasing future value of BHCS is predicted, i.e. the losers regions and finally the outliers , i.e. those predictions that are considered excessive in the metric dimension compared to the typical variation of the observed variable.

Winning regions. The winning regions, i.e. the regions for which a growth in the future value of BHSC is predicted, are indicated below: Basilicata with +185.4%, Friuli Venezia Giulia with +95.4%, Campania with +58.6%, Liguria with +48.2%, Emilia Romagna with +30.9%, Lazio with +24.70%, Puglia with 11.50%, Sicily with 9.00%, Veneto with 9.00%. We can see that the regions for which BHSC value growth is predicted are very geographically and economically diverse. In fact there are both regions of Northern Italy and Central and Southern Italy (Figure 11).

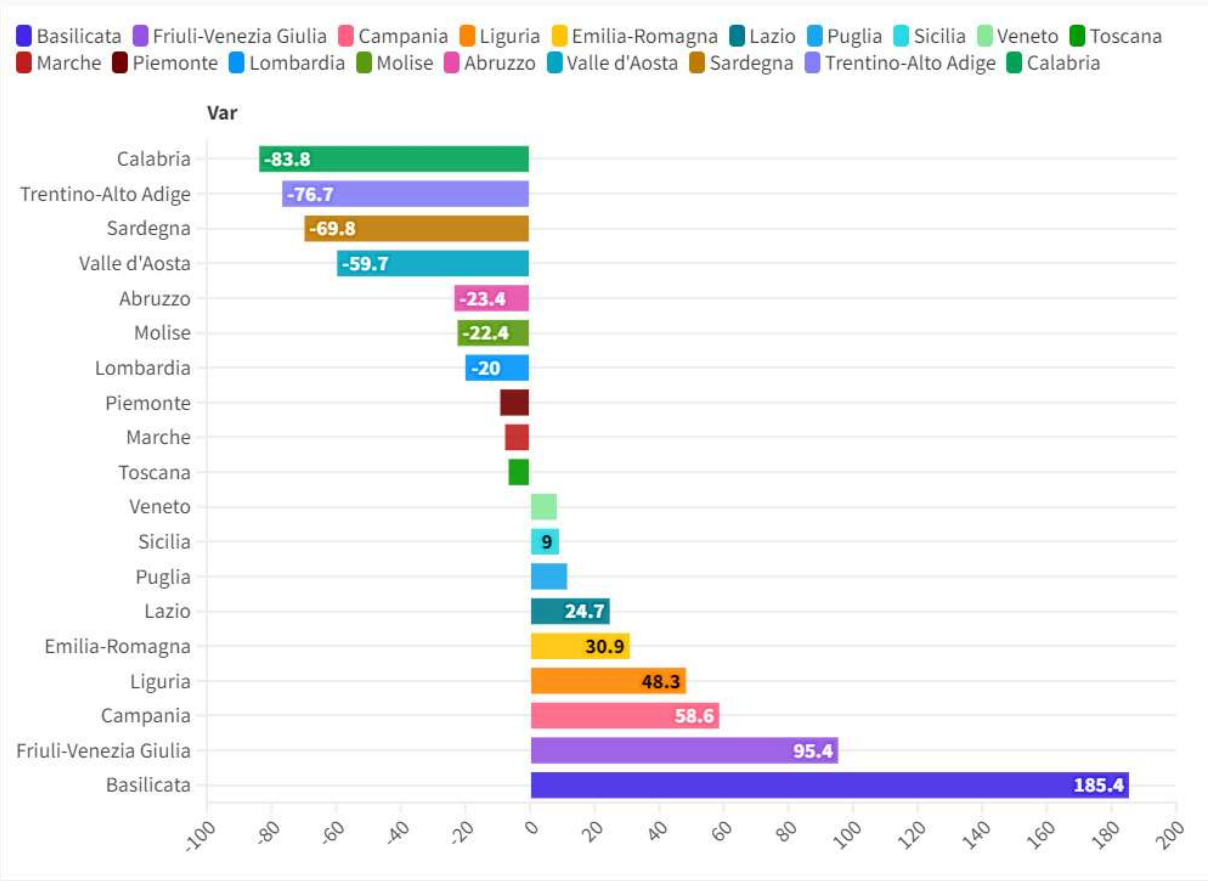

Figure 12. Percentage variations of based on the prediction with ANN-Artificial Neural Network algorithm.

Losers regions. The losers regions, i.e. the regions in which a reduction in the future value of BHSC is predicted, are Tuscany with a value of -6.65, Marche with a value of -7.7%, Piedmont with -9.2 %, Lombardy with a value equal to -20.00%, Molise with -22.4%, Abruzzo with a value equal to -22.4%, Valle d'Aosta with a reduction equal to an amount of -59.7%, Sardinia with a variation equal to an amount of -69.80%, Trentino Alto Adige with a variation equal to an amount of -76.7%, and Calabria with a variation equal to - 83.8%. The losers regions are also characterized by a very large and diversified dimension of the regions analysed which are very heterogeneous both from the point of view of per capita income and from the point of view of geographical positioning (Figure 12).

Outlier regions. However, the value of Umbria was excluded from the analysis, for which an increase of 3,300% was predicted. This value certainly constitutes an outlier and was excluded from the analysis.

Therefore, considering the average of the Italian regions, the predicted value is equal to 4.88%. That is, the algorithm predicts a growth in the value of BHCS in contrast to the historical trend.

6) Conclusions

In this article, we have analyzed the impact of BHCS within the ESG context in the Italian regions between 2004 and 2021 using ISTAT-BES data. The econometric analysis was conducted with various econometric techniques: i.e. Panel Data with Fixed Effects, Panel Data with Random Effects, Pooled Ordinary Least Squares-OLS, Dynamic Panel at 1 stage. The data shows that BHCS is

positively connected to both the E component, the S component, and also the G component of the ESG model.
The clustering analysis with the K-Means algorithm optimized with the Silhouette Coefficient shows the presence of two clusters not corresponding to socio-economic and political differentiations among the Italian regions. Finally, the predictive analysis conducted using machine learning algorithms highlights an expectation of growth in the value of BHCS on average for the Italian regions.
However, from the point of view of health economic policies, it is necessary to underline that many questions remain open. Policy makers involved in the healthcare sector must address and resolve the issue of the adequate provision of healthcare services, especially with attention to specialist care, considering both the socio-economic differences between the Italian regions and the growing phenomenon of the aging of the resident population.

7) **Declarations**

Ethics approval and consent to participate. All authors ethically approve the research work submitted to your journal and express their consent to participate in the authorship.

Consent for publication. All authors give their consent to publication.

Data Availability Statement. The data presented in this study are available on request from the corresponding author.

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Declaration of Competing Interest. The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication.

Software. The authors have used the following software: Gretl for the econometric models, Orange for clusterization and network analysis, and KNIME for machine learning and predictions. They are all free version without licenses.

Authors contributions. Conceptualization, R.E, R.O. C.A. and L.A.; Methodology, R.E, R.O. C.A. and L.A; Software R.E, R.O. C.A. and L.A; Validation, R.E, R.O. C.A. and L.A.; Formal Analysis, R.E, R.O. C.A. and L.A ; Investigation, R.E, R.O. C.A. and L.A; Resources, R.E, R.O. C.A. and L.A; Data Curation, R.E, R.O. C.A. and L.A; Writing – Original Draft Preparation, R.E, R.O. C.A. and L.A; Writing – Review & Editing, R.E, R.O. C.A. and L.A; Visualization, R.E, R.O. C.A. and L.A; Supervision, R.E, R.O. C.A. and L.A; Project Administration, R.E, R.O. C.A. and L.A; Funding Acquisition, R.E, R.O. C.A. and L.A.

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