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The effects of population ageing on health care expenditure: A Bayesian VAR analysis using data from Italy

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ABSTRACT

Currently, the dynamics of the population have raised concerns about the future sustainability of Italy's national health system. The increasing proportion of people over the age of 65 could lead to a higher incidence of chronic-degenerative diseases and a greater demand for health and social care with a consequent impact on health spending. Although in recent years the quantity and quality of works on the relationship between ageing and health expenditure has increased substantially these works do not always obtain similar results.

Starting from this point, we use a B-VAR model and Eurostat data to investigate over the period 1990–2013 the impact of demographic changes on health expenditure in Italy. We estimate these models using impulse-response analysis and variance decomposition. The results show that health expenditure in Italy reacts more to the ageing population compared with life expectancy and per capita GDP. In response to these findings, we conclude that the impact of the increase in the elderly population with disabilities will fall on the long-term care sector. Effective health interventions, such as health-promotion and disease-prevention programs that target the main causes of morbidity, could help to minimize the cost pressures associated with ageing by ensuring that the population stays healthy in old age. We consider the implications of this work for health care policy suggestions and for future research.

1. Introduction

Quality health care is a primary human need. Nutrition and health play an important role in economic growth [1,2]. Developed countries spend a high proportion of their GDP on health care because they believe that the health of their residents can serve as a major driver of economic activities and development.

In Italy, health sector spending accounted for 9.2% of GDP of 2012, a value close to the average of 9.3% of other OECD countries. Funding for health derives mostly from the public sector in nearly all OECD countries: in Italy, the level of spending from public sources was 77% in 2012 slightly more than the average of 72% for OECD countries.

In recent years, in Italy and other European countries, governments have attempted to reduce health spending

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in response to the budgets deficits, which were worsened by the economic crisis. However, despite the reduction in health expenditures, in the same year, life expectancy at birth in Italy was 82.3 years, two years more than the OECD average (80.2 years). Research from the OECD shows that Italy has achieved some progress in reducing tobacco consumption, with the percentage of daily smokers among adults decreasing from 24.4% in 2000 to 22.1% in 2012.

Moreover, the obesity rates among adults in Italy has increased from 8.6% in 2000 to 10.4% in 2012, a modest growth compared to the other OECD countries [3].

The impact of health on economic growth can be studied in the more general context of the relationship between human development and economic growth. Human capital is closely interrelated with welfare and has an impact on economic growth. In the path for economic development, it is necessary for a country to spend a fair amount of money on health care. In an ageing society, such as the Italian population, the mechanisms relating health and health care with economic growth could be influenced by the growing proportion of elderly people. The ageing of the population is deemed to have an impact in every area of the country's life, including economic growth, labour market taxation, health, family composition, housing and migration.

In Italy, the percentage of individuals over age 65 between 1990 and 2011 increased from 14.9% to 20.6%; during the same period, the percentage of individuals over age 85 increased from 1.2% to 2.8% [4]. Moreover, other indicators about the ageing population, such as the ageing index, the elderly dependency ratio, and life expectancy, increased from 1990 to 2011 with a significant impact on health expenditure and economic growth.

The demographic processes that are responsible in Italy for changes in the ageing index are attributable to the rise in the old-age population, followed by a decline in the young population, the rise in survival rates and the limited fertility rate, which is well below the level of generational turnover (2.1 children per woman). According to the ISTAT, the ratio between the old and the young in Italy is large, reaching 151.4% as of January 1st, 2013, and 154.1% as of January, 1st, 2014.

The growth in lifespan has led to a higher incidence of chronic-degenerative diseases (e.g., heart disease, cancer, Alzheimer's disease) and a greater demand for healthy-living resources over time in long-term care.

According to the report "Piano della cronicità" (Chronicity Plan) of the Italian Minister of Health [5], the percentage of Italian people who have at least one chronic disease was equal to 38.4% in 2011 and it was approximately 37.9% in 2013. Moreover, approximately 20% suffer from least two chronic conditions, a level equal to that recorded in 2011. However, if we consider only those of older ages in 2013, the percentages increase significantly, reaching a value equal to 48.7% for the people aged 65–74 that suffer from at least two chronic diseases and 68.1% of those aged 75 years and older. In addition, in 2013, the percentage of chronically ill people who claim to be in good health is 41.5%, while among the elderly the proportion it is only 24.2%. Finally, according to the multi-purpose survey, the most relevant chronic diseases in Italy are osteoarthritis/arthritis (16.4%), hypertension (16.7%), allergic diseases (10%), chronic bronchitis and bronchial asthma (5.9%) and diabetes (5.4%). The expected effect should be higher per capita health spending, which provokes doubts about the financial sustainability of the health care system in terms of system performance and health care supply.

Governments thus tend to face the problem of increased demand for public health services combined with a strain on available resources to provide these services.

With this in mind, the focus of this study is to improve understanding of the consequences of population ageing on health-expenditure growth in Italy.We try to contribute to this literature by examining this relation in terms of economic dynamics to determine whether longevity significantly affects health expenditure. Specifically, we analyse the relationship among per capita health care expenditures, per capita GDP, ageing index and life expectancy by using a B-VAR model based on the Minnesota prior that incorporates useful information to improve the short and long term analysis.

This would help to assess how relevant longevity is to health in a country and what types of policy and/or research recommendations would be needed at that point.

The remainder of this paper is organized as follows. In Section 2, we present the literature review with the search strategy and we include the studies related to the Italian context. In Section 3, we compare VAR models with B-VAR models, briefly describe the data and estimate a frequentist VAR model. Then, we estimate a B-VAR model by including the impulse-response functions and variance decompositions and we discuss the results. In Section 4, we compare B-VAR models based on different priors in terms of their forecasting performance. Finally, in the last section, we conclude by offering suggestions for policy makers and for future investigations.

2. Literature review

2.1. Search strategy

We performed a critical review/survey starting from the "topic" that we want to investigate, which concerns the effects of longevity on health spending.

The identification of the search strategy required the definition of a series of aspects concerning the search process, as illustrated below.

First, we established the databases that we used for the research. We chose the SSCI database (Social Science Citation Index), included in the Web of Science Internet library source, SCOPUS and Google Scholar.

We performed a search of the papers, wide in scope and relatively up to date, using a logical search string that included three key terms: health care expenditure, ageing index and life expectancy. In addition, we used the keyword gross domestic product (GDP) in more refined queries using the Boolean operators "AND" and "OR" to identify the most relevant papers in the field.

Second, we defined the time horizon of the analysis. We did not limit the interval of the research. Moreover, we expanded the search process by also including Italian-language texts.

Finally, we included in the literature review a number of subject categories in order to include the major papers focused on the latest developments in the research area, in terms of theoretical review and applied methodology ("econometric" and "statistical" papers): all included studies were reviewed independently and in duplicate.

Hence, in what follows, we will concentrate mostly on journal articles of this type, and we will compare the different studies in order to develop a basis for the empirical analysis and policy suggestions.

2.2. Major review and survey publications

A large and increasing body of economic literature has analysed the relationship between life expectancy, health expenditure and economic growth, trying to understand whether a linkage exists among the variables with varying degrees of success [4,6–16].

Several authors [12,6,13,14] indicate that income is one of the key determinants of health care expenditures and is mostly represented by per capita gross domestic product (GDP): a higher income will yield higher health care spending.

Others [17] affirm that costs are mainly driven by changes in labour productivity rather than by growth in national income.

The impact of the growth in life expectancy on per capita health expenditures is probably more controversial with respect to the future development of health care expenditures.

Gilligan et al. [18] predicted production functions of health by measuring socioeconomic and expenditure factors that impact on life expectancy in the Eastern Mediterranean Region. They conclude that GDP and health expenditures are positive significant predictors of health expectancy in more industrialized countries.

According to Chetty et al. [19], the differences in life expectancy are correlated with healthy behaviours, local area characteristics and income. In particular, life expectancy is strongly correlated with income. Such a relation produces inequality in life expectancy: they conducted a study in the United States and demonstrated that between 2001 and 2014, individuals in the top 5% of the income distribution gained approximately 3 years of life expectancy, whereas individuals in the bottom 5% experienced no gains [19].

Previous studies indicate that health outcomes across countries (e.g., life expectancy, child mortality) are not associated with the level of expenditure on health [20–24]. Particularly, frequent references are made to the deterring effect that contextual and institutional factors (e.g., good governance, political unrest) may have on the achievement of the desired outcomes of health spending [25]. In most cases, among countries with good health outcomes, the range of health expenditures is extremely wide. Such variation makes it difficult to obtain a conclusive answer regarding the impact of health expenditure on health outcomes.

Although the positive impacts of life expectancy and economic growth on health expenditures are well documented, less is known about the effects of longevity on the "welfare state" when population ageing becomes the main driver of escalating health care costs in developed countries.

Some research reveals a relatively modest impact of age distribution on health expenditures compared to the income effect [25–27].

Several authors [17,15,28] affirm, that age distribution affects the demand for health care services: an older population has a relatively higher propensity to consume health care. Others [17,29] conclude that expenditure projections are strongly influenced by the choice of health-status hypothesis (compression-of-morbidity versus expansion-of-morbidity scenarios). The compression-of-morbidity scenario estimates that expenditures grow more slowly because people are assumed to age more slowly (or to exhibit the patterns of use of younger people).

In contrast, according to Lubitz et al. [30], the expected cumulative health expenditures for healthier elderly persons, despite their greater longevity, are similar to those for less healthy persons. Health-promotion efforts aimed at persons under 65 years may improve the health and longevity of the elderly without increasing health expenditures. Persons in better health at age 70 have longer life expectancies than those in worse health, but their total expected medical care expenses appear to be no greater than those for less healthy persons, even though healthier persons live longer.

Other studies [31–34], rather than assuming that only aged people affect health care expenditures, add the share of young people to their regression model.

There is strong evidence that a large share of the health spending consumed by a person is concentrated in the final years of life [35]. In particular, the difference in the health care expenditures between young and old persons is not primarily due to calendar age but is caused by the differences in time to death [36–38]. In fact, it is suggested that the demand for health services depends ultimately on health status and the proximity to death and not on age per se.

Aisa et al. [39], for a sample of OECD countries, report evidence on the contribution of health expenditures in enhancing longevity. However, its influence diminishes as the size of the public health sector relative to GDP expands.

Finally, according to macro-level studies on OECD country data conducted by Getzen [40] and Barros [26], there is no evidence of a link between ageing and health expenditures.

All in all, the existing literature indicates that the relationship between ageing and health care expenditures is not as straightforward as it appears, and at macro-levels, often the statistical significance of ageing depends on the specification of the empirical model [41].

In addition, it is not clear exactly which demographic features have the strongest effects on health care spending: candidates include the number of people over a certain age, the number with given levels of disability or ill-health and the number in the final years of their lives. As a consequence of this uncertainty, methods of projecting the impact of demographic change onto health care spending vary substantially.

Certainly, increased longevity implies more elderly persons, who tend to use more health resources, thereby potentially putting a strain on the health system. In the most recent survey of ISTAT [42], in Italy, per capita health care expenditures after age 65 are higher than those before age 65. The empirical evidence shows that in Italy the elderly individuals are associated to a greater demand of services for health care and social care and consequently to a higher per capita health spending [43,44]. The analysis of the overall health demand distinct by age group and the related costs shows a “J” trend [4]. Specifically, it detects a local maximum in health care costs relative to the early years of life of individuals, followed by a progressive decrease during the childhood, the curve returns to growth at around fifty years of age, up to the level of absolute maximum during the 75–80 years [43,45].

On the other hand, the much lower labour participation rate of elderly persons implies a lower tax base for government revenue; thus, population ageing could have two effects: an increase in health expenditures coupled with a reduction in tax revenue [46].

Moreover, while the effects of population ageing could be exaggerated, the role of medical technologies on health expenditures for older patients may be understated [47–49].

Starting from the idea that increased longevity, commonly taken to mean an increase in the proportion of elderly persons aged 65 and above affects health expenditure we try to evaluate using aggregate data from ISTAT, OECD and EUROSTAT databases whether there is a relationship between health spending and ageing, the direction of the relation and the intensity of the impact of demographic change on national health expenditures with B-VAR models to discuss the implications of this work for health care policy and future research.

3. Empirical investigations

3.1. VAR model vs B-VAR model

The emergence of the Bayesian approach led to a re-evaluation of the VAR framework in all fields including macroeconomics and finance [50,51]. The application of the Bayesian framework to VAR might give the same results as the frequentist VAR models when we use non-informative priors. Although classical VAR models became the major tool to investigate the monetary policy transmission mechanism and health-policy analysis [52–54] in terms of data description and forecasting [54], VAR analysis is characterized by several deficiencies. First, VAR models suffer from the over-fitting phenomenon, which may occur when the data set is short, sample information is weak or the number of parameters is large. Second, VAR models are not parsimonious because they contain many parameters, and it is often difficult to obtain precise estimates of the coefficients and impulse-response functions. Lastly, the classical VAR approach suffers from the loss of degrees of freedom, the number of which exponentially decreases with respect to the number of lags included. In fact, if the lag length increases and becomes too large, the estimates become imprecise and it will likely end up with large standard errors and unstable point estimates.

Bayesian Inference applied to VAR models [55] provides a logical and consistent solution because in the case of over-parameterization, instead of eliminating longer lags, restrictions are imposed on these coefficients by assuming that they are more likely to be close to zero than the coefficients of the shorter lags [52,53]. Although these restrictions are hard to justify on both economic and statistical grounds, in this way we reduce the estimation error by generating only relatively small biases in the parameter estimate.

Usually, the choice of the prior distribution depends on the structure of the available data. In this section, we consider three different prior distributions: the Litterman/Minnesota, Normal-Wishart and Sims-Zha priors.

The most widely used prior distribution in B-VAR models is the Minnesota prior distribution proposed by Litterman [53] which is based on the normal distribution. A primary advantage of the Minnesota prior is that it leads to a simple posterior inference because it involves only the Normal distribution. The use of a diagonal variance-covariance matrix implies that there is no relationship among the coefficients of the VAR equations. The Minnesota prior makes the large number of coefficients depend on a smaller vector of hyperparameters. Therefore we obtain better precision because of the sheer dimensionality reduction, and the out-of-sample forecasts can be improved. Moreover, when the prior does not reflect well the sample information, this approach may reduce the MSE of the estimates.

However, the prior does not provide a full Bayesian treatment of Σ (variance-covariance matrix of the residuals) as an unknown. By replacing Σ with $\hat{\sum}$ it ignores any uncertainty in this parameter.

Since Σ is replaced by $\hat{\sum}$ we need to specify only a prior for the VAR coefficient θ (the parameters of our interest).The Litterman/Minnesota prior assumes that the prior of θ is normally distributed 0 (where the hyperparameter μ is close to 0). The Litterman/Minnesota prior assumes that the prior of q is normally distributed where the hyperparameter μ is close to 0 and the covariance prior is non-zero.

To better explain the Minnesota/Litterman prior for the covariance coefficients we underline that in the VAR model the independent variables in any equation can be divided in three groups: the first group includes the lags of the dependent variable, the second one includes lags of the other variables, the last one includes any exogenous variables. The remainder of the prior covariance is a diagonal matrix. Therefore, in this way we do not have to specify all the elements and we select a matrix containing the prior covariance for the coefficients by specifying the three scalars: $\lambda 1$ that is the overall tightness on the variance of the first lag. $\lambda 2$ represents the relative tightness on the variance of the other variables and $\lambda 3$ is the relative tightness of the variance of lags. Given this choice of the prior the posterior for θ takes a normal distribution form.

The Normal-Wishart prior represents a conjugate prior for normal data. The prior, the likelihood and the posterior distribution come from the same family of distributions and they are always conjugate. According to Kadiyala and Karlsson [56] the likelihood from the VAR model can be divided in two parts: the former is a Normal distribution and the latter is assumed to be a Wishart (inverse Wishart) distribution. We have a Normal-Wishart distribution if the assumption of a fixed and diagonal matrix is relaxed. Also in this case we need to select the hyperparameter λ1 that controls the overall tightness of the prior.

However equation-by-equation computations are no longer efficient since the posterior covariance matrix obtained using the whole system is different from the covariance matrix obtained using each equation separately.

Finally, the Sims-Zha prior specification differs from the Litterman/Minnesota approach because the estimation of the VAR coefficients is no longer done on an equation-by-equation basis as in the reduced-form version of Litterman [57]; instead, we estimate the parameters for the full system in a multivariate regression.

Moreover, we have no distinction between the prior variances on own lags and other lags and the prior is set for the overall system and not for each equation. This difference is important because the prior for the reduced form as in Litterman [57] is nonconjugate and it gives a nontractable posterior. Instead, Sims and Zha's prior [58] requires that the correlation structure for the regression parameters in the prior is correlated in the same manner as the structural residuals. In this case we have a posterior distribution that can be easily sampled. As Litterman/Minnesota case we can choose for the estimate of Σ among Univariate AR and Diagonal VAR.

The hyperparameters (λ0, λ1, λ2, λ3, λ4, λ5) reflect respectively: the overall tightness of the prior on the covariance matrix (λ0), the standard deviation or tightness of the prior on the AR(1) coefficient (λ1), the no-cross variable shrinkage (λ2 = 1), the control of how fast higher lags go to zero (λ3), the standard deviation or tightness of the prior on the costant (λ4), the tightness of prior on exogenous variable (λ5). In addition we have separate hyperparameters for cointegration and trends.

Sims-Zha [58] propose a more general specification with a prior defined for the simultaneous equation that has the advantage to produce a tractable multivariate normal posterior distribution since the prior has a conjugate form. In this case the posterior can be estimated by a multivariate seeming unrelated regression (SUR) model.

In this environment, since the time frame of our analyses is determined by the data availability and it is short for Italy, the use of VAR models could lead to the problems just described above. Therefore, a Bayesian VAR approach may be relevant for the Italian economy because it incorporates the sample information into the estimation by using a prior distribution. In this way we can obtain more precise results than the classical VAR approach in examining the dynamic interrelations between the variables. Through the use of a B-VAR model we analyse the impact of ageing on health expenditure in terms of causality patterns in the short-run and in the long-run and it may be regarded as a novel tool for the analysis because it solves the disadvantages of VAR models. For these reasons this work is important from both an economic and a policymaking perspective.

3.2. A comparison between VAR and B-VAR approaches

In this section we estimate a frequentist VAR model (Table 1) and a B-VAR model (Table 2) and we discuss the results. For this purpose we use annual data of ageing index (AI), life expectancy at birth (LFE), per capita expenditure on health (HEX) and per capita nominal gross domestic product (GDP). According to the glossary of ISTAT the ageing index is defined as the ratio between people aged 65 and over and the youth population (0–14). This indicator is measured as a percentage of population.

It is a good indicator: since the ageing of a population generally involves an increase in the number of elderly people and a concurrent decrease in the number of younger people, the numerator and denominator vary in opposite directions amplifying the effect of ageing population.

According to the OECD, life expectancy at birth is defined as how long, on average, a new-born can expect to live, if current death rates do not change. Life expectancy at birth is one of the most frequently used health-status indicators and it is measured in years. Gains in life expectancy at birth can be attributed to a number of factors, including rising living standards, improved lifestyle and education, as well as greater access to quality health services. We use this indicator as a total value, without distinguishing between genders.

Finally, we define per capita variables (variables divided by the total population, one value for each year of observation): per capita gross domestic product at nominal values (GDP) and per capita health expenditure (HEX).

The data are drawn from ISTAT, OECD health statistics and EUROSTAT databases that collect historical data on health spending, economic growth population and demographic events. The time frame of our analysis is from 1990 until 2013. The sample span is determined by the data availability.

In our analysis we employ Eviews 9 and R packages. Before analysing the Bayesian VAR model, we start with a VAR model with two lags, four endogenous variables (AI, LFE, HEX, GDP) and a dummy exogenous variable (dum) for the economic crisis, estimated using classical techniques, as a benchmark for comparison.

As we can see in Table 1 the goodness of fit of the VAR model is poor. In this case the coefficient values are not very well determined (low precision) since we have a short sample and we estimate a VAR model with four endogenous variables and two lags selected as optimal lags in accordance to Akaike (AIC), Schwarz-Bayesian (BIC) and Hannan-Quinn (HQC) criteria. In fact the dynamics between the variables that we investigate are not clear and the results are hard to interpret (i.e., one lag of per capita health expenditure does not influence life expectancy, while the second lag of the same variable does impact life expectancy). For these reasons we do not comment on the VAR parameters; instead we compare the standard errors of the VAR model with the standard errors of the B-VAR model to underline how the prior information improves the estimation.

Using the B-VAR approach, we prefer a model that is estimated in levels rather than in first differences for several reasons. First, the Minnesota prior that we use

Table 1
VAR (2) estimation.

	HEX_t	LFE_t	AI_t	GDP_t
$\mathbf{HEX_{t-1}}$	0.015	0.78	0.036	0.0021
	(0.055)	(0.23)	(0.9)	(0.8)
$\mathbf{HEX_{t-2}}$	0.09	0.31	0.028	1.1
	(0.64)	(0.255)	(0.19)	(0.35)
$\mathbf{LFE_{t-1}}$	0.22	0.15	0.78	0.86
	(0.31)	(0.44)	(0.39)	(0.59)
$\mathbf{LFE_{t-2}}$	0.1	0.42	0.35	0.74
	(0.03)	(0.7)	(0.19)	(0.163)
$\mathbf{AI_{t-1}}$	0.45	0.05	0.56	0.37
	(0.032)	(0.092)	(0.6)	(0.3)
$\mathbf{AI_{t-2}}$	0.26	0.21	0.18	0.66
	(0.054)	(0.04)	(0.44)	(0.45)
$\mathbf{GDP_{t-1}}$	0.013	0.67	0.55	0.0033
	(0.76)	(0.6)	(0.44)	(0.07)
$\mathbf{GDP_{t-2}}$	0.019	0.88	0.79	0.059
	(0.088)	(0.51)	(0.86)	(0.08)
c	0.001	0.45	0.04	0.06
	(0.008)	(0.06)	(0.049)	(0.01)
dum	0.05	0.07	0.08	0.13
	(0.006)	(0.07)	(0.029)	(0.012)

Notes: The values in parentheses are the respective *standard errors*. **GDP** denotes per capita nominal gross domestic product, **HEX** denotes per capita health expenditure, **LFE** denotes life expectancy, **AI** denotes ageing index. Finally, **dum** denotes the exogenous dummy variable inserted to capture crises effect. According to Akaike (AIC), Schwarz–Bayesian (BIC), and Hannan–Quinn (HQC) we choose 2 lags as optimal lags.

in this work is generally applicable only to economic series in levels (or log-levels). Second, differencing discards long-run information in the data, which may be of use for impulse-response functions and for variance-decomposition analysis. Finally, if the data in question are cointegrated in levels, a VAR model in first differences will be misspecified because it does not incorporate adjustment to the long-run cointegration relationship into the system dynamics.

Also for the B-VAR framework, we set up a model with 4endogenous variables (HEX, LFE, AI, GDP), 2 lags in accordance to Schwarz-Bayesian (BIC) criterion and an exogenous temporal dummy (dum) to capture the effects of the Great Recession [59], having a value of one in the years 2008–2009 and zero in all other years. We use the Litterman-Minnesota prior with diagonal VAR estimate and prior specification of the hyperparameters. We select the hyperparameters as follow: $\lambda 1$ (the overall tightness on the variance of the first lag) is set to a small value because the prior information dominates the sample information. $\lambda 2$ (relative tightness on the variance of the other variables) and $\lambda 3$ (relative tightness of the variance of lags) are set greater than zero because we use a diagonal VAR and the lag decay are important for our analysis.

The Bayesian VAR estimator of $\theta(\beta,\sum)$ depends on the data, prior, and loss function.

The Bayesian inference on the parameter vector θ is based on the posterior distribution. The moments of the

Table 2
Posterior Means of B-VAR coefficients of the Minnesota prior distribution.

	HEX_t	LFE_t	AI_t	GDP_t
$\mathbf{HEX_{t-1}}$	0.012	0.28	0.046	0.013
	(0.004)	(0.188)	(0.031)	(0.01)
	[0.003720.02028]	[−0.6690.11]	[−0.110 0.02]	[−0.03 0.01]
$\mathbf{HEX_{t-2}}$	0.05	0.29	0.03	0.9
	(0.01)	(0.23)	(0.144)	(0.289)
	[0.02930.0707]	[0.18610.7661]	[−0.1 0.6]	[−0.3 1.5]
$\mathbf{LFE_{t-1}}$	0.1	0.18	0.64	0.8
	(0.01)	(0.4)	(0.34)	(0.55)
	[0.07930.1207]	[−0.648 1.008]	[−0.0638 1.3438]	[−0.338 1.9385]
$\mathbf{LFE_{t-2}}$	0.12	0.2	0.23	0.34
	(0.03)	(0.193)	(0.164)	(0.149)
	[0.05790.1821]	[−0.2 0.6]	[−0.11 0.57]	[−0.03 0.65]
$\mathbf{AI_{t-1}}$	0.23	0.03	0.47	0.32
	(0.002)	(0.009)	(0.111)	(0.125)
	[0.225860.23414]	[−0.02 0.05]	[−0.04 0.06]	[−0.06 0.58]
$\mathbf{AI_{t-2}}$	0.28	0.18	0.10	0.6
	(0.004)	(0.033)	(0.121)	(0.0821)
	[0.271720.28828]	[−0.24 0.25]	[−0.15 0.35]	[−0.47 0.77]
$\mathbf{GDP_{t-1}}$	0.13	0.7	0.50	0.04
	(0.06)	(0.053)	(0.338)	(0.091)
	[0.00580.2542]	[−0.59 0.81]	[−0.199 1.2]	[−0.15 0.23]
$\mathbf{GDP_{t-2}}$	0.06	0.78	0.8	0.022
	(0.078)	(0.410)	(0.721)	(0.0101)
	[0.002040.11796]	[−0.07 1.63]	[−0.691 2.3]	[0.0010930.042907]
c	0.05	0.55	0.03	0.05
	(0.008)	(0.06)	(0.011)	(0.01)
	[0.033440.06656]	[0.42580.6742]	[0.007230.05277]	[0.02930.0707]
dum	0.01	0.066	0.056	0.12
	(0.004)	(0.05)	(0.019)	(0.02)
	[0.001720.01828]	[0.022530.10947]	[0.016670.09533]	[0.07860.1614]

Notes: The values reported in the table are the posterior means of B-VAR coefficients for the Minnesota prior distribution. The values in parentheses are the respective standard errors. The values in the squared brackets are the *credible intervals* at the probabilities of 95%.
According to Schwarz–Bayesian (BIC) we choose 2 lags as optimal lags.

posterior distribution are in general of interest. In fact, the posterior mean is often used as a point estimator for θ if the posterior distribution is normal.

In our case the use of Minnesota prior that involves a normal distribution results in a simple, analytically tractable, normal posterior distribution.

Using the absolute error loss function the point estimate corresponds to the posterior median that it represents the Bayes estimator that minimizes the expected loss under the absolute error loss function.

Since for normal distributions the mean and median coincide, the Bayes estimator with absolute-error loss function is also equal to the mean of the posterior.

Comparing the two models we can see that the posterior results for point estimates of B-VAR model (Table 2) are different with respect to the VAR estimation (Table 1). In particular, the standard errors (in round brackets) of VAR model in Table 1 are in general marginally higher than for the B-VAR model (Table 2). This means that since the sample is short, the prior information influences the estimates and is crucial for our analysis. In fact, in the OLS case of the VAR model we are incorporating potential uncertainty over prediction errors that comes from not considering the prior distribution.

Moreover, in the B-VAR approach with respect to the frequentist VAR we do not have confidence intervals and hypothesis tests and we do not use sampling distributions of estimators to model certain processes; the Bayesian inference uses the probability more widely to model both sampling and other kinds of uncertainty.

A Bayesian inference starts with a “prior distribution”, i.e a probability distribution that reflects the state of knowledge about the parameter of interest before collecting data. The Bayesian inference updates the prior distribution in the light of the data to obtain a new probability distribution for the parameter of interest called the posterior distribution. Using the posterior distribution, and according to the credible intervals the Bayesian can make a statement.

Thus, we can say that in the case of the B-VAR model, for our data and according to the credible intervals and posterior distribution results, we have that the first and second lags of life expectancy, ageing index and per capita GDP influence per capita health expenditure with a probability of 95% but the reverse is not true (Table 2).

To better investigate the model dynamics we accompanied B-VAR with tools such as the impulse response-function, forecast error-variance decomposition and forecasts.

3.3. *Impulse response functions and forecast variance decomposition*

In this section, we calculate the impulse response functions and the forecast variance decomposition to obtain long-run information and to investigate the dynamic properties of the B-VAR approach. The variance decomposition and the impulse-response functions both provide a method of depicting the system dynamics of the B-VAR model. The impulse response functions trace the effects of one-unit shock (percentage points) to a variable on the other variables in the B-VAR approach (Table 3). In contrast, the forecast-variance decomposition provides information about how much of the forecast error variance of each of the variable can be explained by exogenous shocks to the other variables (Table 4). In both cases, we use different time intervals to analyse how these effects change over time. We end the analyses when these effects become poor.

In particular for the impulse-response function we limit the period to ten years because the impulse responses after ten years are close to zero. Instead, for variance decomposition, we prefer to use a number of periods equal to twelve years because the role of each variable in explaining the fluctuations of the other variables becomes negligible after twelve years.

Given the B-VAR model, by using the impulse-response functions we trace out the effect of a one-unit shock (percentage points) to a variable on the other variables (Table 3). In our work, it is of interest to know the response of each variable to a shock in another variable in a system that involves a number of additional variables as well. Of course, if there is a reaction of one variable to an impulse in another variable, we may say that the latter is causal for the former.

We study this type of causality by inspecting the impulse responses to analyse what occurs to the system during the periods $t=0,\ldots.10$. By tracing one-unit shock (percentage points) in the first variable in period $t=0$ in this system we get the effects of exogenous shocks in the variables of the system after “i” periods.

We investigate whether this effect is significant after 1, 3, 6 and 10 years and when it becomes weaker in terms of: a) the response of per capita health expenditure to the effects of per capita health expenditure, per capita GDP, life expectancy and ageing index (IRF-HEX); b) the response of ageing index to the effects of per capita health expenditure, per capita GDP, life expectancy and ageing index (IRF-AI); c) the response of life expectancy to the effects of per capita health expenditure, per capita GDP, life expectancy and ageing index (IRF-LFE); d) the response of per capita GDP to the effects of per capita health expenditure, per capita GDP, life expectancy and ageing index (IRF-GDP).

We observe from Table 3 that in response to an ageing index shock, a life expectancy shock and a per capita GDP shock, the health expenditure increases instantaneously ($t=1$) and this effect remains significant for about three years. Finally, it becomes weaker until to be close to zero with lags becoming longer in period ten (IRF-HEX). We also observe from Table 3 that in response to an ageing index shock, the health expenditure increases more than it does in response to a life expectancy shock or a per capita GDP shock. A one percent increase in the ageing index would raise health expenditure by approximately 1.1 percent after one year and by 0.7 percent after three years. The estimated impulse response for life expectancy implies that a 1 percent increase in life expectancy raises health expenditure by 0.18 percent after one year and by 0.11 percent after three years. Finally, per capita GDP also has a substantial effect on health spending; an increase of 1 percent in the per capita GDP increases the health expenditure close to 0.12 percent after one year and to 0.1 percent after three years.

Table 3
Impulse Response Functions (IRF) of per capita health expenditure, ageing index, life expectancy and per capita GDP.

	HEX	GDP	LFE	AI
IRF-HEX (Horizon in years)				
0	0.001	0.02	0.004	0.001
1	0.004	0.12	0.18	1.1
3	0.002	0.1	0.11	0.7
6	0.001	0.02	0.0006	0.0002
10	0.0003	0.01	0.00014	0.00011
IRF-AI (Horizon in years)				
0	0.004	0.08	0.04	0.02
1	0.003	0.09	0.05	0.062
3	0.0062	0.02	0.4	0.046
6	0.0001	0.0065	0.012	0.0177
10	0.0001	0.00133	0.0024	0.013
IRF-LFE (Horizon in years)				
0	0.0018	0.06	0.031	0
1	0.0023	0.07	0.035	0.06
3	0.0031	0.022	0.04	0.044
6	0.0006	0.006	0.012	0.03
10	0.00001	0.001	0.0024	0.0027
IRF-GDP (Horizon in years)				
0	0.0012	0.0005	0	0
1	0.001	0.0001	0.0013	0.002
3	0	0	0.001	0.001
6	0	0	0	0
10	0	0	0	0

Notes: The IRF denotes for a forecast horizon from 0 to 10 years the impulse response function respectively for per capita health expenditure (**IRF-HEX**), for ageing index (**IRF-AI**), for life expectancy (**IRF-LFE**), and for per capita GDP (**IRF-GDP**).

In contrast, the other impulse responses (IRF-AI, IRF-LFE, IRF-GDP) are close to zero. In fact, a shock on health expenditure in the long term does not affect the ageing index (IRF-AI), life expectancy (IRF-LFE) or per capita GDP (IRF-GDP). Finally, the life expectancy and ageing index positively react to a shock on per capita GDP, but this effect is poor and short lived.

Our findings underline the great long run variability in the relationship between health outlays and longevity in terms of the cost impact of the population senility rate usually caused by chronic illnesses and severe diseases that increases over time. The results suggest more investments in health care expenditure in order to improve the health status of the ageing population. In particular, the positive impacts of a shock to the ageing index and the life expectancy on the public spending may indicate that health care provided through the government requires better management, especially after the economic crisis of 2007–2008. Therefore, greater health expenditure should help the old to live longer. Moreover, we find a positive impact of a shock to the per capita GDP on the per capita health care expenditure.

In line with the economic theory, wealthier individuals tend to spend a larger fraction of their income on better quality nutrition and they have a better standard of living. If income levels increase then the health expenditure as a function of income rises. Public health expenditure improves the health and the labour force and consequently increases productivity, with positive impact on gross domestic output and development. In this case, policy makers should consider health expenses as an investment rather than a cost to sustain and improve economic and social outcomes. However, we find a weaker impact of a shock to GDP on health spending than on ageing and life expectancy. This result suggests that since Italy has one of the lowest ratios of births to deaths in the world, but also has a rapidly ageing society this effect is stronger on health expenditures than the effect of potential economic growth.

On the whole, as it can be seen from the impulse responses, the relationship between health expenditure and the ageing index is found to be more significant with respect to the other variables inserted into the model. Starting from the B-VAR model we present the variance decomposition for each variable of the model, with a forecast horizon from 3 to 12 years (Table 4).

As we can see from Table 4, the ageing index, life expectancy and per capita GDP shocks are the fluctuations dominant source of health expenditure fluctuations in Italy (FVD-HEX), but the reverse is not true (FVD-AI; FVD-LFE; FVD-GDP). The roles of the ageing index and life expectancy are relatively stable over time, with ageing index explaining roughly 6.03% of the fluctuations in health expenditure after six years and becoming negligible after 12 years. For the same period the life expectancy can account for up to 5% of the variation in health expenditure (FVD-HEX) and this effect is greatly reduced after 12 years.

Finally, GDP explains 3.45% of the variations in health spending after six years. The effect decreases after 12 years. On the contrary, in the cases of ageing index (FVD-AI) and life expectancy (FVD-LFE) the results suggest no role in health expenditure shocks.

These results are in line with the impulse response functions and confirm the significant influence in the

Table 4
Forecast Variance Decomposition (FVD) for per health expenditure, ageing index, life expectancy, per capita GDP.

	HEX	GDP	LFE	AI
FVD-HEX (Horizon in years)				
3	1.81	3.28	2.61	5.28
6	2.2	3.45	5.0	6.03
9	4.8	2.66	3.6	5.67
12	2.7	1.78	2.1	3.07
FVD-AI (Horizon in years)				
3	0.071	0.18	0.14	0.15
6	0.9	1.01	2.79	1.23
9	0.8	0.66	3.08	1.9
12	0.017	0.78	3.47	0.44
FVD-LFE (Horizon in years)				
3	0.51	1.28	0.22	0.56
6	1.9	2.31	2.79	1.45
9	0.8	1.66	1.8	1.66
12	0.47	1.08	0.89	0.011
FVD-GDP (Horizon in years)				
3	0.81	0.28	0.01	0.22
6	0.9	0.03	0.09	0.04
9	0.8	0.066	0.13	0.03
12	0.7	0.078	0.1	0.018

Notes: The FVD denotes for a forecast horizon from 3 to 12 years the forecast variance decomposition respectively for per capita health expenditure (**FVD-HEX**), for ageing index (**FVD-AI**), for life expectancy (**FVD-LFE**), and for per capita GDP (**FVD-GDP**).

medium-long term of ageing index on health expenditures in Italy by suggesting longevity as a determinant of health spending.

4. Different priors

In this section we compare the performance of the B-VAR framework based on different types of prior distributions to forecast the dynamics of our variables. We develop four B-VAR models based on the Litterman-Minnesota, Normal-Wishart, Sims-Zha normal-Wishart and Sims-Zha normal flat priors and we compare them in terms of forecast statistics such as the root mean square error (RMSE) and the Theil U statistics. We derive these statistics for one-year ahead and two-year ahead forecasts.

The four estimated models are all different version of the same baseline B-VAR model. The results are reported in Table 5.

As we can see from Table 5, the forecasting statistics for the prior distributions are quite closer to one another. However, the RMSE and the Theil U values of the Minnesota and the Sims-Zha normal flat distributions have more similar values. This means that Sims-Zha normal flat showed a good performance. In this case the Sims-Zha normal flat prior can be used as an alternative to Minnesota prior.

In contrast, the Normal-Wishart prior gives the highest values of RMSE and Theil U statistics having the worst performance.

These findings confirm that the B-VAR approach based on the Litterman-Minnesota prior, outperforms the other priors specification except for Sims-Zha normal flat prior. Moreover, the results suggest that the prior information can significantly improve the forecasts of economic models.

Table 5
B-VAR forecast statistics of the different prior distributions for per capita health expenditure, ageing index, life expectancy and per capita GDP.

Step Forecast	1		2	
	RMSE	Theil U	RMSE	Theil U
HEX				
Minnesota	0.022	0.79	0.031	0.77
Sims-Zha normal flat	0.023	0.87	0.032	0.78
Sims-Zhanormal-Wishart	0.032	0.88	0.043	0.80
Normal-Wishart	0.033	0.89	0.042	0.85
AI				
Minnesota	0.0287	0.35	0.0299	0.23
Sims-Zha normal flat	0.0326	0.36	0.0406	0.25
Sims-Zhanormal-Wishart	0.0339	0.51	0.0498	0.43
Normal-Wishart	0.0391	0.67	0.0474	0.54
LFE				
Minnesota	0.0961	0.12	0.0970	0.10
Sims-Zha normal flat	0.0967	0.16	0.0977	0.12
Sims-Zhanormal-Wishart	0.0969	0.28	0.0978	0.21
Normal-Wishart	0.0978	0.30	0.0979	0.28
GDP				
Minnesota	0.070	0.12	0.077	0.10
Sims-Zha normal flat	0.071	0.22	0.087	0.21
Sims-Zhanormal-Wishart	0.082	0.32	0.091	0.27
Normal-Wishart	0.087	0.41	0.093	0.38

Notes: The table shows for one-year ahead and two-year ahead forecasts the forecast statistics such as root mean square error (**RMSE**) and the Theil U statistic (**Theil U**) of the prior distribution (Litterman-Minnesota, Normal-Wishart, Sims Zha normal Wishart and Sims Zha normal flat) respectively for per capita health expenditure, for ageing index, for life expectancy and for per capita GDP.

5. Conclusions

Health is one of the most important development issues facing the world today. In the future decades, according to ISTAT demographic forecasts, Italy will experience a gradual ageing of the population due to both for fertility rate reduction and longevity gains. Therefore, the increasing share of older people in the population will be characterized by poorer health (chronic-degenerative diseases, self-reported health, mental and physical illness) because the period of time that people lived with disability or morbidity will increase which in turn will change the demand for health services. The increasing demand for health and social care services, such as Long Term Care (LTC), will have an inevitable impact on the cost of the National Health System (NHS). The growth of the health costs related to the ageing population raises doubts about the capability of the National Health System to provide adequate funding for its healthcare delivery. The greater use of resources is linked to the increase of both the ageing index and elderly population ratio [45,60]. The trend of health care spending appears to follow a J-shaped curve, with a decrease in the years after infancy, a restart in growth at age fifty with a peak when people are aged 75–80 [45], and a subsequent reduction after 80 [60]. Some authors analyse this trend by considering the spending on health care during the last year of an individual's life (mortality-related costs) which does not depend on the age at death [38,61,62]. In this case, the correlation between health-spending growth and the age of the population depends on the mortality rate which is higher for the elderly [43]. A study on Brescia's ASL data [60] highlights the strong correlation between population's age and per capita health expenditures. The analysis shows a great increase in health care spending as age increases with a reduction for the "oldest old" people (over age 89). However, if we consider the health expenditure for chronic diseases there is a strong incidence of the individuals less than ages 68 (considered "non-elderly").

Moreover, the much lower labour participation rate of elderly persons implies a lower tax base for government revenue; thus, population ageing can result in a double whammy in public finance: increased health expenditures coupled with a reduction in tax revenue [48].

According to this demographic scenario in Italy a policy effort becomes necessary to investigate the long-lasting effect of the ageing process, chronic disease and disability among the elderly on health care expenditures and economic growth in later years.

This paper contributes to the discussion on the societal consequences of population ageing by using Bayesian VAR estimations based on EUROSTAT and OECD datasets which collect aggregate information on health care expenditure, economic growth, ageing index and life expectancy in Italy during the years 1990–2013.

The development of a B-VAR model has been motivated by the necessity of obtaining with a small dataset, short-run and long-run information about the relationship between health care expenditures and demographic changes without deciding a-priori the direction of causality. In fact, although the VAR models represent a good approach analysing short-term and long-term relations because they are a-theoretical models, they fail in terms of forecasting, impulse response functions and variance decomposition analysis in the case of a short sample. Therefore, the B-VAR models, by introducing prior distribution for estimating the coefficients, provide a solution to this problem and they allow the investigation of the possible dynamic interactions between our variables.

For these reasons, our results may be interesting for alternative scenarios or health policy intervention.

In particular, we learned that per capita health care expenditure is more influenced by ageing index than by per capita GDP and life expectancy in the short-run. The results are also confirmed in the long-run on a forecast horizon from 1 to 10 years by the impulse-response function and on a forecast horizon from 3 to 12 years by the variance decomposition analysis. The impulse response functions indicate that changes in ageing index provide a more significant stimulus to the Italian health expenditure than life expectancy and per capita GDP. Conversely, changes in health spending have a scarce impact on ageing index, life expectancy and per capita GDP.

The variance-decomposition analysis reveals that per capita GDP, life expectancy and ageing index are important determinants of health spending in Italy, with the contribution from the latter being higher. In contrast, the impact of health spending on ageing index, life expectancy and per capita GDP is not significant. Our study shows that health care expenditures increase with age and life expectancy; therefore, – advances in longevity will increase the lifetime health care expenditures per person. This evidence will have a significant impact in the short term as well as in the long term, and shows the need for a redesign of the health system through an intensive promotion of the public health system.

Therefore, the critical concern for the future healthcare system is understanding how the health conditions of older people will affect public policy. Estimating how many disabled old people there will be is crucial to evaluate the social and economic consequences and consequently the level of expenditures of a country. In our opinion, policy makers should recognize that healthcare is a priority involving different institutional players. The "new care demand" requires paths, planning and policy design. It is necessary to increase the investments not only in the healthcare system but also in education for about healthy lifestyle and paying attention to the environment to reduce the fragility of old people. Moreover, the local context is important to adapt the policy to the specific conditions of the population in terms of economy, education, income etc. It is essential to realize a spending system that is oriented not towards pathology and services (typical of the acuteness size), but towards the person and the individual care path (typical of the chronicity size). It is also important to simplify programming and planning in order to strengthen and facilitate the integration processes between the institutions, in the allocation of resources and competencies. Strengthening the role of primary care as a point of access to the integrated system of care, (both health and social) will improve the system's ability to respond to the complex needs of fragile population in the future. Improving the quality of primary care will reduce the overall fragility of the population. In addition, a safe environment with low levels of pollution is another key factor to reduce the fragility of the ageing population.

Finally, the policy actions should include improvements in public health, such as retirement plans that support elderly individuals with age-specific risk factors and that help them not to become poor (i.e., improving health-insurance coverage, household income, informal care supply) or intervention plans oriented towards young people for primary and preventive services.

However, the empirical evidence about health efficiency is not conclusive. For instance, the ranks of health efficiency given by Evans et al. [63] do not coincide, due to the use of different estimation methods and the use of different health efficiency definitions, suggesting that the countries with better health performances are not always those with the most efficient health systems. Apart from health-efficiency, the financing schedule (insurance vs tax mechanisms) or even cultural differences may also be important [64,65]. In this context, our results may be used as a signalling device to design more effective intervention plans oriented to the accessibility of health care, pioneering medicine for chronic diseases and encouraging healthier lifestyles for the elderly.

Therefore, we think that policy makers should recognize longevity policy as a distinct policy area: the challenges arising from increased longevity are best dealt with when intersectional shifts social security, pensions, health, environmental actions and education are recognized as important and an integrated approach among different institutions is adopted.

However, in the present paper we focused only on ageing population while the so-called demographic transition that Italy, such as other OECD countries, has been experiencing involves a higher life expectancy combined with a lower fertility rate, which could affect health expenditures and economic growth. In this case, a larger share of the old (due to ageing) would be associated with a lower number of young (due to lower fertility rates). Another important point that could be interesting to take into account for future research is the connection between demographic transition and higher investment in education. The relationship between education and longevity is positive and possibly going in mutually casual directions. Longer life expectancy and longevity can prompt individuals to acquire better education and more human capital, as their returns are expected to be enjoyed over a longer period; however, there are also good reasons to believe that life expectancy and longevity depend on the educational background of an individual: skilled people usually face more stable social situations, have higher incomes and have ways of living more conducive to health, compared to unskilled people. In this sense, an ageing society would also lead to more educated people, especially considering that better educated people are also more likely to be aware, and this will have an effect on health expenditures and economic growth. These points are left for further research.

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