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ANALYSIS OF TRENDS IN LIFE EXPECTANCIES AND *PER CAPITA* GROSS DOMESTIC PRODUCT AS WELL AS PHARMACEUTICAL AND NON-PHARMACEUTICAL HEALTHCARE EXPENDITURES

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Abstract: Life expectancy is a common measure of population health. Macro-perspective based on aggregated data makes it possible to approximate the impact of different levels of pharmaceutical expenditure on general population health status and is often used in cross-country comparisons. The aim of the study was to determine whether there are long-run relations between life expectancy, total healthcare expenditures, and pharmaceutical expenditures in OECD countries. Common trends in *per capita* gross domestic products (GDPs) (excluding healthcare expenditures), *per capita* healthcare expenditures (excluding pharmaceutical expenditures), *per capita* pharmaceutical expenditures, and life expectancies of women and men aged 60 and 65 were analyzed across OECD countries. Short-term effect of pharmaceutical expenditure onto life expectancy was also estimated by regressing the deviations of life expectancies from their long-term trends onto the deviations of pharmaceutical and non-pharmaceutical health expenditures, as well as GDP from their trends. The dataset was created on the basis of OECD Health Data for 34 countries and the years 1991-2010. Life expectancy variables were used as proxies for the health outcomes, whereas the pharmaceutical and healthcare expenditures represented drug and healthcare consumption, respectively. In general, both expenditures and life expectancies tended to increase in all of the analyzed countries; however, the growth rates differed across the countries. The analysis of common trends indicated the existence of common long-term trends in life expectancies and *per capita* GDP as well as pharmaceutical and non-pharmaceutical healthcare expenditures. However, there was no evidence that pharmaceutical expenditures provided additional information about the long-term trends in life expectancies beyond that contained in the GDP series. The analysis based on the deviations of variables from their long-term trends allowed concluding that pharmaceutical expenditures significantly influenced life expectancies in the short run. Non-pharmaceutical healthcare expenditures were found to be significant in one out of four models (for life expectancy of women aged 65), while GDPs were found to be insignificant in all four models. The results of the study indicate that there are common long-term trends in life expectancies and *per capita* GDP as well as pharmaceutical and non-pharmaceutical healthcare expenditures. The available data did not reveal any cause-effect relationship. Other factors, for which the systematic data were not available, may have determined the increase in life expectancy in OECD countries. Significant positive short-term relations between pharmaceutical expenditures and life expectancies in OECD countries were found. The significant short-term effect of pharmaceutical expenditures onto life expectancy means that an increase of pharmaceutical expenditures above long-term trends would lead to a temporary increase in life expectancy above its corresponding long-term trend. However, this effect would not persist as pharmaceutical expenditures and life expectancy would converge to levels determined by the long-term trends.

Keywords: statistical data analysis, gross domestic product, life expectancy, health expenditures

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The work reported in this paper was a part of Work Package 3 within the International Research Project on Financing Quality in Healthcare - InterQuality (co-funded by the 7th Framework Programme (FP7) for Research and Technological Development of the European Union). The aim of the project was to validate pharmaceutical benefit financing models to find promising solutions in the area of pharmaceutical care and provide implementation recommendations for policy-makers from European countries.

The first step in the validation of pharmaceutical benefit financing models was to evaluate them from the macro-perspective. Life expectancy variables were used as proxies for the health outcomes, whereas the pharmaceutical and healthcare expenditures represented drug and healthcare consumption, respectively.

Life expectancy is an indicator of how long a person can expect to live on average, given prevailing mortality rates. In the available literature this indicator was a common measure of population health in general, and was often used as a summary measure when comparing different populations. There was a consensus amongst researchers that health expenditures, reflecting the quality of healthcare, may have a positive impact on the population health status and that this impact should be evaluated. Positive and statistically significant relationship between life expectancy (LE) and pharmaceutical expenditure was found in many studies (1-6). It was found that the consumption of newer drugs was associated with significantly lower mortality than the consumption of older drugs and that the use of newer drugs limits all types of nondrug medical expenditure, resulting in a reduction of the total cost of treating a particular condition (7). Studies carried out from micro-perspective (8, 9) provided valuable insights concerning particular drugs, diseases, therapeutic groups, or individual patients. However, these studies did not inform about the overall effect of drug consumption onto the population health status. Therefore, in order to approximate the impact of pharmaceutical expenditure on general population health status, a macro-perspective based on aggregated data was adopted.

The study analyzed common trends in *per capita* GDPs (excluding health expenditures), *per capita* healthcare expenditures (excluding pharmaceutical expenditures), *per capita* pharmaceutical expenditures and life expectancies of women and men aged 60 and 65 across OECD countries. This approach allowed separating long-term and short-term dynamics in life expectancies and health expenditures. The analysis of common trends made it possible to identify possible long-run relations between life expectancy, total healthcare and pharmaceutical expenditures in OECD countries.

MATERIAL AND METHODS

The dataset containing information about *per capita* GDPs, *per capita* healthcare expenditures, *per capita* pharmaceutical expenditures and life expectancies of women and men aged 60 and 65 was built on the basis of OECD Health Data for 34 OECD countries and the period 1991-2010 (10). Natural logarithms of all the variables were used.

To investigate if there are common trends in *per capita* GDPs, *per capita* healthcare expenditures, *per capita* pharmaceutical expenditures and life expectancies, methods described by Bai (11) were employed. This methodology was chosen as the data under investigation were non-stationary. The idea of this approach was to identify the number of common stochastic trends in two panels of non-stationary time series separately and in a panel of concatenated time series. If the number of common trends in the concatenated panel was lower than the sum of common trends extracted from each of the analyzed panels, it implied the existence of long-run relations between the two analyzed indicators in the countries under investigation.

In order to identify common trends in life expectancies, *per capita* pharmaceutical and non-pharmaceutical healthcare expenditures, and *per capita* GDP, the analysis was carried out in a few stages. First, common trends across countries were identified for each of the variables, allowing for the maximal number of common trends equal to five. Second, the common trends were identified in pairs of variables. Finally, life expectancy was added to various types of expenditures in order to identify the total number of trends that is sufficient to describe non-stationary dynamics of all the indicators.

This approach made it possible to identify those variables which have long run relations with life expectancy. However, it should be noted that the existence of long run relations between life expectancy and another variable did not imply causation.

RESULTS

Figures 1 and 2 show the association between pharmaceutical expenditures and life expectancies of males and females aged 60 for selected OECD countries. The graphs illustrate some general tendencies which could be observed for the whole panel of countries. Six countries participating in the InterQuality project were selected so that the figures were not overcrowded. In general, in all the countries, increase of both expenditures and life expectancies was observed; however, the growth rates differed between countries. For example, the relative increase in pharmaceutical expenditures in Denmark was much lower than in the US, but the relative increase in life expectancies was rather similar.

The analysis of common trends in each of the analyzed variables revealed two common trends for

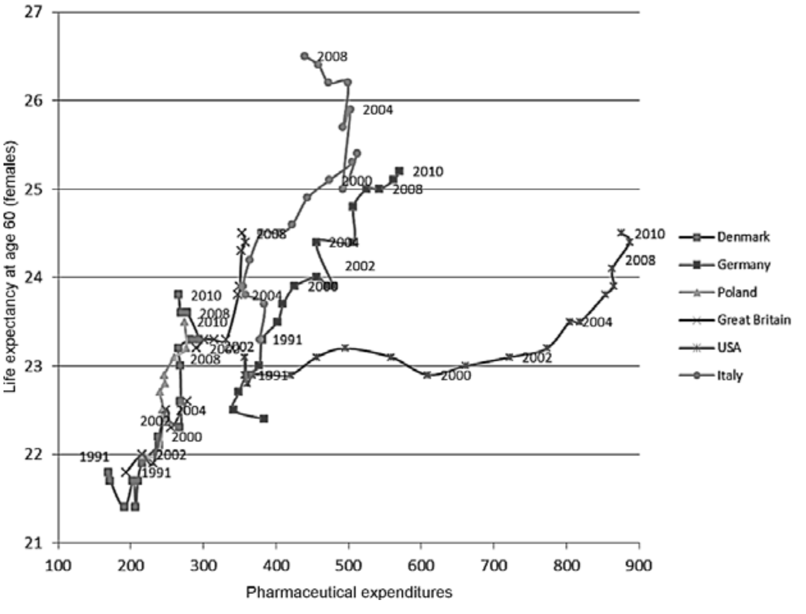

Figure 1. Pharmaceutical expenditures and life expectancy of females aged 60

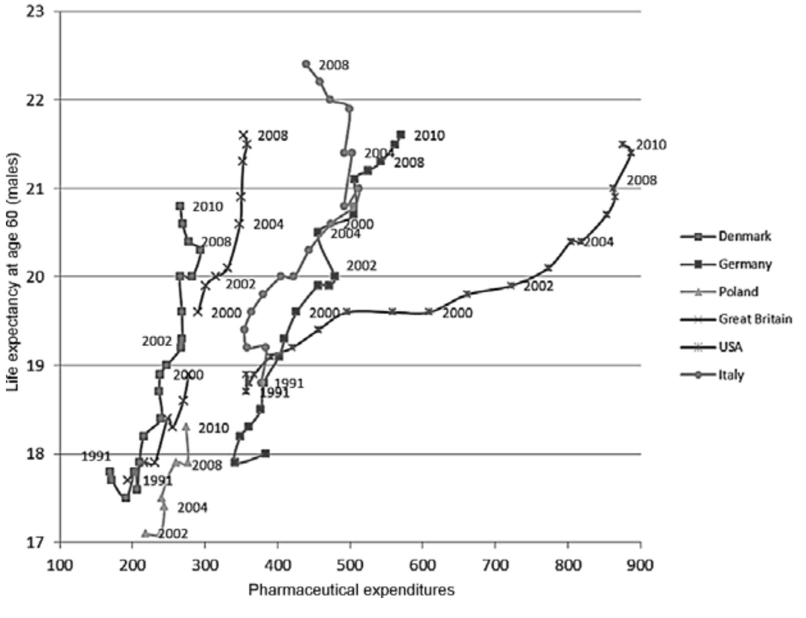

Figure 2. Pharmaceutical expenditures and life expectancy of males aged 60

all four indicators of life expectancy, four common trends for *per capita* GDP, and five common trends for pharmaceutical and non-pharmaceutical healthcare expenditures.

In the second step of the analysis, the number of common trends for pairs of variables was estimated. Combining the data on life expectancies for different ages and genders did not change the estimated number of common trends. It can be suggested that two trends are sufficient to describe common non-stationary dynamics of life expectancies across countries. For any data set combining life expectancies and GDPs, pharmaceutical or non-pharmaceutical healthcare expenditures, there was no increase in the number of non-stationary trends as compared with the maximal number of trends in any of the paired data sets, i.e., common trends in life expectancies can be included in subsets of common trends in GDPs, pharmaceutical or healthcare expenditures. However, the data set of GDPs included two additional common trends and the data sets of pharmaceutical and non-pharmaceutical healthcare expenditures included three additional trends as compared to the data set of life expectancies.

In the last step of the common trends analysis, the number of common trends was estimated for groups of four to seven data sets of indicators. Two common trends were found for the group composed of life expectancies for females and males aged 60 and 65. It means that all considered measures of life expectancies shared the same long-term trends. Five common trends were found for each measure of life expectancy combined with *per capita* pharmaceutical expenditures, *per capita* healthcare expenditures, and *per capita* GDP. Given the results of the analysis conducted for pairs of variables, it can be concluded that there were two common trends that were shared by all the variables in each of these subsets. There were two additional common trends shared by GDP, total healthcare expenditures and pharmaceutical expenditures, and one more trend shared by total healthcare expenditures and pharmaceutical expenditures.

Finally, deviations of life expectancy variables from their long-term trends were analyzed by regressing them on their own lags and onto the lags of deviations of pharmaceutical and non-pharmaceutical healthcare expenditures from their common trends, as well as lags of deviations of GDPs from their trends. The explanatory variables were lagged in order to avoid simultaneity bias. Three-year lags were allowed for each explanatory variable.

The estimation results are presented in Table 1. Significance of lagged dependent variable (at the level of significance equal to 5 percent) for all four indicators of life expectancy indicated that after removing the long-term trends there was large residual time dependence. Deviations of *per capita* GDPs

Table 1. Short-term relationships between de-trended life expectancy variables and expenditure variables.

	*LE*60*F*	*LE*65*F*	*LE*60*M*	*LE*65*M*
PE(-1)	0.024*	0.036	0.041***	0.040**
PE(-2)	0.029*	0.023	-0.011	0.007
PE(-3)	0.028**	0.044**	0.061**	0.063*
HE(-1)	-0.008	0.000	0.014	0.018
HE(-2)	0.019	0.038**	0.005	0.016
HE(-3)	0.015	0.004	-0.001	0.000
GDP(-1)	-0.036	-0.046	-0.080	-0.047
GDP(-2)	-0.062	-0.002	0.100	0.037
GDP(-3)	-0.003	-0.006	-0.026	0.015
dep.var(-1)	0.432***	0.447**	0.414***	0.379***
dep.var(-2)	0.085	0.165***	0.035	0.068*
dep.var(-3)	-0.143***	-0.238***	-0.189***	-0.145***

Notes: All variables represent deviations from the long-term trends. Values in parentheses indicate the lag used and *dep.var.* stands for the dependent variable. Abbreviations: *LE*60*F*, *LE*65*F*, *LE*60*M*, *LE*65*M* stand for life expectancies of females aged 60 and 65 and males aged 60 and 65, respectively. *PE* = pharmaceutical expenditures, *HE* = healthcare expenditures and *GDP* = gross domestic product. *, ** and *** indicate significance at 10%, 5% and 1% levels, respectively.

from long-term trends were found to be insignificant in all four models. This can be interpreted as follows: *per capita* GDP determined long-term trends in life expectancy, but deviations of GDP from the long-term trends had no significant short-term effect on life expectancy.

Deviations of pharmaceutical expenditures from the long-term trends were found to be significant in all four estimated models: short-term expansions of pharmaceutical expenditures had a significant short-term effect onto life expectancy of people aged 60 and 65 (Table 1). Thus, if pharmaceutical expenditure in a country is above its long-term trend in a given year (i.e., there is an unexpected increase in the pharmaceutical expenditure), life expectancy will also be above its long-term trend in a few years following the increase in pharmaceutical expenditure. Non-pharmaceutical healthcare expenditures were found to be significant in one model only (for life expectancy of women aged 65). The lack of a significant partial correlation between life expectancies and non-pharmaceutical healthcare expenditures can be explained by the fact that non-pharmaceutical healthcare expenditures include both current expenditures of the healthcare systems and long-term investment. The long-term investment may have no immediate effect onto health status.

DISCUSSION

The aim of the study was to analyze relations between pharmaceutical expenditures and life expectancy. The analysis used panel data to evaluate common trends in pharmaceutical expenditures and life expectancies across countries. There were two key findings. Firstly, the study revealed significant positive short-term relations between pharmaceutical expenditures and life expectancies in OECD countries. Secondly, it demonstrated that there are common long-term trends in life expectancies and *per capita* GDP as well as pharmaceutical and non-pharmaceutical healthcare expenditures. However, there was no evidence that pharmaceutical expenditures provide additional information about the long-term trends in life expectancies beyond that contained in the GDP series. As the GDP series are correlated with various determinants of life expectancies, which include healthcare expenditures as well as life-style and environmental factors, the common long-term trends in life expectancies can be interpreted as generated by a variety of factors. No specific contribution of healthcare expenditures to these long-term trends can be identified on the basis of the data set under study.

The methodological differences do not allow direct comparisons of the results presented in this paper with other published studies. Nevertheless, the reported conclusions are consistent with other research. In similarity to our analysis, Caliskan et al. (1) found a positive relationship between pharmaceutical spending and life expectancy. The authors used unbalanced panel data of 21 OECD countries over the period from 1985 to 2002. The empirical results showed that pharmaceutical expenditure, measured by *per capita* drug spending, had positive, but heterogeneous effects on life expectancies for females and males of various ages.

A positive effect of drug consumption, measured as *per capita* pharmaceutical expenditure, on population life expectancy at various ages was also confirmed in the study by Shaw et al. (2). They found that pharmaceutical consumption had a positive effect on life expectancies at middle and advanced ages. It was concluded that doubling annual drug spending added about one year of LE for males at the age of 40 and slightly less than a year of LE for females at the age of 65. The estimation was based on cross section data collected for 19 OECD countries.

The link between pharmaceutical expenditures and health outcomes in 14 countries using OECD panel data from the years 1985 to 2001 was also studied by Liu et al. (3). It was confirmed that significant, but marginal gains in population health outcomes were associated with increased pharmaceutical expenditures. A 10% increase in drug spending was connected with a 0.3% increase in female LE at the age of 65. A similar increase was associated with a 0.4% increase in male LE at the age of 65 years and a 0.5% increase at the age of 80 years.

Similar studies were conducted by Crémieux et al. (4, 5), who assessed the statistical relationship between pharmaceutical expenditures and population health outcomes in Canada. The results of the study showed a strong statistical relationship between drug spending and LE at 65 and LE at birth. This link was stronger for private drug expenditure than for public drug expenditure.

The empirical analysis presented in this paper is not free from limitations. Firstly, the choice of adopted methodology limits the conclusions. It does not allow estimating a cause-effect relationship. Existence of common trends does not necessarily mean that systematic increase in pharmaceutical expenditures would significantly increase life expectancy in the long run. The presence of common trends does not exclude heterogeneity in pharmaceutical expenditures and life expectancies across countries either. As more trends are needed to explain the long-term tendencies in pharmaceutical expenditures than long-term tendencies in life expectancy across the data panel, it can be suggested that there is more heterogeneity in drug spending trends than in life expectancy trends across countries. The relatively large heterogeneity in pharmaceutical expenditures can be attributed to variation in health policies. However, in order to build and estimate a parametric statistical model that would allow determining if the variation in policies can explain the variation in health outcomes, a systematic collection of comparable cross-country data is needed. The data should include other factors that determine health outcomes.

Secondly, the results can be sensitive to the choice of the model. As argued by Grootendorst et al. (9), the analysis of the influence of healthcare expenditure on life expectancy is highly sensitive to model specification. He demonstrated that the introduction of some seemingly innocuous changes in the model specification leads to large changes in the parameter estimates or even obtaining estimates with different signs. It is concluded that it is difficult to estimate the parameters of the relationship between life expectancy and its determinants using aggregate data.

Thirdly, there is a number of confounding variables that can distort the causal link between healthcare spending and life expectancy (12). The most important one is GDP's growth which implies higher healthcare spending but also has an indirect impact on determinants of mortality such as better nutrition, less air pollution or better infrastructure. Life habits such as smoking or obesity are another important group of confounding variables. Finally, the causal link between healthcare spending and life expectancy can be distorted by reverse causality (increase in life expectancy may positively impact GDP and hence healthcare spending or a higher GDP may increase healthcare spending and hence improve health outcomes).

Lastly, the results presented in this paper should be treated with caution due to the limited number of analyzed health outcomes. In addition to the life expectancy, other studies (4-8) took into account infant mortality, life expectancy at birth or potential years of life lost. Consequently, no conclusions can be formulated regarding the impact of healthcare expenditures on other health measures.

CONCLUSIONS

The results of the study indicate that there are common long-term trends in life expectancies and *per capita* GDP as well as pharmaceutical and non-pharmaceutical healthcare expenditures. These common trends can be determined by a variety of factors, including life style and environmental factors which are correlated with life expectancy and income level. The dataset under investigation did not allow establishing the existence of cause-effect relationship between life expectancy and health expenditures. Significant positive short-term relations between pharmaceutical expenditures and life expectancies in OECD countries were found.

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