Kyiv School of Economics & Kyiv Economics Institute

DISCUSSION PAPER SERIES

Health Expenditures and Life Expectancy Around the World: a Quantile Regression Approach

Maksym Obrizan
Kyiv School of Economics and Kyiv Economics Institute

George L. Wehby
University of Iowa

DP# 47 **January 2012**

Kyiv School of Economics and Kyiv Economics Institute
Yakira St. 13, 3d floor, 04119 Kyiv, Ukraine
Phone: (+380 44) 492-8012, Fax: (+380 44) 492-8011
E-mail: info@kse.org.ua, Internet: www.kse.org.ua

HEALTH EXPENDITURES AND LIFE EXPECTANCY AROUND THE WORLD: A QUANTILE REGRESSION APPROACH

Running head: “Health Expenditures and Life Expectancy”

Key Words: Health Expenditures, Life Expectancy, Quantile Regression

Words in text: 1,724 with 2 Figures

Maksym Obrizan[a] and George L. Wehby[b,*]

[a]*Kyiv School of Economics and Kyiv Economics Institute, Kyiv, Ukraine*
[b]*Department of Health Management and Policy, College of Public Health, The University of Iowa, Iowa City, USA*

[*]Correspondence to: Dr. George L. Wehby, Department of Health Management and Policy, College of Public Health, The University of Iowa, Iowa City, USA

Acknowledgments: Maksym Obrizan would like to thank the Victor Pinchuk foundation, EERC and Stockholm Institute of Transition Economics (SITE) for their support. George Wehby acknowledges support from the NIH/NIDCR 1 R03 DE018394. The opinions expressed here are those of the authors and do not necessarily reflect those of any of the funding, academic or governmental institutions involved. The authors thank Kwame Nyarko for providing excellent research assistantship. Maksym Obrizan would like to thank academic seminar participants at Kyiv School of Economics and Kyiv Economics Institute in April of 2011 for their helpful suggestions.

Conflict of interest: Authors declare that they have no conflicting interests related to this manuscript.

SUMMARY

Previous literature has produced mixed results on the effects of country health expenditures on longevity. More importantly, all previous studies have evaluated the expenditure effects on the mean of the life expectancy distribution, ignoring the possibility that the expenditure returns may not be the same for countries that differ in their life expectancies. In this paper, we evaluate the heterogeneity in country health expenditure effects throughout the life expectancy distribution applying quantile regression to an assembled dataset of 177 countries. We find significant heterogeneities in expenditures effects on life expectancy that are completely masked by ordinary least squares (OLS), which underestimates (overestimates) the expenditure returns for countries ranking at low (high) life-expectancy quantiles. The largest returns from increased spending are for countries at the left margin of the life expectancy distribution (mainly at quantiles 0.25 and lower), for which a $100 increase in per capita spending leads to 11.5 and 11 months of life for males and females, respectively. The results suggest that increasing healthcare spending in these countries may have significant population-wide life expectancy returns.

1. INTRODUCTION

Previous literature has produced mixed results on the effects of population-level health expenditures on average life expectancy across countries. For example, in a study of several OECD countries, Wolfe (1986) found that when life-style (smoking, drinking and accidents), inflation and population size are accounted for, health expenditures have a positive effect on life expectancy. On the other hand, McCarthy and Wolf (2001) found that health expenditures are not well predictive of life expectancy in Africa, compared to access to health services, clean water, sanitation and education. This mixed empirical evidence suggests that health expenditure effects on life expectancy may vary between countries, possibly due to differences in population and economic factors that modify the expenditure effects. From this perspective using ordinary least squares (OLS) to estimate expenditure effects on life expectancy mean (i.e. for the "average" country) may be inadequate in the presence of possible unobserved heterogeneity between countries.

Theory would also support this heterogeneity. For example, increasing average healthcare spending by $100 per capita is expected to result in much higher returns in life expectancy in poorer countries with low life expectancy where several low-cost improvements in health can still be achieved especially by treating and preventing infectious diseases. In contrast, the same increase in spending in richer countries with high life expectancy is unlikely to result in a similar gain in life expectancy since the well-established public health infrastructures and advanced medical technology have already resulted in significant health and longevity improvements (Cutler, 2006). Such a heterogeneity does not only occur because of the diminishing marginal returns of spending, but due to interactions between spending and several country characteristics that may modify spending effects such as population demographic, economic, social, cultural, and environmental factors. Therefore, simply accounting for diminishing marginal returns in OLS does not address this heterogeneity.

In this paper, we employ quantile regression to evaluate the heterogeneity in country health expenditure effects at various locations of the life expectancy distribution, while allowing for diminishing marginal returns of expenditures at each location by including squared expenditure terms. This is the first study to formally evaluate the heterogeneity in life expectancy returns from health expenditures for countries at different ranks of the life expectancy distribution.

2. METHODS

2.1. Estimation approach

Our model is based on a country-level analysis of the country's life expectancy (*LE*) as a function of its per capita spending on health (*HE*) controlling for conceptually relevant socioeconomic and demographic characteristics (*X*); the country is the unit of the analysis. We estimate this model separately for males and females due to differences in their health characteristics and disease epidemiology which may modify expenditure effects. We model the conditional quantiles of *LE* as follows:

$$LE = Q\left(\alpha_0^q + \beta_1^q HE + \beta_2^q HE^2 + \sum_{k=1}^{8} \lambda_k^q X_k\right) \qquad (1).$$

In this equation q is the quantile rank between 0 and 1, and Q is the conditional qth quantile of *LE*. We estimate this function using quantile regression (QR) to identify the health expenditure effects (β) at different quantiles of the country-level life expectancy distribution. When estimating these effects on a certain quantile q, QR holds constant at that specific quantile the net value of the unobserved country-level factors that determine the countries' rank on the life expectancy distribution and that result in countries with similar observable characteristics (*HE* and *X*) to have different life expectancies. This is why QR estimates may be interpreted as representing expenditure effects by the heterogeneity in unobserved relevant factors for life expectancy (Chernozhukov and Hansen, 2005; Wehby *et al.*, 2009). We estimate QR by minimizing the weighted sum of absolute deviations for each observation i (country) between the conditioned and actual *LE* for q ranging from 0.05 to 0.95 in increments of 0.05 (Koenker and Bassett, 1978; Koenker and Hallock, 2001):

$$\min[q \sum_{LEi \geq Qi}^{n} | LE_i - Q_i | + (1-q) \sum_{LEi < Qi}^{n} | LE_i - Q_i |] \qquad (2),$$

We estimate the variance-covariance matrix using bootstrap with 1,000 replications and test differences in expenditure effects between different quantiles using standard Wald tests (Hao and Naiman, 2007). For comparison to the QR results, we also estimate the expenditure effects on mean life expectancy using OLS.

2.2 Data

Data are taken from the World Development Indicators (WDI) database (World Bank) for years 2006-2008 for life expectancy, for years 1997-1999 for health expenditures, and for 2005-2007 for model covariates. We lag health expenditures 10 years in order to mitigate the simultaneity problem between health expenditures and life expectancy – countries with better life expectancy may have better productivity and spend more on health – and to allow for reasonable time for spending effects to occur. To further reduce simultaneity issues, we also lag other pecuniary covariates by one year. We decided not to impute any missing values for three key variables of interest: female and male life expectancy at birth and health expenditure per capita in current USD. This leaves us with an unbalanced panel of 531 observations with up to three waves of data for most of the 177 countries.

We control for lagged Gross National Income (GNI) per capita and Net Official Development Assistance (ODA) received per capita (both in current USD); Net ODA is set to 0 for non-receiving countries. We include female labor force participation rate (% of female population ages 15+) and public health expenditure as percent of GDP, which capture additional aspects of economic development. We also control for access rates to clean water and sanitation which are considered key factors for life expectancy (McCarthy and Wolf, 2001). Since there are no data on these two variables for 2006 and 2007, we use 2005 data for all three waves. We also include percent of urban population in order to account for different levels of access to modern health technology.

Ideally, we would also include additional covariates such as measures of inequality (Gini coefficient), road and public transport infrastructure, and education rates in order to further reduce the problem of endogeneity between healthcare spending and life expectancy. However, the WDI database has only a handful of non-missing observations for these additional variables which prevented us from including them. We do not include a measure of fertility because it is clearly endogenous to life expectancy and may be on the causal pathway between health expenditure and life expectancy. In the final set of included control variables, GNI per capita is missing in 19 cases (country-year observations), access to clean water and improved sanitation are missing in 34 and 40 cases, respectively, and female labor force participation is missing in 16 cases. Since excluding these observations would substantially reduce our sample size, we set missing values to the observation in previous or, if not available, in next year for each country. If a country has missing values in all three years for a particular covariate we set it to the median for the continent. Table 1 provides descriptive statistics on the model variables.

3. RESULTS

In 1997-1999 countries spent anywhere between 1.87 and 4291.07 USD per capita on health expenditures with a mean of 417.15 dollars, and had Female LE (FLE) from 42.9 to 86.1 and Male LE (MLE) from 41.4 and 80.0 years.

Table 2 shows the expenditure effects at 0.1, 0.25, 0.5, 0.75 and 0.9 quantiles for female and male life expectancy, which provide good coverage for the entire LE distribution. Figures 1 and 2 show the expenditures effects for the 19 quantiles (0.05 through 0.95). For both males and females, health expenditures have the expected positive effect on LE, but overall have larger effects at lower than higher quantiles. A 100$ increase in health expenditures from the mean of 417 $ is associated with 11 and 11.5 additional months gained for females and males, respectively, at the 0.1 quantile, compared to only 4.1 and 3.5 months, respectively, at the 0.9 quantile. Squared health expenditures have the expected negative sign due to diminishing marginal effect of expenditures at all quantiles. The expenditures and expenditures squared effects are significant at all quantiles at $p<0.01$ except for the last. The differences in expenditure effects between the five quantiles in Table 2 are significant for both females ($p= 0.037$) and males ($p = 0.003$). The OLS effects clearly mask the heterogeneity in expenditure effects. Based on OLS, an increase of $100 in health expenditures per capita is associated with 6.5 and 7.2 more months of mean life expectancy in women and men, respectively (Table 2).

Other variables of interest have the expected effects on LE. Access to clean water has the largest effect on LE at lower quantiles among all covariates, but the effect diminishes at higher quantiles. Similarly, gross national product and the amount of development assistance have higher and more significant effects at lower quantiles.[1]

4. DISCUSSION AND CONCLUSIONS

We show in this paper that health expenditures may have different effects on life expectancy for countries with different ranks on the life expectancy distribution. Specifically, increased expenditures have larger effects at the left margin of the LE distribution, i.e. for countries with lower life expectancies. There are many unobserved factors that determine the country's rank on the LE distribution and that may lead to different health expenditure effects on LE such as the types and magnitude of disease risks, population economic and demographic characteristics, geographic effects, and the supply and quality of healthcare services. The results suggest that countries with the largest need for increasing healthcare spending as measured by their poor LE performance will benefit the most in terms of increased LE from additional spending. As theorized above, this may occur due to the high prevalence of acute health problems that may have large detrimental effects on LE but that can be effectively reduced by healthcare interventions such as childhood infectious diseases which can be significantly lowered by vaccinations and proper treatments.

[1] Complete results of all regressions are available upon request.

Ignoring this unobserved heterogeneity between countries may lead to underestimation of the effects of health expenditures per capita on LE for countries with low LE and overestimation of these effects for those with higher LE. Estimating these effects on the mean LE (i.e. for the average country) underestimates the effects for countries at low LE quantiles by up to 69.7% and 59.4% and overestimates the effect for countries at high LE quantiles by up to 37.3% and 51.9% for females and males. These results suggest that other multi-country studies of income, spending or other healthcare effects should recognize the significant unobserved heterogeneity between countries and should not employ estimation approaches that mask such heterogeneity such as OLS.

REFERENCES

Chernozhukov, V. and C. Hansen. 2005. "An IV Model of Quantile Treatment Effects." Econometrica 73(1): 245-61.

Cutler DM, Rosen AB, Vijan S (2006). The value of medical spending in the United States, 1960-2000. *N Engl J Med* 355(9):920-7.

Hao, L., Naiman, D., 2007. Quantile Regression. *In* Quantitative Applications in the Social Sciences. Sage Publications.

Greene, W. 2000. *Econometric Analysis.* 4th ed. Upper Saddle River, NJ: Prentice Hall.

Koenker R, Bassett G. 1978. Regression Quantiles. *Econometrica* 46 (1): 33-50.

Koenker R, Hallock K. 2001. Quantile Regression. *Journal of Economic Perspectives* 15(4):143-56.

McCarthy F, Wolf H. 2001. Comparative Life Expectancy in Africa. Policy Research Working Paper.

Wolfe B. 1986. Health status and medical expenditures: is there a link? *Soc Sci Med* 22(10): 993-

9.

Wehby, G. L., J. C. Murray, E. E. Castilla, J. S. Lopez-Camelo, and R. L. Ohsfeldt. 2009. "Quantile effects of prenatal care utilization on birth weight in Argentina." *Health Economics* 18(11): 1307-21.

Table 1. Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Female life expectancy	70.66	10.92	42.93	86.05
Male life expectancy	65.92	9.72	41.42	79.98
Health expenditure per capita (lagged 10 yrs)	4.17	7.86	0.02	42.91
Health expenditure squared (lagged 10 yrs)	79.10	240.83	0.00	1841.33
GNI per capita (lagged 1 year)	93.45	146.06	1.00	787.70
Net Official Development Assistance (lagged 1 year)	0.54	1.11	-0.40	10.43
% of population with access to sanitation	70.11	30.09	9.00	101.00
% of population with access to clean water	84.94	16.78	35.00	100.00
% of public health expenditures in total	3.74	2.20	0.19	14.13
Female labor force participation, %	52.98	14.89	13.30	91.00
Female population, %	50.07	2.85	24.75	53.98
Urban population, %	54.74	22.79	9.80	100.00

**Note: All monetary variables are in 100 of USD*

Table 2. The effects of health expenditures at different quantiles vs OLS estimates

		Female LE			Male LE		
		Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value
OLS	HE	0.674	0.215	0.002	0.745	0.207	0.000
	HE^2	-0.014	0.005	0.003	-0.015	0.005	0.001
Quantile							
10^{th}	HE	1.147	0.207	0.000	1.188	0.237	0.000
	HE^2	-0.024	0.005	0.000	-0.025	0.007	0.001
25^{th}	HE	0.704	0.118	0.000	1.135	0.171	0.000
	HE^2	-0.014	0.003	0.000	-0.025	0.005	0.000
50^{th}	HE	0.528	0.092	0.000	0.731	0.148	0.000
	HE^2	-0.012	0.002	0.000	-0.016	0.003	0.000
75^{th}	HE	0.587	0.170	0.001	0.534	0.118	0.000
	HE^2	-0.012	0.004	0.002	-0.012	0.003	0.000

90th	HE	0.413	0.190	0.030	0.351	0.215	0.104
	HE^2	-0.007	0.003	0.026	-0.006	0.004	0.095

Note: Results adjusted for all covariates (not included to save space)

LEGENDS

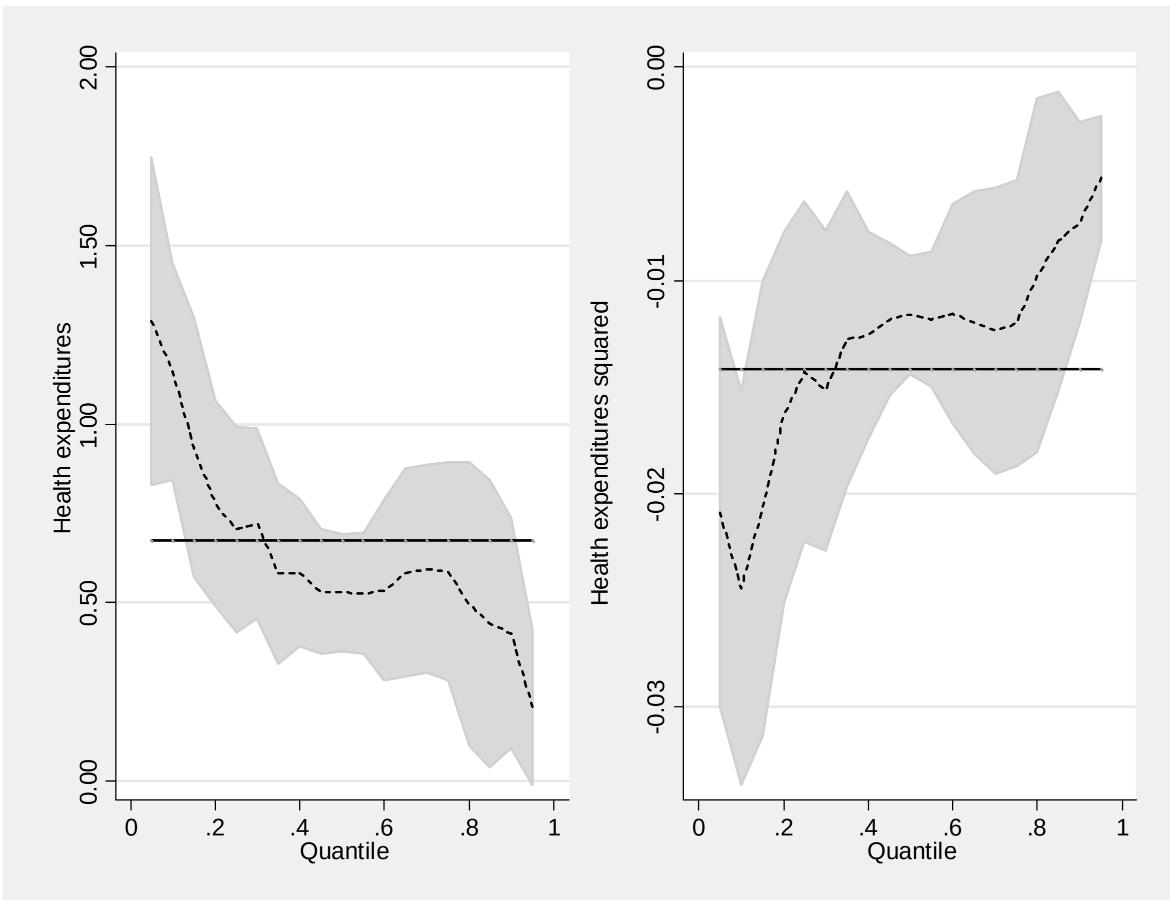

Figure 1. Female life expectancy.

Notes:Y-axis denotes expenditure effects at LE quantiles at x-axis. Dashed line represents QR effects with the shaded area representing 95% interval. The solid horizontal line depicts the OLS effect.

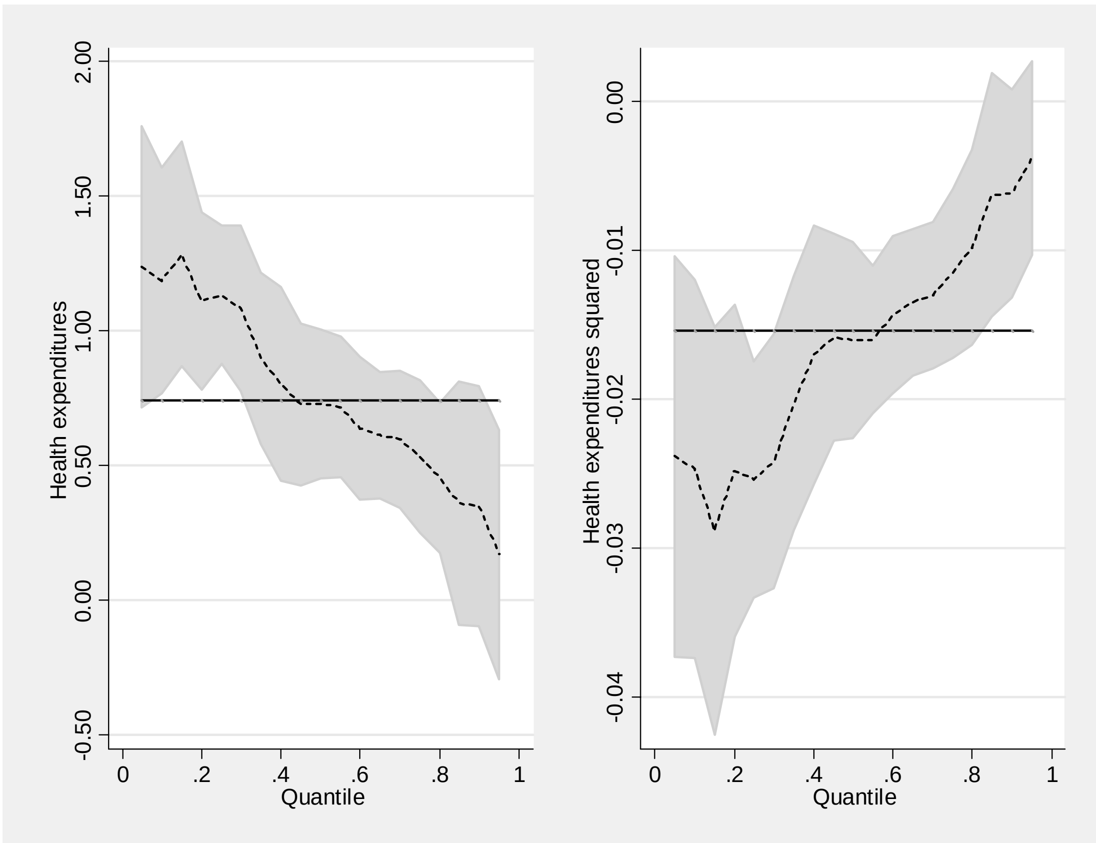

Figure 2. Male life expectancy.

Notes:Y-axis denotes expenditure effects at LE quantiles at x-axis. Dashed line represents QR effects with the shaded area representing 95% interval. The solid horizontal line depicts the OLS effect.