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Income and total expenditure on health in OECD countries: Evidence from panel data and Hsiao's version of Granger non-causality tests

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Abstract

Panel data and Hsiao's version of Granger non-causality tests are used to revisit the relationship between GDP and aggregate health care spending, their growth rate series and de-trended series. The possible causality is assumed to be valid in either or in both directions. For the sample of 34 OECD countries tested over the period 1970-2012, it appears that the bilateral relationship is predominant in sample countries. Interestingly, our results show evidence with Hsiao method based on final prediction error (FPE) that the lag length of relationship between health care expenditure and GDP is much higher that is found in previous empirical studies. The lag length is around 8. We consider this as an additional merit of the method as it helps us to avoid some inference problems with series being co-integrated or having different orders of integration.

Keywords: health care expenditure; GDP; Granger non-causality test; OECD
JEL Classification Codes: I10, I18

1. Introduction

Since the pioneering surveys proposed by Kleiman (1974) and Newhouse (1977), majority of studies agree that most of the variation in health care expenditure (*HCE*) can be related to variation in national income and *GDP*. Prominently aggregate health spending is a function of *GDP* (see Hansen and King 1996). In fact, *GDP* is the only *robust* explanatory variable for *HCE* that the health economics literature has been able to uncover so far (Hartwig, 2008). Studies with support that income leads to *HCE* include but are not limited to Newhouse

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(1987), Cullis and West (1979), Leu (1986), Parkin et al. (1987), Culyer (1990), Milne and Molana (1991), Gerdtham and Jonsson (1991a, 1991b), Hitiris and Posnett (1992), Murthy and Ukpolo (1994), McCoskey and Selden (1998), Roberts (1998), Gerdtham and Lothgren (2000), Jewell et al. (2003) and Carrion-i-Silvestre (2005).

On the other hand, the theory of economic growth posits that *GDP* is a function of human capital services, and health has been known for long to be an important element of the human capital stock (see Schultz, 1961; Mushkin, 1962). Increasing health level prepares better conditions for labors to work longer and to be more productive. This leads to increases in income, welfare, and in economic growth (Weil 2009; Amiri and Ventelou, 2012). A number of articles, including Bloom and Canning (2000), Kalemli-Ozcan et al. (2000), reviewed in Hartwig (2010) have found a significantly positive impact of investment in health on *GDP* growth.

From a theoretical point of view, the relationship between *HCE* and *GDP* is likely to run in both directions. Devlin and Hansen (2001), Erdil and Yetkiner (2009), and Amiri and Ventelou (2012) have used the concept of Granger causality to test this. Devlin and Hansen find causal direction running for 8 OECD countries from *GDP* to *HCE* and 8 from *HCE* to *GDP* out of 20 OECD countries in an annual sample for the period of 1960 to 1987. Erdil and Yetkiner's sample covers 75 countries on different income levels for the period of 1990 to 2000. They find bi-directional relationship for 46 countries, unidirectional relationship from *GDP* to *HCE* for 12 and from *HCE* to *GDP* for 10. Amiri and Ventelou (2012) use the Toda-Yamamoto version of Granger non-causality test (Toda and Yamamoto, 1995) for OECD countries. They find 10 bilateral and 9 from *GDP* to *HCE* relationships out of 20 OECD countries during the 1970-2009 period.

As a conclusion, pervious literature suggests that relationship between *HCE* and *GDP* can be defined in either or in both directions. This study recalculates for the presence and direction of Granger causality between *HCE* and *GDP* using panel non-causality test and a novel version of Granger test proposed by Hsiao (1981) for a selection of 34 OECD countries.

The deficiency of the ordinary Granger non-causality test is that it lacks "theoretical justification in assuming that two or more related variables must have identical predetermined lag lengths" (Cheng and Lai, 1997). To correct this shortcoming in previous empirical studies Hsiao's approach is used in this context. Furthermore, for the reason of testing high lag lengths in Hsiao's version of Granger method[1] compared with other approaches have been unable until now because of the lack of available health expenditure data for many countries.

2. Data description

GDP per capita data was derived from growth rates of main income accounts (c, g, i) at 2005 PPP converted constant prices. It was collected from Penn World Tables 7.1 (Heston et al. 2012), The World Bank IBRD-IDA (2015) database as well as from the UN database (2014). Health spending data (as share of *GDP*) for OECD countries were taken from OECD.org (2015). These sources gave possibility calculate the annual observations of (logs of) *GDP per capita* (*lnGDPc*) and logs of *HCE per capita* (*lnHCEc*) for the following 34 OECD countries in period from 1970 to 2012: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungry, Iceland, Ireland, Israel, Italy, Japan, Luxemburg, Mexico, Netherland, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

[1] Lag lengths close to 10 have to be calculated with Hsiao method, and this causes a significant decrease the degree of the freedom of Granger structure.

3. Panel unit root testing

The first essential step in the analysis is unit root testing. The order of integration of test series modifies non-causality testing (see Lutkepohl 2005; Section 7.6.) In this context we conducted unit root test in panel form to get a general view of stationarity properties of series in efficient way. Various panel tests were applied to investigate the stationary of *lnGDPc* and *lnHCEc* series, their growth rates, and their de-trended[2] transformations. Different test have been proposed in the literature, and we use here the *ADF*-type tests by Levin et al. (2002) and Im et al. (2003), and Fisher tests by Maddala and Wu (1999). Result unit root tests verify strong evidence that panel of both *lnGDPc* and *lnHCEc* series are stationary with individual mean and trend components. Likewise growth rates series and de-trended series are stationary (see Table 1).

4. Panel Granger non-causality testing

Based on the stationary results of unit root tests we are able to test Granger non-causality without test modifications needed with non-stationary series. Table 2 present the result of panel Granger non-causality tests for *lnGDP*c and *lnHCEc*, their growth rates, and de-trended series. We conduct the Granger non-causality test in two different forms (Eviews, 2012). The first is to treat the panel data as one large stacked set of data, and then perform the pairwise Granger non-causality test in the standard way (GC_1-test). This method assumes that all coefficients are same across all cross-sections. A second approach adopted by Dumitrescu and Hurlin (2012) allows all coefficients to be different across cross-sections (GC_2-test). The test is calculated by running standard Granger causality regressions for each cross-section individually. *Wbar* statistic is based on the average of these test statistics, and *Zbar* statistic is the Normal standardized version of this statistic.

Results in Table 2 show that the direction of causality between *lnGDP*c and *lnHCEc* is bilateral and in growth rates it is from *ΔlnGDPc* to *ΔlnHCE*c. For the de-trended series the result of panel Granger non-causality tests are different. GC_1-test gives bilateral causality and GC_2-test supports *lnGDPc_detr* → *lnHCEc_detr* relationship. This non-consistency result compared to results with growth rate series directs us to investigating Granger non-causality for each country in sample separately. This is conducted with Hsiao's version of Granger non-causality test that is based on minimization of *FPE* –criterion.

Table 1. Panel unit root test. H_0: unit root.

	lnGDPc		lnGDPc	
Exogenous variables	*Individual effects, individual linear trends*		*Individual effects*	
	Statistic	Probability	Statistic	Probability
Levin, Lin & Chu t*-test	-3.08253	0.0010	-6.101	0.0000
Im, Pesaran and Shin W-stat	-2.75023	0.0030	1.11878	0.8684
ADF - Fisher Chi-square	102.360	0.0045	67.2408	0.5032
PP - Fisher Chi-square	206.263	0.0000	110.409	0.0009
	ΔlnGDPc		lnGPc_detr	
Exogenous variables	*Individual effects*		*None*	
	Statistic	Probability	Statistic	Probability
Levin, Lin & Chu t*-test	-24.8483	0.0000	-7.61102	0.0000
Im, Pesaran and Shin W-stat	-23.3024	0.0000		
ADF - Fisher Chi-square	594.034	0.0000	167.524	0.0000
PP - Fisher Chi-square	607.213	0.0000	158.358	0.0000

[2] De-trended transformation of lnX is the residuals from fixed effect panel regression $lnX_{it} = a_i + bTREND_t + e_{it}$.

Exogenous variables	lnHCEc		lnHCEc	
	Individual effects, individual linear trends		*Individual effects*	
	Statistic	Probability	Statistic	Probability
Levin, Lin & Chu t*-test	-4.09263	0.0000	-8.54981	0.0000
Im, Pesaran and Shin W-stat	-2.53026	0.0057	-0.56195	0.2871
ADF - Fisher Chi-square	120.866	0.0001	123.529	0.0000
PP - Fisher Chi-square	213.812	0.0000	150.203	0.0000
Exogenous variables	ΔlnHCEc		lnHCEc_detr	
	Individual effects		*None*	
	Statistic	Probability	Statistic	Probability
Levin, Lin & Chu t*-test	-23.5967	0.0000	-6.58659	0.0000
Im, Pesaran and Shin W-stat	-22.3941	0.0000		
ADF - Fisher Chi-square	567.482	0.0000	200.503	0.0000
PP - Fisher Chi-square	608.140	0.0000	219.441	0.0000

Note: Probabilities for all tests except Fisher tests, which have Chi-square distribution, are calculated using an asymptotic normality assumption.

Table 2. Panel Granger non-causality tests.

GC₁-test:		*F-Stat.*	*Probability*	*Direction*
lnHCEc does not Granger Cause lnGDPc		16.3336	1.00E-07*	Bilateral
lnGDPc does not Granger Cause lnHCEc		34.6590	2.00E-15*	
GC₂-test:	*W-Stat.*	*Zbar-Stat.*	*Probability*	*Direction*
lnHCEc does not homogeneously cause lnGDPc	4.56860	6.36273	2.00E-10*	Bilateral
lnGDPc does not homogeneously cause lnHCEc	9.73660	19.7790	0.00*	
GC₁-test:		*F-Stat.*	*Probability*	*Direction*
ΔlnHCEcn does not Granger Cause ΔlnGDPc		0.09783	0.9068	ΔlnGDPc → ΔlnHCEc
ΔlnGDPc does not Granger Cause ΔlnHCEc		5.96122	0.0026*	
GC₂-test:	*W-Stat.*	*Zbar-Stat.*	*Probability*	*Direction*
ΔlnHCEc does not homogeneously cause ΔlnGDPc	2.02033	-0.26099	0.7941	ΔlnGDPc → ΔlnHCEc
ΔlnGDPc does not homogeneously cause ΔlnHCEc	5.00614	7.46342	8.00E-14*	
GC₁-test:		*F-Stat.*	*Probability*	*Direction*
lnHCEc_detr does not Granger Cause lnGDPc_detr		2.20033	0.1112	lnGDPc_det → lnHCEc_detr
lnGDPc_detr does not Granger Cause lnHCEc_detr		19.8856	3.00E-09*	
GC₂-test:	*W-Stat.*	*Zbar-Stat.*	*Probability*	*Direction*
lnHCEc_detr does not homogeneously cause lnGDPc_detr	2.93983	2.13440	0.0328*	Bilateral
lnGDPc_detr does not homogeneously cause lnHCEc_detr	7.16536	13.1040	0.00*	

Note: Maximum lag length is 2. * means that null hypothesis is rejected.

5. Hsiao's version of Granger causality test

Hsiao (1981) offered final prediction error (*FPE*) criterion to estimate the optimum lag length of Granger's test structure. The procedure of the Hsiao method[3] implements the testing null hypothesis of *HCE* does not Granger cause *GDP* in the following way. In the first step we use $lnGDPc\_detr_t$ alone (the restricted equation) and calculate the sum of squared errors (*SSE*) for each lags from 1 to maximum order of lags *M*. With finding *SSE* for various lags the *FPE* is computed using equation (2). Next we are able to choose the optimum lag length which corresponds to the smallest value of *FPE*, i.e. $m^* \leq M$ (*T* is the total number of observations in the sample).

$$lnGDPc_t\_detr = \alpha_0 + \sum_{i=1}^{M} \alpha_{1i} lnGDPc\_detr_{t-i} + \lambda_{1t} \quad [Restricted\ Equation] \tag{1}$$

[3] In order to explain Hsiao version of Granger non-causality test we refer directly to paper by Cheng and Lai (1997, pp. 21 – 22).

$$FPE(m) = \frac{(T+m+1)}{(T-m-1)} \cdot \frac{SSE}{T} \quad (2)$$

In the following step two, $lnGDPc\_detr_t$ is used in unrestricted equation (3) as a control variable with m^* lags and $lnHCEc\_detr_t$ is treated as a manipulated variable. The procedure is same as above but now the focus is on the unrestricted equation (3). We iterate for the smallest *FPE* value using equation (4) by varying the order of lags for $lnHCEc\_detr_t$ from *1* to *N* giving n^*.

$$\begin{aligned} lnGDPc_t\_detr_{t-i} = \beta_0 + \sum_{i=1}^{m^*} \beta_{1i} lnGDPc\_detr_{t-i} & \\ + \sum_{j=1}^{N} \beta_{2j} lnHCEc\_detr_{t-j} + \lambda_{2t} & \quad [Unrestricted\ Equation] \end{aligned} \quad (3)$$

$$FPE(m^*, n) = \frac{(T+m^*+n^*+1)}{(T-m^*-n^*-1)} \cdot \frac{SSE(m^*, n^*)}{T} \quad (4)$$

The Hsiao version of Granger test with null hypothesis of $lnHCEc\_detr_t$ does not Granger cause $lnGDPc\_detr_t$ can be now formulated: If $FPE(m^*, n^*)$ is less than $FPE(m^*)$, then the null hypothesis of non-causality is rejected. Conversely, if $FPE(m^*,n^*)$ is larger than $FPE(m^*)$, then the null hypothesis cannot be rejected. The procedure is same for estimating Granger test from $lnGDPc\_detr_t$ to $lnHCEc\_detr_t$. Note that Hsiao's method is not a statistical test. It is procedure based on *FPE* to determine the optimal lag length. In this sense it is not sensitive to inference problems found with ordinary Granger non-causality tests in presentence of integrated series.

6. Result of Hsiao's Granger non-causality test

Appendix A gives the ordinary *ADF*-unit root test results with constant and trend for each country in sample. Here the optimal lag length for *ADF*-test is determined with Schwarz information criteria (*SIC*). We observe that *SIC* gives different lag lengths to series *lnGDPc_detr* and *lnHCEc_detr*. Likewise the *ADF*-test values indicate that in many cases the country specific series have different orders of integration or they are both *I(1)* series. Clearly we have here a valid starting point for Hsiao's method.

In order to estimate Granger causality, Hsiao's version of Granger non-causality test was estimated with three to ten lags with the *FPE* criterion. The results of Hsiao's method confirm (see Table 3) bidirectional relationship between *lnHCEc_detr* and *lnGDPc_detr* for most countries. In 18 countries (53% of the total), we find that the direction of relationship to be bilateral. This result could suggest that the role of *HCE* on *GDP* increases with the wealth of nations (see Bloom and Canning, 2000). However, we find a unidirectional relationship from *lnHCEc_detr* to *lnGDPc_detr* only for 3 countries; Belgium, Chile and Poland. There exists *lnGDPc_detr* → *lnHCEc_detr* relationship in 9 counties included Austria, Canada, Czech Republic, Denmark, Greece, Hungry, Japan, Norway, and Spain. In Luxemburg, Mexico, Slovakia, and Turkey we find no significant relationship between *lnHCEc_detr* and *lnGDPc_detr*. More interestingly, the *FPE* results show that the optimum lag length of the relationship between *GDP* and *HCE* is dramatically higher than previously estimated, and it is around 8.

Table 3. Result of Hsiao Granger causality test.

Countries	*lnGDPc_detr to lnHCEc_detr* Unrestricted	Restricted	*lnHCEc_detr to lnGDPc_detr* Unrestricted	Restricted	*Direction*
	Lowest FPE & lag length				
Australia	0.173 (10)	0.148* (5)	0.144 (10)	0.040* (10)	Bilateral
Austria	1.623 (7)	1.218* (10)	0.191 (9)	0.221 (3)	lnGDPc_detr → lnHCEc_detr
Belgium	0.569 (6)	0.609 (10)	0.285 (10)	0.147* (7)	lnHCEc_detr → lnGDPc_detr
Canada	0.335 (6)	0.249* (10)	0.456 (3)	0.499 (3)	lnGDPc_detr → lnHCEc_detr
Chile	1.292 (6)	1.431 (3)	2.111 (7)	2.110* (7)	lnHCEc_detr → lnGDPc_detr
Czech Republic	2.884 (5)	1.247* (10)	6.986 (5)	7.568 (5)	lnGDPc_detr → lnHCEc_detr
Denmark	0.580 (10)	0.464* (3)	0.604 (10)	0.652 (9)	lnGDPc_detr → lnHCEc_detr
Estonia	0.801 (8)	0.453* (9)	2.205 (3)	1.534* (9)	Bilateral
Finland	0.803 (6)	0.279* (10)	1.231 (4)	1.185* (3)	Bilateral
France	0.513 (10)	0.499* (10)	0.208 (10)	0.186* (3)	Bilateral
Germany	0.374 (9)	0.325* (10)	0.364 (9)	0.325* (10)	Bilateral
Greece	2.979 (3)	2.863* (3)	0.598 (5)	0.602* (9)	lnGDPc_detr → lnHCEc_detr
Hungary	1.971 (3)	1.890* (8)	0.822 (3)	0.898 (9)	lnGDPc_detr → lnHCEc_detr
Iceland	1.995 (8)	1.945* (3)	2.687 (10)	2.421* (4)	Bilateral
Ireland	1.531 (10)	0.558* (10)	1.686 (3)	1.191* (10)	Bilateral
Israel	3.894 (10)	3.113* (10)	0.656 (7)	0.450* (10)	Bilateral
Italy	0.571 (3)	0.524* (8)	0.533 (10)	0.428* (9)	Bilateral
Japan	0.192 (9)	0.078* (10)	0.607 (6)	0.692 (3)	lnGDPc_detr → lnHCEc_detr
Luxembourg	3.288 (3)	3.678 (5)	0.620 (10)	0.703 (3)	No
Mexico	1.307 (6)	1.365 (3)	1.857 (10)	1.960 (3)	No
Netherlands	0.435 (9)	0.369* (10)	0.240 (10)	0.147* (9)	Bilateral
New Zealand	0.776 (9)	0595* (10)	0.245 (7)	0.204* (7)	Bilateral
Norway	1.409 (6)	0.457* (10)	0.322 (3)	0.334 (3)	lnGDPc_detr → lnHCEc_detr
Poland	1.368 (8)	1.379 (3)	1.463 (10)	1.049* (10)	lnGDPc_detr → lnGDPc_detr
Portugal	2.745 (10)	1.996* (8)	0.440 (8)	0.355* (10)	Bilateral
Slovakia	585.849 (3)	671.948 (3)	5.688 (5)	6.479 (3)	No
Slovenia	0.689 (10)	0.668* (3)	1.198 (5)	0.743* (10)	Bilateral
South Korea	1.809 (5)	1.587* (9)	1.950 (10)	1.536* (10)	Bilateral
Spain	1.154 (10)	0.535* (10)	0.324 (7)	0.361 (3)	lnGDPc_detr → lnHCEc_detr
Sweden	0.340 (9)	0.300* (10)	0.497 (10)	0.449* (6)	Bilateral
Switzerland	0.269 (10)	0.200* (5)	0.244 (10)	0.234* (10)	Bilateral
Turkey	9.313 (10)	9.830 (3)	1.549 (9)	1.622 (10)	No
United Kingdom	0.537 (10)	0.437* (5)	0.329 (10)	0.307* (3)	Bilateral
United States	0.089 (9)	0.056* (10)	0.450 (10)	0.441* (9)	Bilateral

Note: * confirms that FPE in unrestricted equation is lower than restricted equation. The numbers in parentheses denotes the optimum lag length.

7. Conclusions

There has been much interest in investigating the presence of and the direction of causality between *GDP* per capita and total health expenditure per capita. From the theoretical point of view, this is a bilateral relationship. To test this, we used first panel Granger non-causality tests to *lnGDPc* and *lnHCEc* series, to their growth rate series, and to their de-trended series in 34 OECD countries in period from 1970 to 2012. The empirical result of panel Granger non-causality tests indicate that bi-directional causality is dominant between *lnGDPc* and *lnHCEc* series, while in growth series the relationship is from economic growth to *HCEc* growth. Moving to de-trended series, result of panel Granger tests were different and needed a closer analysis.

To correct the statistical shortcomings of previous empirical studies, Hsiao's version of Granger non-causality test was applied. The Hsiao’s test results indicate that bi-directional causality is widely dominant. Bilateral relationship is observed in more than half of OECD countries. This indicates that improvements of human capital in the form of health on GDP are significantly effective in rich countries. Our results also indicate that the optimum lag length of relationship between *HCEc* and *GDPc* is higher than estimated in previous empirical studies. This finding alerts research to pay more attention to higher lag lengths in further estimations to avoid specification errors in their models. This is also supported by the theoretical results in the co-integration literature and for series that are of different order of integration. In such contexts it is recommended to add in Granger non-causality tests additional lags to obtain correct asymptotic test distribution results (see Lutkepohl, 2005; Section 7.6). However Hsiao's approach is based on *FPE* criteria which does not depend on asymptotic distribution results although the method is sensitive to long lag lengths.

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Appendix A
ADF –unit root test for sample countries

Table 4. ADF: Unit root test for sample countries.

Cross section	*lnGDPc_detr*			*lnHCEc_detr*		
	t-Stat	*Prob.*	*Lag*	*t-Stat*	*Prob.*	*Lag*
Australia	-3.4487	0.0589	1	-3.0151	0.1409	2
Austria	-3.5095	0.0513	0	-1.7079	0.7301	0
Belgium	-2.9389	0.1613	0	-3.0796	0.1243	0
Canada	-3.3889	0.0669	1	-2.2307	0.4607	1
Chile	-3.1984	0.0989	1	-2.6994	0.2421	0
Czech Republic	-5.0102	0.0011	0	-1.9836	0.5931	0
Denmark	-2.9818	0.1495	1	-1.9207	0.6261	0
Estonia	-2.1561	0.5004	1	-1.6865	0.7392	1
Finland	-3.5070	0.0519	1	-2.8584	0.1861	1
France	-3.2341	0.0921	1	-1.6988	0.7342	0
Germany	-2.1143	0.5231	0	-6.4595	0.0000	0
Greece	-2.0660	0.5487	1	-0.9890	0.9347	0
Hungary	-2.0655	0.5490	1	-1.9602	0.6055	0
Iceland	-2.8544	0.1874	1	-1.0489	0.9254	1
Ireland	-2.0862	0.5378	1	-1.7094	0.7290	1
Israel	-2.8349	0.1935	0	-2.6233	0.2726	0
Italy	-1.1876	0.8996	2	-2.4900	0.3312	1
Japan	-1.0678	0.9225	0	-3.0270	0.1372	0
Luxembourg	-1.8166	0.6779	2	-2.2016	0.4758	2
Mexico	-2.4851	0.3335	0	-3.6466	0.0380	1
Netherlands	-2.4183	0.3652	1	-2.0528	0.5554	2
New Zealand	-2.1305	0.5141	1	-1.3912	0.8492	0
Norway	-2.1334	0.5125	1	-2.8410	0.1915	0
Poland	-1.8083	0.6825	1	-1.3602	0.8581	0
Portugal	-2.2309	0.4606	1	-2.8262	0.1964	0
Slovakia	-2.4657	0.3425	1	-6.0754	0.0000	0
Slovenia	-1.7509	0.7099	1	-1.8640	0.6547	1
South Korea	-0.5598	0.9763	0	-5.7232	0.0001	0
Spain	-3.0407	0.1341	1	-1.9542	0.6082	1
Sweden	-2.2528	0.4491	1	-3.6994	0.0342	3
Switzerland	-2.8179	0.1996	2	-2.6868	0.2470	0
Turkey	-3.0091	0.1419	0	-1.9779	0.5961	0
United Kingdom	-3.9468	0.0192	3	-1.9628	0.6037	1
United States	-2.4501	0.3499	1	-0.3351	0.9868	1