An Empirical Study of the Key Determinants of Health Care Expenditure

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神戸大学大学院経済学研究科

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（医療支出の主要決定要因に関する実証研究）

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Contents

Introduction

This study investigates the long-run relationships among health care expenditure, gross domestic product (GDP), and the share of the elderly (i.e., the ratio of people of 65 years old and over to the total population).

In developed countries, health care expenditure as a proportion of GDP is not small, and health care expenditures there have been on the rise. Controlling the amount of health care expenditure is an important issue for governments, if they wish to maintain public finances appropriately. In fact, international organizations like the International Monetary Fund and the Organization for Economic Co-operation and Development (OECD) examine a number of measures by which governments can understand or control health care expenditures, such as special measures for reducing or exempting private insurance premiums on medical insurance and the introduction of a "gatekeeper" system. In England, for example, the National Institute for Health and Clinical Excellence analyzes cost-effectiveness.

On the other hand, many citizens can generally obtain benefits from public goods, without incurring any burden; in such circumstances, therefore, it would be rational for them to exhibit "free rider" behavior. If this were to occur, a so-called market failure would also occur. In other words, in a country where health care services can be considered a public good—in Japan, for example, which established a national health insurance program—the person who receives health care services is not necessarily the person who bears the costs and expenses related to those services. This can create a burden on national finances—especially in Japan, where the population is aging rapidly, and where the number of service consumers has grown and the overall burden related to that consumption has increased. If this chain of events were to occur, health care expenditures would expand; under such circumstances, several measures need to be undertaken by international organizations or national governments.

Given the aforementioned motivations regarding health care service, it is important to investigate the determinants of health care expenditure and generate political insights, in order to control health care expenditure appropriately.

GDP is said to be a main determinant of health care expenditure. Since the seminal work of Newhouse in 1977, much research has examined the relationship between health care expenditure and GDP. Conventionally, health care expenditure is a certain kind of good and is modeled as a function of GDP. In this context, as people become more affluent, they wish to "purchase" a longer and higher-quality life, and this can drive an increase in health care expenditures. On the other hand, health care expenditures constitute a kind of investment—specifically, an investment in human capital. In this sense, there may be a long-run relationship between health care expenditure and GDP.

On the other hand, another main determinant of health care expenditure is the share of the elderly. In fact, an OECD reported considers it one of the key determinants of health care expenditure in 2013. There is the consideration here that the elderly tend to use health care services more frequently and more extensively than do younger individuals.

This study analyzes the determinants of health care expenditure, from the following three perspectives. First, this study takes up the case of Japan, on which there has been a dearth of empirical research in this area, and which has the social "problem" of a rapidly increasing share of the elderly. We use prefecture-level panel data not previously used in the literature. Second, we use G20 panel data to focus on health care expenditure, GDP, and the share of the elderly, in the context of developed countries in recent years. Third, we also investigate whether there was a structural break following the global financial crisis, which was triggered by the collapse of Lehman Brothers. In chapter 3, especially, we again take up the case of Japan, and two of the three variables (i.e., health care expenditure and GDP), to investigate whether the relationship between these variables features a regime shift (i.e., whether there is a two-regime threshold cointegration relationship) and how error correction adjustments are conducted.

The following is an outline of the previously described research.

In Chapter 1, we investigate the cointegrating relationships among health care expenditure, GDP, and share of the elderly; we do so by using the panel cointegration tests developed by Pedroni in 1999 with a panel dataset of 47 prefectures in Japan. Our empirical results indicate that there are cointegrating relationships among the three variables. We also estimate the effects of GDP and the share of the elderly on health care expenditure by employing the group-mean fully modified ordinary least squares method of Pedroni in 2001; we find that the coefficient on the share of the elderly is positively significant. These results indicate that in order to cope with the imminent issue of rising health care expenditures, policymakers should address population policies from a long-run perspective.

In Chapter 2, we investigate whether the findings in Chapter 1 are seen in developed countries. In other words, this chapter examines the relationships between each of the share of the elderly and per-capita GDP on per-capita health care expenditure, by applying dynamic generalized methods of moments (dynamic GMM) and pooled mean group (PMG) techniques. We use a panel dataset of G20 countries from the 1995–2012 period; this dataset spans the timeframe of the global financial crisis, which was triggered by the collapse of Lehman Brothers. First, we find evidence of cointegrating long-run relationships among health care expenditure, GDP, and the share of the elderly. Second, our dynamic GMM and PMG estimation results suggest that the share of the elderly and GDP each has significantly positive effects on health care expenditure in the long run. Third, the coefficient of the Lehman shock dummy variable is significantly positive, which implies the occurrence after the financial crisis of a structural break in terms of the level of per-capita health care expenditure within the cointegrating relationship.

Chapter 3 uses quarterly data from 1994 through to 2013 and Hansen–Seo tests to examine the long-run relationship in Japan between real per-capita GDP (PGDP) and real per-capita health care expenditure (PHCE), with threshold effects; this study is the first to do so. We detect the presence of a threshold cointegrating relationship between the two variables. In addition, we find that in a typical regime, error correction adjustments are significantly conducted only through PGDP, whereas in an extreme regime, both PGDP and PHCE drive adjustments. We find that the extreme regime occurred mainly after Q4 2008. The implication is that a April 2008 policy introducing a late-stage medical care system for the elderly—which expanded the ratio of personal expenses for the elderly—may be effective in attaining long-run equilibrium between PGDP and PHCE.

We conclude that both GDP and the share of the elderly are determinants of health care expenditure. Furthermore, we find that there was a structural break among the three variables, after the financial crisis triggered by the bankruptcy of Lehman Brothers. Especially in Japan, we find that there was a structural break after the crisis between health care expenditure and GDP; the suggestion is that it may have occurred with the introduction of an advanced system of elderly medical services. Topics left for future research include (i) the analysis, in greater detail, of structural breaks among the three variables, (ii) the analysis of causality among the three variables, and (iii) an investigation of the relationships among these three variables, in the context of developing countries.

Chapter 1

Health care expenditure, GDP and share of the elderly in Japan：a panel cointegration analysis

1.1 Introduction

Since the seminal work by Newhouse (1977), much research has examined the relationship between health care expenditure and gross domestic product (GDP). Conventionally, health care expenditure is modelled as a function of GDP, and earlier studies estimate the aggregate health care expenditure equation using cross-country data (e. g. Culyer, 1990). However, a reverse causation – GDP as a function of health care expenditure – is also considered, based on a theory that health care expenditure is regarded as an investment in human capital (Grossman, 1972).

Recent empirical studies have uncovered positive cointegrating relationships between real per capita health care expenditure and GDP (e.g. Gerdtham and Jönsson, 2000; Clemente et al., 2004). Most of these used panel datasets for multiple OECD countries. A rare example that focused on analysing one specific country is Wang and Rettenmaier (2007). Using a panel cointegration technique that allowed for data from 50 US states, they found that both health care expenditure and GDP are nonstationary, and the two have a cointegrating relationship.

In this article, we study the relationships between health care expenditure, GDP and share of the elderly (65 years old and over) by employing a panel of 47 prefectures in Japan over the period 2001–2010. We believe that our primary contributions to the literature are two-fold. First, this article is among the first to investigate the linkage between health care expenditure and GDP in Japan. Whilst health spending has markedly slowed in other OECD countries since 2009, Japan has experienced a unique and continued growth in health care expenditure despite sluggish GDP growth (OECD, 2013). Second, we include the population share of the elderly in the cointegrating equation as well; as Zweifel at el. (1999) and Matteo (2005) contended, the ageing structure can be an important nonincome determinant of health care expenditure. Because Japan is believed to be ageing more rapidly than other countries, it is interesting to see the relationship once accounting for the share of the elderly.

Our empirical results based on Pedroni’s panel cointegration technique show a cointegrating relationship between the three variables. Applying the group-mean Fully Modified Ordinary Least

Squares (FMOLS) method, we interestingly detect that the coefficient on the share of the elderly is positively significant, while that on health care expenditure is insignificant. These findings may provide crucial implications to policymakers in Japan, highlighting the importance of coping with an ageing population in order to curb the increasing trend of health care expenditure.

The reminder of this article proceeds as follows. Section 1.2 explains the model specification and our data; Section 1.3 reports the empirical results; Section 1.4 concludes.

1.2. Model Specification and Data

Following the convention in the related literature, we express real per capita health care expenditure as a function of GDP. At the same time, we add the proportion of population aged 65 and over as another explanatory variable based on Matteo (2005), who argues that an ageing population is also a key determinant of health spending. He does not deny the possibility of other explanatory variables, such as new techniques in the health care industry, number of doctors or public share of health care expenditure. However, the author focuses on the ageing population because analysing baby boomers' demands is critically important for making health policies, since the baby boomers—the biggest age group of the entire population—has now entered the 65-and-over age group. Therefore, our model in logarithmic form is specified as $ln(HE_{i,t}) = \beta_0 + \beta_1 ln(GDP_{i,t}) + \beta_2(SE_{i,t}) + e_{i,t}$ where $ln(HE_{i,t})$ is the natural logarithm of real health care expenditure per capita for the *i*th prefecture, $ln(GDP_{i,t})$ is the natural logarithm of real GDP per capita for the *i*th prefecture, $SE_{i,t}$ is share of the elderly for the *i*th prefecture and $e_{i,t}$ represents the error term.

This article uses an annual data series for 47 prefectures in Japan covering the 2001–2010 period. Our sources for the data are (1) health care expenditure in each prefecture from the Ministry of Health, Labor and Welfare, (2) nominal GDP in each prefecture from the Cabinet Office and (3) age composition of the population in each prefecture from the Statistics Bureau of Japan. We use a GDP deflator and the size of the population, both of which are taken from the Cabinet Office, to transform each of the three above variables into real per capita measurements.

For each of these variables, we perform four types of unit root tests, namely the Levin, Lin and Chu (LLC) test (Levin et al., 2002), Im, Pesaran and Shin (IPS) test (Im et al., 2003), PP–Fisher chi-square test (Maddala and Wu, 1999) and PP–Choi test (Choi, 2001). The auxiliary regression of each test includes both the individual effect and the individual linear trend. The results of these tests indicate that all the variables are integrated with order one, that is, they are all I(1) variables.[1]

1.3. Empirical Results

The empirical analysis of this article takes the following two steps. First, we use the residual-based approach by Pedroni (1999), which is considered the most typical panel cointegration test. This methodology consists of seven statistics allowing for heterogeneous slope coefficients across cross-sections (Panel v, Panel rho, Panel PP, Panel ADF, Group rho, Group PP and Group ADF) to test the null hypothesis of no cointegrating relationship. Second, if the existence of the cointegrating relationship is supported, we estimate the effects of $ln(GDP_{i,t})$ and $SE_{i,t}$ on $ln(HE_{i,t})$ by employing Pedroni's (2001) group-mean FMOLS method. Here, we cannot use ordinary OLS, because we would suffer from the endogeneity problems of panel data; hence, we pursue the group-mean FMOLS.

Panel Cointegration Tests

Since we find that $ln(HE_{i,t})$, $ln(GDP_{i,t})$ and $SE_{i,t}$ are non-stationary variables, we now perform the panel cointegration test proposed by Pedroni (1999). Table 2 shows the results of the test. It indicates that the null hypothesis of no cointegration is rejected in five out of seven cases at the 5% significance level. Thus, it is likely that the three variables are cointegrated in Japan.

Group-mean FMOLS Estimation

Now that the existence of cointegration is supported above, our next step is to estimate the cointegration equation using the FMOLS developed by Pedroni (2001). Table 3 reports the estimation results. As seen from this table, the coefficient for $SE_{i,t}$ is significantly estimated at a positive value around 6.4. This finding suggests that a 1.0 point increase in the share of the elderly results in a 6.4% increase in the associated real health care expenditure per capita. Moreover, we also find that the coefficient for $ln(GDP_{i,t})$ is insignificant at the 5% level. For robustness check, we also used the group-mean dynamic OLS framework with zero lead and zero lag and confirmed that the similar results can be obtained at Appendix A. As shown from the above results, in the case of using panel data for Japan, it is clear that real GDP per capita does not affect real health care expenditure per capita, but the share of the elderly has a significant influence on real health care expenditure per capita. Our conclusion is similar to Matteo (2005) in that an ageing population is

[1] We do not present the results of the panel unit root tests to save spaces, but they are available upon request.

shown to be a significant factor in explaining health care expenditure. The Japanese health insurance system started in 1922 and was established as a universal health insurance system covering the whole nation in 1961. Consequently, any citizen in Japan who needs health care service can obtain appropriate health care at any time and at any medical institution nationwide without excessive, personally borne medical expenses, although he or she must pay a certain insurance premium and co-payment (10% to 30%) to his or her insurers (MHLW, 2012). However, the working generation has to bear and pay for the elderly's medical health through insurance premiums, with medical expenditure per elderly person being 5 times that of a young person. Moreover, the rapidly ageing population (especially given the baby-boomers' recent entrance into the elderly age group) has potentially triggered a trend of increasing health care spending.

1.4. Conclusion

Using annual data from 2001 through 2010, this study employed the Pedroni cointegration tests to examine the long-term relationships between real health care expenditure per capita, real GDP per capita and share of the elderly for 47 prefectures in Japan. Having found evidence to support a cointegrating relationship between the three variables, we also used the group-mean FMOLS methodology to estimate the equation representing the co-movement between the three items.

The main findings can be summarized in the following points: we find that the share of the elderly positively affects real health care expenditure per capita; however, we cannot find a positive relationship between real health care expenditure per capita and real GDP per capita, which is contrary to the findings of former articles. Therefore, the share of the elderly, not real GDP per capita, is a factor affecting the recent growth of health care expenses in Japan. Over the past 10 years, Japan's government has tried to prevent excessive increases in medical expenses, especially for ageing people, such as establishing the latter-stage elderly medical insurance system and changing acute-style nursing to recuperation style nursing (MHLW, 2012). Our findings suggest that merely restraining excessive governmental medical expenses for ageing people will have minimal effects and that the Japanese government also has to take more drastic actions – such as balancing the control of health care expenditure, delaying or preventing marriage of the young and encouraging women's participation in the workforce.

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Table 1. Descriptive statistics real health care expenditure per capita, real GDP per capita and share of the elderly

Prefecture	Population	HE(000)	GDP(000)	SE	Prefecture	Population	HE(000)	GDP(000)	SE
Hokkaido	5,605,532	3,147.0	34,579.1	0.2187	Shiga	1,384,930	2,214.7	43,819.2	0.1846
Aomori	1,426,903	2,684.7	31,769.9	0.2292	Kyoto	2,644,663	2,658.0	36,766.8	0.2078
Iwate	1,376,281	2,607.9	32,578.0	0.2482	Osaka	8,834,128	2,778.0	43,694.1	0.1914
Miyagi	2,359.043	2,436.8	35,723.6	0.2020	Hyogo	5,587,931	2,535.2	34,155.0	0.20.37
Akita	1,137,169	2,905.4	33,050.3	0.2705	Nara	1,420,324	2,448.7	26,887.1	0.2056
Yamagata	1,208,710	2,632.0	32,777.3	0.2561	Wakayama	1,033,097	2,860.2	34,999.2	0.2448
Fukushima	2,081,663	2,607.7	36,793.7	0.2296	Tottori	603,631	2,914.8	34,429.3	0.2441
Ibaraki	2,297,660	2,193.4	38,082.4	0.1973	Shimane	739,383	2,859.2	33,343.1	0.2745
Tochigi	2,013,614	2,388.6	39,960.0	0.1981	Okayama	1,954,386	2,896.9	38,545.9	0.2295
Gunma	2,022,074	2,443.8	37,723.6	0.2101	Hiroshima	2,873,614	2,988.9	39,412.2	0.2152
Saitama	7,078,326	1,941.8	28,912.2	0.1700	Yamaguchi	1,488,258	3,024.2	40,002.1	0.2544
Chiba	6,085,256	2,048.7	31,853.5	0.1817	Tokushima	805,996	3,104.9	35,588.9	0.2474
Tokyo	12,661,562	2,605.3	75,456.5	0.1889	Kagawa	1,010,065	2,984.5	37,324.1	0.2364
Kanagawa	8,823,334	2,137.9	34,929.8	0.1743	Ehime	1,462,645	2,889.6	34,451.9	0.2364
Niigata	2,424,730	2,503.5	37,329.4	0.2423	Kochi	790,744	3,350.8	29,226.2	0.2640
Toyama	1,109,192	2,646.9	42,383.2	0.2377	Fukuoka	5,053,027	3,060.7	35,361.3	0.2017
Ishikawa	1,175,134	2,839.9	39,706.4	0.2142	Saga	863,950	2,917.9	33,891.7	0.2284
Fukui	819,612	2,443.1	41,192.1	0.2307	Nagasaki	1,470,917	3,160.3	30,226.4	0.2382
Yamanashi	879,612	2,443.9	35,870.6	0.2230	Kumamoto	1,839,396	3,027.7	31,047.1	0.2393
Nagano	2,190,754	2,423.9	37,802.3	0.2417	Oita	1,209,379	3,027.7	31,047.1	0.2463
Gifu	2,102,628	2,392.0	35,622.7	0.2138	Miyazaki	1,151,594	2,860.5	30,698.8	0.2372
Shizuoka	3,786,899	2,314.6	47,124.2	0.2101	Kagoshima	1,745,986	3,095.5	31,587.2	0.2495
Aichi	7,274,068	2,314.6	47,124.2	0.1771	Okinawa	1,362,202	2,429.8	26,942.1	0.1628
Mie	1,865,712	2,418.9	40,485.0	0.2183					

Notes: HE means real health care expenditure per capita, GDP means real GDP per capita and SE means share of the elderly. HE and GDP are expressed in thousands JPY. Averages of the samples during 2001 and 2010 are presented above.

Table 2. Results of Pedroni's residual-based cointegration test

Test	Test statistic	p-value
H_0:: no cointegration; H_A: cointegration (within dimension)		
Panel v-Static	6.440	0.000
Panel rho-Statistic	-1.380	0.084
Panel PP-Statistic	-9.227	0.000
Panel ADF-Statistic	-9.241	0.000
H_0: no cointegration; H_A: cointegration (between dimension)		
Group rho-Static	1.608	0.946
Group PP-Statistic	-13.722	0.000
Group ADF-Statistic	-13.966	0.000

Table 3. Group-mean FMOLS estimators and *t*-statistic

Explained variable	Explanatory variables			
$In(HE_t)$	$In(GDP_t)$		SE_t	
	Estimate	t-stat	Estimate	t-stat
	0.0197	-0.1685	6.4372	22.9202*

* denotes significance at the 5% level.

Appendix A. Group-mean DOLS estimators and *t*-statistic

Explained variable	Explanatory variables			
$In(HE_t)$	$In(GDP_t)$		SE_t	
	Estimate	t-stat	Estimate	t-stat
	-0.0358	-1.0680	6.5848	28.9050*

* denotes significance at the 5% level.

Chapter 2

Health care expenditure, GDP and share of the elderly in G 20: a Dynamic Panel Heterogeneous Analysis

2.1. Introduction

Identifying the determinants of health care expenditure has been a primary concern over the last two decades in the field of macroeconomics. Martin *et al*. (2011) survey the literature from 1998 to 2007 and find 20 articles that studied the determinants of health care expenditure. They conclude that 'income' has been considered as the main determinant of health care expenditure, while 'population ageing' and 'closeness to death' are the other principal determinants of health care expenditure. Gross Domestic Product (GDP) per capita is also demonstrated to be one of the main factors contributing to aggregate health care expenditure (Giannoni and Hitiris 2002; Clemente *et al*. 2004). The theoretical background for this argument is that medical care is a kind of good that allows people to live longer and enjoy a better life (e.g. Newhouse 1977). In this context, as income becomes greater and people get richer, they want to purchase additional life expectancy and pursue quality of life, thus driving an increase in health care expenditure.

As for the share of the elderly, which has also been examined as a key determinant of health care expenditure, a number of studies have argued that health care expenditure per capita may increase when the proportion of the elderly increases (e.g. Herwartz and Theilen 2010; Bech *et al*. 2011; Pammolli *et al.* 2012). In fact, the share of health expenditure in GDP is forecasted to increase by at least 3.3 percentage points between 2010 and 2060 for member countries of the Organisation for Economic Co-operation and Development (OECD), of which 1.2 percentage points are attributable to demographic and income effects (OECD 2013). Japan, one of the world's developed countries, is known to suffer from an ageing society. According to a forecast made by the Office of the Prime Minister of Japan, a decrease in the productive-age population will increase national health care expenditure from ¥35.1 trillion in 2012 to ¥54.0 trillion in 2025, the reasoning being that ageing will drive health expenditure up, because the elderly tend to use health care services more frequently and more extensively than the youth (Hall and Jones 2007).

Nonetheless, evidence on whether the share of the elderly is really a determinant at the macro level is unclear, as the results depend on the data and specification of empirical models used in the reviewed studies. Some of the earlier studies using cross-country panel data conclude that age structure has only a minimal impact on health care expenditure, while GDP has a significant impact (e.g. Dormont *et al*. 2006; Werblow *et al*. 2007). In contrast, single-country studies find that population ageing is an important and positive determinant of health care expenditure (e.g. Matteo 2005; Crivelli *et al.* 2006; Tamakoshi and Hamori 2014). Furthermore, recent studies using cross-country panel data also find a positive relationship between health care expenditure and the ageing population. For example, Herwartz and Theilen (2010) use the annual data set of 18 OECD countries over the period 1976 to 2006 and apply a mean group estimation technique to examine the relationship between health care expenditure, GDP, population ageing and public expenditure. They conclude that proximity to death is more important than population ageing, but they do not deny the importance of population ageing as a determinant for health care spending.

Dreger and Reimers (2005) use the annual series data of 21 countries over the period 1975 to 2001 to estimate the relationship between health care expenditure, GDP and several other factors, including the share of the elderly. They apply the Fully Modified OLS, Dynamic OLS and Breitung's 2-step techniques and show that health care expenditure is determined by GDP, life expectancy, infant mortality and the share of the elderly. Pammolli *et al*. (2012) apply the Pooled Mean Group (PMG) method to data from 15 European countries to investigate the effects of income, productivity growth, ageing population, technological progress, female labour participation and public budget. They find that GDP, ageing population and female labour have positive impacts on health care expenditure.

Given this background, our article makes two contributions to the literature. First, using the recent panel data of developed countries, we examine the impacts of ageing population and GDP on health care expenditure. Our data span from 1995 to 2012. Thus, we include the period of the economic downturn experienced by advanced economies, which was triggered by the collapse of Lehman Brothers in September 2008 and culminated in the global financial crisis. We incorporate potential effects of the crisis by including a dummy variable in our panel-based model.

Our second contribution lies in applying and comparing the results of the dynamic Generalized Methods of Moments (dynamic GMM) and PMG techniques, both of which are important but infrequently used methods in health economics studies.[1] In fact, we see clear benefits of using these two methods. Both techniques deal with panel data and estimate dynamic relationships between variables. Panel-based methods have become popular, since they allow the use of both time series and cross section data and provide greater power than studies on individual countries. A dynamic approach is also suited to the common assumption; according to Balestra and

[1] The Mean Group (MG) estimator might be used when T is quite large. Here, we do not use the MG estimator because our data only cover the period between 1995 and 2012.

Nerlove (1966), an economic phenomenon is basically the result of the action by a certain economic entity existing in a dynamic framework. With these benefits in mind, scholars in other research areas, such as financial economics, have applied either dynamic GMM or PMG techniques (e.g. Biliquess *et al*. 2011; Boubaker and Jouini 2014; Sisay 2015) to empirically study such systems. However, only a limited number of studies in the health economics field apply either technique,[2] and furthermore, none of these studies compare the empirical results obtained by using these two methods.

Our main findings are as follows: (i) there is a long-run cointegration relationship between GDP, health care expenditure and the share of the elderly; (ii) in the long term, not only GDP but also share of the elderly exerts positive effects on health care expenditure; and (iii) the Lehman shock dummy, which is adopted to incorporate the impacts of the global financial crisis, is significantly positive in the long term, suggesting that the level of health care expenditure is higher after the crisis. These findings suggest the policymakers should tackle the issues pertaining to demographic composition and health care policies together in order to control health care expenditure effectively.

This article is organized as follows. Section 2.2 briefly introduces the dynamic GMM and PMG econometric approaches. Section 2.3 presents a preliminary analysis of the data. Section 2.4 analyses the cointegration hypotheses between health care expenditure, GDP and the share of the elderly and discusses the estimation results. Section 2.5 offers concluding remarks and policy implications of the empirical results.

2.2. Model and Methodology

The model

Based on the previous literature (e.g. Giannoni and Hitiris 2002; Clemente *et al*. 2004), which predicts GDP to be a positive function of health care expenditure, the latter can be specified as

$$HCE = f(PGDP) \qquad (1)$$

where HCE is the real health care expenditure per capita, and PGDP is the real GDP per capita. The role of the share of the elderly has also been highlighted as a determinant for health care expenditure; therefore, Equation 1 is extended to examine the potential impact of the share of the

[2] For instance, Fedeli (2015) applies the Westerlund ECM panel cointegration test to Italian data and investigates the long-run relationship between health-care expenditure and GDP. He finds that the long-run movement of health-care expenditure is contributed by GDP alone and that the short-run movement is driven by political and institutional variables. Mehmood *et al.* (2014) apply the PMG method to data of 26 Asian countries over the period 1990 to 2012 and show that there are long-run relationships between health-care expenditure, income and literacy rate. They report positive linkages between the three variables.

elderly on health care expenditure following previous studies (e.g. Dreger and Reimers, 2005; Herwartz and Theilen, 2010; Pammolli *et al.*, 2012). Thus, the basic equation is specified as follows:

$$HCE = f(PGDP, SE) \tag{2}$$

where SE is the share of the elderly. Equation 2 provides the basis for the empirical model that will be estimated in this article. In line with previous studies (e.g. Blomqvist and Carter, 1997; Sen, 2005), we specify the log-linear equation as follows:

$$ln(HE_{i,t}) = \beta_0 + \beta_1 ln(GDP_{i,t}) + \beta_2(SE_{i,t}) + e_{i,t} \tag{3}$$

where $ln(HE_{i,t})$ is the natural logarithm of real health care expenditure per capita for the *i*th country, $ln(GDP_{i,t})$ is the natural logarithm of real GDP per capita for the *i*th country, $SE_{i,t}$ is share of the elderly for the *i*th country and $e_{i,t}$ represents the error term. For estimating Equation 3, two dynamic panel techniques, namely the dynamic GMM and PMG estimator, are employed.

The methodology

We use panel data regression methods to investigate the relationship between health care expenditure, GDP and ageing population. We select a dynamic panel framework, which includes lagged explained variables as explanatory variables and thus allows endogeneity in all explanatory variables.

Firstly, we use the dynamic GMM technique developed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998). The main advantage of the dynamic GMM technique is its perceived robustness to heteroscedasticity and nonnormality of the disturbance. The model is specified as follows:

$$HCE_{it} = \delta HCE_{i,t-1} + \gamma X_{it} + \mu_i + \varepsilon_{it} \tag{4}$$

where μ_i represents fixed effects, and X_{it} are dependent variables.

After taking first differences, Equation (4) yields

$$\Delta HCE_{it} = \delta \Delta HCE_{i,t-1} + \gamma \Delta X_{it} + \Delta\varepsilon_{it} \tag{5}$$

By taking the first differences, countries' fixed effects are excluded from the model, while the slope coefficients remain the same as in Equation (4).

The main problem in Equation (4) is the potential endogeneity of the control variables as well as the correlation between the lagged dependent variables $HCE_{i,t-1}$ and the error term ε_{it}. Furthermore, the dynamic GMM has other disadvantages: (i) statistical significance may not be provided under small samples; (ii) the bias of the dynamic GMM expands when δ approaches one; and (iii) the dynamic GMM technique cannot estimate fixed effects.

With this in mind, we also employ the PMG technique developed by Pesaran *et al*. (1999).

This method assumes common coefficients (i.e. the same coefficients between groups) in the long-run cointegrating relationship, while the short-term parameters vary across groups (i.e. the speed of error correction in each group is different). The PMG method is regarded as an expansion of the Autoregressive Distributed Lag system of equations for t = 1, 2, …, T time periods and for i = 1, 2, …, N countries. For the dependent variable y_{it}, the model is written as

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij}\, y_{i,t-j} + \sum_{j=0}^{q} \delta_{i\,j}{}' x_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (6)$$

where $x_{i,t}(k \times 1)$ is the vector of explanatory variables for group i , μ_i is the fixed effect, $\lambda_{i,j}$ is the scale and $\delta_{i,j}$ is the k × 1 coefficient vector. The equation is re-parameterized as follows:

$$\Delta \mathrm{y}_{it} = \emptyset_i y_{i,t-1} + \beta_i' x_{it} + \sum_{j=1}^{p-1} \lambda^*{}_{ij} \Delta \mathrm{y}_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*\prime}{}_{ij} \Delta \mathrm{x}_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (7)$$

where $\emptyset_i = -(1 - \sum_{j=1}^{q-1} \lambda^*{}_{ij}\ )$, $\beta_i = \sum_{j=0}^{q} \delta_{ij}$, $\lambda^*{}_{ij} = -\sum_{m=j+1}^{p} \lambda_{im}$, $\delta^*{}_{ij} = -\sum_{m=j+1}^{q} \delta_{im}$ and j = 1, 2, …, q – 1. This assumption ensures that $\emptyset_i < 0$, and there exists a long-run relationship between $y_{i,t}$ and $x_{i,t}$, defined by $y_{it} = -(\frac{\beta_i'}{\emptyset_i}) x_{i,t} + \eta_{it}$. The long-run homogeneous coefficient is $\theta = \theta_1 = -(\frac{\beta_i'}{\emptyset_i})$.

2.3. Data

We use annual data series for G20 countries[3] covering the period 1995 to 2012. We source the following data from the World Bank database: (i) real health care expenditure per capita in each country, (ii) real GDP per capita in each country and (iii) population aged 65 and above as a percentage of the total population in each country (Table 1). Real health care expenditure is the sum of public and private health care expenditures and covers the provision of health services and nutrition activities. GDP per capita is gross domestic product divided by mid-year population, and GDP is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. We choose the percentage of the population aged 65 and above as the indicator of share of the elderly, as is commonly done in the previous literature.

Place Table 1 here

2.4. Empirical Results

[3] The G20 countries include France, the United States, Germany, Japan, Italy, Canada, Argentina, Australia, Brazil, China, Indonesia, India, the Korean Republic, Mexico, Russian Federation, Saudi Arabia, Turkey, South Africa and the European Union. However, as the G20 also includes some European countries, such as Germany, we exclude the European Union from consideration in this article. Namely, we consider only 19 countries.

We investigate the estimation results of the relationship between the logarithm of health care expenditure per capita (LnPHCE), logarithm of GDP per capita (LnPGDP) and the share of the elderly (SE). As our data cover a recent period, it might be worthwhile to consider whether the recent financial turmoil may have caused structural breaks in the relationship between the variables. Hence, we incorporate, in particular, the effects of the global financial crisis resulting from the bankruptcy of Lehman Brothers in the United States in September 2008. A dummy variable (Dummy Lehman (DL)) that takes 1 for the period between 2009 and 2012 is adopted.

We apply the dynamic GMM and PMG methods to our panel data set. Table 2 reports the results for both methods.[4] We find that the estimated coefficients for LnPGDP and SE through both techniques are significantly related with that of LnPHCE at the 1% significance level. This suggests that there is a long-run relationship between LnPHCE, LnPGDP and SE. Furthermore, the result shows that the coefficients for LnPGDP and SE are positive. It means that not only GDP per capita but also the share of the elderly positively affects health care expenditure per capita. These findings are consistent with the results of other studies (e.g. Herwartz and Theilen 2003; Koening *et al.* 2003; Mosca 2007), which highlight the importance of not only GDP but also the share of the elderly as key determinants of health care expenditure.

Another interesting finding from Table 2 is that the coefficient of the dummy variable in the PMG estimation is significantly positive. This may suggest that despite the financial turbulence and resulting economic downtown triggered by the Lehman crisis, the level of health care expenditure per capita in the cointegrating relationship is higher after the crisis compared to the pre-crisis period. This implies the significance of the challenge of rising health care expenditure faced by policymakers in developed economies. Further, the results suggest the existence of a structural break between the variables, which may have occurred around time of the financial crisis. Indeed, the fact that the health care expenditure increased even during the economic downturn after the crisis is counterintuitive at first glance. In the United States, for example, many people lost their jobs and became rapidly poorer after the crisis. These circumstances compelled President Obama to announce the so-called ‘ObamaCare’ in 2010, which made provisions for the use of public funds for medical care for aged people and aid care for the unemployed. According to ObamaCare Facts, these activities continue to be key elements even in ObamaCare 2015.

Place Table 2 here

2.5. Concluding Remarks

[4] The PMG estimation in Table 4 uses the Akaike Information Criterion (AIC) to select the lag orders for each group with the condition that the maximum dependent lag is 3. We also check the robustness using the Schwarz Bayesian Information Criterion (SBIC) and find that the results are qualitatively similar to those derived using the AIC.

Using the two panel-based techniques, dynamic GMM and PMG, we examine the impacts of GDP and ageing population on health care expenditure. Our data on G20 countries range from 1995 to 2012, including the recent period after the global financial crisis. Our empirical results are as below. (i) Pedroni's (1999) residual-based panel cointegration technique indicates that there is a long-run cointegrating relationship between GDP, health care expenditure and the share of the elderly; (ii) the results of both dynamic GMM and PMG methodologies show that the share of the elderly as well as GDP have significantly positive effects on health care expenditure in the long run; and (iii) the Lehman shock dummy in the cointegration equation is significantly positive, implying that the level of health care expenditure is higher after the financial crisis, that is, despite the economic downturn.

Our results provide support for the theory that ageing might increase health spending as people want to purchase additional life expectancy and quality of life. Besides, both ageing and GDP are found to have positive effects on health care expenditure, at least in the long run. Therefore, in order to cope with the rising trends of health care expenditure during and even after a financial crisis, policymakers should tackle the issues raised by demographic composition in their respective economies. Therefore, it might be appropriate for governments to consider health care policy and population policy simultaneously, because an ageing population usually drives the smaller proportion of the working-age population to finance the health care system, thus increasing their financial burden over time. In this context, policies such as the UK government's thorough and periodic reviews of the cost effectiveness of health care expenditure[5] and parent-friendly policies passed in the 1990s that help both parents to continue work/retain their jobs (i.e. enabling women to secure employment during and after a pregnancy and allowing fathers to avail of paternity leaves) might be good reference points for policymakers facing the imminent threats posed by an ageing society.

[5] Here, cost effectiveness is measured by Quality-Adjusted Life Years.

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Table 1. Data

Country	HCE per capita (constant 2011 international $)			GDP per capita (constant 2005 US$)			Share of the elderly (%)		
	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.
France	3102	4213	2161	33 703	36 074	29 845	16.3	17.5	15.4
United States	6215	8845	3810	41 741	45 420	35 149	12.6	13.6	12.3
United Kingdom	2411	3402	1347	37 228	41 567	30 842	16.1	17.2	15.8
Germany	3299	4635	2276	34 747	39 274	30 940	18.2	21.1	15.4
Japan	2415	3632	1578	34 967	37 118	32 942	19.2	24.4	14.4
Italy	2396	3203	1496	30 808	32 831	28 186	19.0	20.8	16.7
Canada	3253	4610	2070	34 154	37 442	28 710	13.1	14.8	11.9
Argentina	962	1550	649	5930	7662	4540	10.2	10.8	9.6
Australia	2792	4042	1625	32 586	37 218	26 572	12.8	14.0	11.9
Brazil	839	1388	522	4795	5791	4279	6.0	7.3	5.0
China	239	578	61	1756	3378	782	7.4	8.7	6.2
Indonesia	150	273	82	1282	1715	1037	4.8	5.1	4.2
India	120	196	63	720	1103	4667	4.6	5.2	4.1
Korean Republic	1240	2244	493	17 650	23 303	12 271	8.7	11.8	5.9
Mexico	684	1062	372	7717	8449	6599	5.3	6.3	4.5
Russian Federation	748	1529	301	4944	16,703	3 283	13.0	13.8	12.1
Saudi Arabia	1255	1990	759	13 303	8,472	11 486	3.1	3.5	2.6
Turkey	577	971	174	6765	6051	5417	6.3	7.3	5.1
South Africa	760	1091	478	5327	7831	4758	4.2	5.4	3.3

Notes: PHCE denotes real health care expenditure per capita (constant 2011 international $), PGDP denotes real GDP per capita (constant 2005 US$) and SE refers to the share of the elderly (over 65 years old). The averages, maximum and minimum of the samples between 1995 and 2012 are presented above.

Table 2. Empirical results of the dynamic GMM and PMG methods with dummy Lehman (Dependent variable: logarithm of health care expenditure per capita)

	Dynamic GMM[1]		PMG[2]	
	Coefficient	*p*-value	Coefficient	*p*-value[3]
Long-run coefficients				
LnPHCE(-1)	0.8887	0.0000		
LnPGDP	0.1934	0.0000	0.6293	0.0000
SE	0.0044	0.0024	0.0363	0.0000
DL	-0.0010	0.7903	0.0490	0.0000
Short-run coefficients (average)[4]				
COINTEQ01			-0.4329	0.0184
D(LnPHCE(-1))			-0.0273	0.8999
D(LnPHCE(-2))			0.0108	0.9522
D(LnPGDP)			0.2526	0.4640
D(LnPGDP(-1))			0.5229	0.2088
D(LnPGDP(-2))			0.7731	0.0912
D(SE)			0.6924	0.7585
D(SE(-1))			-0.1436	0.9641
D(SE(-2))			-0.2418	0.8584
D(DL)			0.0060	0.6102
D(DL(-1))			0.0034	0.8764
D(DL(-2))			0.0110	0.5897
No. of countries	19		19	
No. of observations	304		285	
Log-likelihood			1236.0080	

Notes: 1. We use LnPGDP(-1) and SE(-1) as instrument specifications. We use the orthogonal deviations transformation.

2. AIC has been used to select the lag orders for each group, on the condition that the maximum dependent lag is 3. The selected model is ARDL(3,3,3,3). All the long-run parameters have been restricted to remain constant across groups.

3. The *p*-values and any subsequent tests do not account for model selection.

4. Over the short run, the PMG coefficients are obtained by averaging the estimates across equities.

Chapter 3

Testing cointegration between health care expenditure and GDP in Japan with the presence of a regime shift

3.1. Introduction

Health care expenditure (HCE) is considered a function of gross domestic product (GDP) according to the so-called demand function approach (e.g. Newhouse, 1977; Devlin and Hansen 2001). By contrast, GDP can be viewed as a function of HCE in the context of the health capital model (e.g. Grossman, 1972). Against this background, past studies have examined the cointegrating relationship between HCE and GDP (e.g. Murthy and Ukpolo, 1994; Gerdtham and Lothgren, 2000). They analysed time-series data spanning relatively long periods and concluded that there was a strong and positive long-term correlation between HCE and GDP at the aggregate level (i.e. on real per-capita basis). However, if structural breaks exist between the two variables, their conclusion is spurious, leading us to misleading estimation results.

Recent empirical studies have investigated the interrelationships between the two variables, considering that structural breaks in the relationship may exist. For instance, Esteve (2007), using the multiple structural break test by Bai and Perron for annual data from 1971 to 1991 in Spain, found the existence of a long-run relationship between the two variables with two structural changes in 1971 and 1991, respectively. He concluded that the first regime shift was related to the full implementation of the Social Security Act 1967 and that the second shift was triggered by the General Health Care Act 1986 in Spain. Chakroun (2009), applying the panel smooth threshold regression model developed by Fouquau et al. (2008) to the annual data from 1975 to 2003 in 17 OECD countries found that a nonlinear cointegration relationship exists between income and health spending and that such a relationship changes over time.

This article mainly contributes to the literature in two ways. First, we are among the first to study a threshold cointegrating relationship between real per-capita GDP (PGDP) and real per-capita HCE (PHCE) in Japan. The sample covers quarterly data over the period from 1994 to 2013. We pay particular attention to recent situations in Japan primarily because (1) among advanced economies, Japan in particular faces an ageing society, with HCE increasing under sluggish GDP growth and (2) in April 2008, Japan introduced a late-stage medical care system targeted for people aged 75 or older to allocate cost burdens for HCE efficiently, and thus, analysing how such policy changes may have changed the dynamic relationship between PGDP and PHCE is interesting.

Second, we apply the novel methodology by Hansen and Seo (2002) to incorporate the possibility of threshold effects in the cointegrating relationship between PGDP and PHCE. Since the study by Balke and Fomby (1997), several methodologies allowing for nonlinear adjustment to a long-run equilibrium based on the vector error correction model (VECM) have been developed. Hansen and Seo (2002) developed a two-regime threshold VECM model that describes short-run dynamic relationships of two regimes divided by a threshold. Their methodology has been adopted by a wide range of empirical studies (e. g. Chung et al, 2005; Hu and Lin, 2008; Esteve and Prats, 2010).

Our empirical results showed the existence of a nonlinear cointegrating relationship between PGDP and PHCE. We found evidence of asymmetry in terms of the dynamic adjustment processes between the two variables classified by the 'typical' regime rather than the 'extreme' regime[1]. Moreover, the regime shift might have occurred in Q4 2008, right after a main change of the Japanese health care system. The policy implications of these findings are discussed.

3.2. Data

Our data sources are as follows: (1) HCE data were extracted from the Ministry of Health, Labour and Welfare, (2) nominal GDP data were obtained from the Cabinet Office and (3) population data were drawn from the Statistics Bureau of the Ministry of Internal Affairs and Communications. We use a GDP deflator sourced from the Cabinet Office to transform each of the two variables into real per-capita measurements.

For each of the two variables, we performed an ADF unit root test as well as a Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test. The results of these tests indicated that all variables are integrated with order 1, that is, they are all I(1) variables (See Table 1).

3.3. Empirical Results

Although a standard linear VECM model assumes a constant adjustment speed toward a

[1] The 'typical' regime and the 'extreme' regime comprise approximately 83% and 17% of all observations, respectively.

long-run equilibrium, threshold cointegration approaches hold that error correction occurs depending on the threshold. The Hansen and Seo (2002) model considers a two-regime model that can be considered a nonlinear VECM of order ℓ+1, as follows:

$$\Delta y_t = \begin{cases} A_1' X_{t-1}(\beta) + u_t, & \text{if } w_{t-1}(\beta) \leq \gamma \\ A_2' X_{t-1}(\beta) + u_t, & \text{if } w_{t-1}(\beta) > \gamma \end{cases} \quad (1)$$

with

$$X_{t-1}(\beta) = \begin{cases} 1 \\ w_{t-1}(\beta) \\ \Delta y_{t-1} \\ \Delta y_{t-2} \\ \cdot\ \cdot\ \cdot \\ \Delta y_{t-\ell} \end{cases} \quad (2)$$

where γ is the threshold parameter, y_t is a p-dimensional I(1) time series with one $p \times 1$ cointegrating vector β, $y_t(\beta) = \beta' y_t$ denotes the I(0) error correction term, u_t is an error term, and A_1 and A_2 are coefficient matrices.

Under this framework, we test a presence of the threshold effect under the null hypothesis that there is no threshold. We apply the $sup\, LM$ test, which is denoted by

$$sup\, LM = sup_{\gamma_L \leq \gamma \leq \gamma_U} LM\,(\tilde{\beta}, \gamma) \quad (3)$$

where $\tilde{\beta}$ is the null estimate of β, $[\gamma_L, \gamma_U]$ is the search region set, γ_L is the π_0 percentile of $\widetilde{w}_{t-1}$ and γ_u is the (1-π_0) percentile. The *sup*LM statistic has a nonstandard asymptotic distribution. The fixed regressor bootstrap and the residual bootstrap methods were used, and both were simulated using 5000 replications. A lag length of ℓ =1 was selected based on the AIC and BIC criteria.

Table 2 reports the test results for the linear versus nonlinear hypothesis with the structural break[2]. Both bootstrapping tests reject the null hypothesis of linear cointegration at the 10% significance level, and thus, the threshold cointegration model is more appropriate to our data than the linear model. The cointegrating vector and the threshold parameter estimates $(\tilde{\beta}, \tilde{\gamma})$ are (0.248, -1.745). In each regime, the error-correction mechanism differs depending on deviations from the equilibrium below (Regime1) or above (Regime2) the threshold parameter γ. Regime 1 corresponds to $PCHE_{t-1}$ – 0.248 $PCDP_{t-1}$ ≤-1.745%, occupying 83.33% of all observations. We term this regime the 'typical' regime. However, it holds in Regime 2 (termed the 'extreme' regime) that $PCHE_{t-1}$ – 0.248 $PCDP_{t-1}$ >-1.745%. In total, 16.67% of all observations are included in this regime.

Table 3 reports the VECM estimation threshold. In a typical regime, the error-correction effects

[2] We assumed that 80 grid points for the threshold and vector.

represented by the parameter accompanying w_{t-1} appear significant at the 1% level only for $\Delta PGDP_t$. This implies that error correction occurs through only PGDP. On the other hand, in the extreme regime, the error correction terms for both $\Delta PGDP_t$ and $\Delta PHCE_t$ are statistically significant at the 1% level, meaning that both PGDP and PHCE contribute to the long-run equilibrium adjustment.

In Figure 1, the response function for the discrepancy between PGDP and the adjustment for PHCE is plotted as a function of w_{t-1} in the previous period. We find that in the typical regime (left-hand side of the graph), the error-correction effect of PHCE is flat and near zero, but the effect in response to PGDP is upward-adjusting, consistent with the finding that only PGDP significantly contributes to the equilibrium adjustments. In contrast, in the extreme regime (right-hand side of the graph), the error-correction effect of PGDP is upward-adjusting with sharp slopes. More interestingly, the effect of PHCE indicates an increase in the size of the slope compared to the typical regime. This is in line with the finding that in the extreme regime, both PGDP and PHCE significantly derive long-term adjustment processes.

Next, we investigate the timing of the regime shift in the cointegrating relationship. We find that the extreme regime occurred mostly after Q4 2008, whereas the typical regime occupied most periods before that date. This suggests that the relationship may have experienced a structural break in Q4 2008. This timing is associated with the sudden drop in PGDP triggered by the bankruptcy of Lehman Brothers, which had adverse effects on the Japanese economy. Furthermore, the timing is close to the implementation of the late-stage medical care system for the elderly in April 2008. This policy aims to maintain the sustainability of the universal health insurance system[3]. In order to control swelling health care expenditures owing to the ageing of the society, the defraying ratio for medical services between those working and retired was clearly set. As a result, a larger burden was virtually imposed on the elderly population. Our empirical results indicate that the late-stage medical care system, which expands the ratio of personal expenses for the elderly, is considered effective for attaining a stable long-run equilibrium relationship between PGDP and PHCE, allowing not only the former but also the latter to contribute to the adjustment processes.

3.4. Conclusion

Using quarterly data from 1994 through 2013, this study employed the Hansen and Seo (2002) tests to examine the long-term relationships between PGDP and PHCE in Japan with

[3] The ‘universal insurance system’, under which everyone can receive medical services at any medical institution nationwide in Japan, was developed in 1961.

threshold effects. We found evidence to support the presence of a threshold cointegrating relationship between the two variables. The main findings can be summarized in the following points: (1) we detect evidence to support the presence of a threshold cointegrating relationship between the two variables; (2) in the typical regime, error corrections are significantly driven only by PGDP, whereas both PGDP and PHCE contribute to the long-run equilibrium adjustment in the extreme regime; and (3) the extreme regime emerges mostly after Q4 2008 and the typical regime appears prior to that, implying the occurrence of a regime shift. These results suggest that the introduction of the late-stage medical care system for the elderly in April 2008 may have affected the relationship between PGDP and PHCE such that PHCE and PGDP began driving adjustments to the long-run equilibrium.

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Table 1. Unit Root Test

	ADF test		KPSS test	
	Level	First differences	Level	First difference
PGDP	-0.882	-5.155**	1.100**	0.114
PHCE	1.110	-5.819**	1.212**	0.172

Notes:

The lag length for ADF tests are selected using BIC.

The null hypothesis for the ADF test is that the statistics have a unit root. The null hypothesis for the KPSS test is stationary.

** Statistically significant at the 1% level.

Table 2. Test for threshold cointegration between PGDP and PHCE

Estimates	
Threshold parameter estimate (γ)	-1.745
Cointegrating vector estimate (β)	0.248
Lagrange Multiplier threshold test	
*sup*LM value	16.792
p-value of fixed regressor bootstrap	0.071
p-value or residual bootstrap	0.009

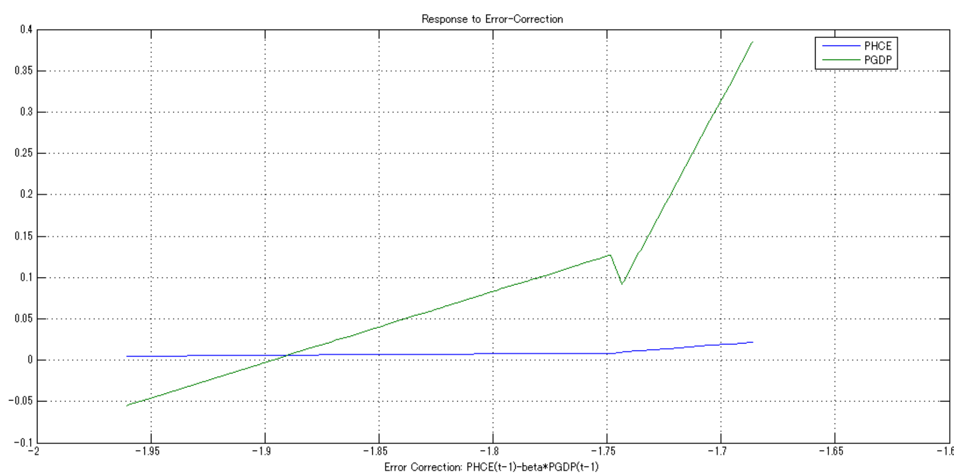
Note: Selection of lag length 1 is based on both the AIC and BIC criteria.

Table 3. Threshold VECM estimation between PHCE and PGDP

	$\Delta PHCE_t$		$\Delta PGDP_t$	
	Regime1 (typical regime)	Regime2 (extreme regime)	Regiem1 (typical regime)	Regime2 (extreme regime)
Constant	0.036	0.379***	1.626**	9.002***
	(0.041)	(0.115)	(0.740)	(2.862)
w_{t-1}	0.016	0.212***	0.857**	5.111***
	(0.022)	(0.068)	(0.405)	(1.675)
$\Delta PGDP_{t-1}$	-0.504***	-0.939***	-5.360**	-11.609***
	(0.122)	(0.164)	(2.270)	(3.071)
$\Delta PHCE_{t-1}$	-0.027***	0.004	-0.580***	0.317
	(0.008)	(0.012)	(0.144)	(0.348)
	$w_{t-1} \leq -1.745$	$w_{t-1} > -1.745$	$w_{t-1} \leq -1.745$	$w_{t-1} > -1.745$

Note : Figures in parentheses indicate standard errors.

Figure 1. Response to Error Correlation



Publication list

Chapter 1

Health-care expenditure, GDP and share of the elderly in Japan: a panel cointegration analysis

Tamakoshi, Tomoko and Hamori, Shigeyuki.

Applied Economics Letters (2015), 22, 725-729.

Chapter 3

Testing cointegration between health care expenditure and GDP in Japan with the presence of a regime shift.

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