Long-term Effect of Telecare on Patients with Chronic Diseases

Masatsugu Tsuji[1], Yuji Akematsu[2]

[1]University of Hyogo, Kobe, Japan
[2]Osaka University, Toyonaka, Japan

Abstract

This paper examined the long-term effects of the use of telecare (e-Health) on the residents of Nishi-aizu Town, Fukushima, Japan, between 2002 and 2010. We compared medical expenditure and days of treatment between telecare users (treatment group) and non-users (control group) based on receipt data obtained from the National Health Insurance, which is operated by the government. In previous studies, we used receipt data obtained for the years 2002 to 2006; this study expands the analysis period four more years with respect to respondents who were included in previous analyses. 90 users and 118 non-users were included in both analyses. Using rigorous statistical methods, including system generalized method of moments (GMM), this paper demonstrates that telecare users require fewer days of treatment and lower medical expenditure than non-users with respect to the chronic diseases of stroke, hypertension, heart failure, and diabetes. To date, there have been no publications examining the long-term economic effects of the use of telemedicine, so the current study presents a new facet to the research in this field.

1. Introduction

To cope with the serious healthcare situation in Japan such as increase in medical expenditure, local governments have begun implementing telecare or e-Health, which allow the local government to remotely monitor the health of elderly residents at home by transmitting health-related data, such as blood pressure, blood oxygen level, and ECG, to medical institutions via telecommunications networks. Telecare is thus expected to improve users' health, as our previous studies [1], [2], [3], and [4] demonstrated.

This study is conducted in Nishi-aizu, a town located in Fukushima Prefecture, Japan, and the objective of the paper is to demonstrate that telecare use reduces not only medical expenditure but also days of treatment for the long-term such as nine years. System generalized method of moments (GMM) is used to statistically assess the causal relationship that telecare use actually reduces medical expenditure and days of treatment. This relationship is not "seemingly correlated" ([3], [5], and [6]).

We conducted our field research in March 2012 to obtain two basic data for statistical analysis such as receipt data for 272 telecare users (treatment group) and 247 non-users (control group) for the period 2007 to 2010 and their responses of questionnaire were collected. This data included individuals who were included in our previous studies of the period 2002 to 2006; therefore, data for 90 telecare users and 118 non-users for the period 2002 to 2010 were used in this study.

Another objective of this study is to compare the results of the same telecare project of Nishi-aizu obtained by our previous studies ([1], [2], [3], and [4]) which covered the data of 2002-2006 and subjects of 199 (treatment) of telecare and 209 non-users (control). This paper examines how these results are different.

2. Materials and methods

2.1. Sample selection

Here two kinds of data for analysis, namely receipt data and responses of questionnaire are explained. In our previous study, the receipt data of 199 users and 209 non-users collected between 2002 and 2006 was obtained from the National Health Insurance. The receipts for each month are kept at the Nishi-aizu town office, and include a range of information. In the current study, the following data was used: (i) name of patient, (ii) birth date, (iii) regular outpatient treatment or hospitalized patient treatment, (iv) name(s) of major disease(s), (v) date of initial treatment, (vi) number of days of treatment needed, and (vii) "point" of medical treatment (one point is equivalent to JPY 10).

We next collected receipt data for the years 2007 to 2010. To ensure that the patients included in the previous studies were also included in the current study, we first checked whether they responded to the questionnaire survey (in case of death, etc.); about half of the respondents had not responded, which resulted in a lack of samples. We therefore selected 565 new respondents from among the telecare users. The questionnaire used in this study was the same as that used in our previous studies. The

questionnaire asks about characteristics such as sex, age, and the individuals' use of the telecare system, which is data not included in the receipt data. Non-users were selected by stratified sampling from the list of subscribers to the National Health Insurance, which amounted to 1035 non-users. The respondents are summarized in Table I, which shows that 272 users and 247 non-users were selected as valid respondents for this study; 91 users and 118 non-users were included in both the previous study and the current study. We then collected their data mentioned above.

Table 1. Respondents to mail questionnaire.

	No. of residents sent questionnaire	No. of valid respondents between 2002 and 2009
Users	565	272 (91)
Non-users	1035	247 (118)
Total	1600	519 (209)

2.2. Summary of mail survey

The percentage of sex of users and non-users is shown in Table 2. The percentage of males (59.1%) is higher than that of female (40.9%).

Table 2. Gender.

	Users (%)	Non-users (%)	Total (%)
Male	52 (57.1)	72 (61)	124 (59.3)
Female	39 (42.9)	46 (39)	85 (40.7)
Total	91	118	209

The average ages of users and non-users are shown in Table 3. The average ages of the two groups are similar, but they are naturally higher than in the previous research, since the last survey was five years ago.

Table 3. Average age of respondents.

	N	Average age
Users	90	75.67
Non-users	118	75.76

The telecare system in Nishi-aizu was implemented to help in the management of chronic diseases such as heart disease, hypertension, diabetes, and stroke. Table 4 shows the number of patients with these four diseases that were treated within the study period. Hypertension was the most common of these four diseases, followed by heart disease. Table 5 summarizes the number of years of individual telecare use. Users that had used the telecare system for more than 10 years accounted for 25.6% of the total number of users, which is the largest percentage, and this makes examining the long-term effect of the system possible. The number of respondents who replied they did not use the telecare system accounted for 30% of the respondents, which was larger than expected. It is possible that they responded that they did not use the system, even though they had a telecare device in their homes.

Table 4. Diseases treated between 2002 and 2010.

	Users (%)		Non-users (%)		Total (%)	
	2002–2006	2007–2010	2002–2006	2007–2010	2002–2006	2007–2010
Heart disease	19 (0.21)	19 (0.21)	15 (0.13)	15 (0.13)	34 (0.16)	34 (0.16)
Hypertension	49 (0.54)	51 (0.56)	40 (0.34)	57 (0.48)	89 (0.43)	108 (0.52)
Diabetes	8 (0.09)	11 (0.12)	9 (0.08)	14 (0.12)	17 (0.08)	25 (0.12)
Stroke	5 (0.06)	8 (0.09)	7 (0.06)	9 (0.08)	12 (0.06)	17 (0.08)

Table 5. Years using Telecare

Years	1–3	3–5	5–7	7–10	>10	Do not use	Total
N	8	8	11	13	23	27	90

Table 6 summarizes frequency of telecare use. More than half of the respondents reported that they used the telecare system at least once a week. This high frequency of use is possibly due to the town office's effort to hold public meetings for users to teach them how to use the system, as already mentioned. One fourth of respondents answered that they rarely use the telecare system, which corresponds with the number of users who answered that they do not use the system (Table 5).

Table 6. Frequency of use.

Almost every day	3–4 times a week	1–2 times a week	1–2 times a month	Rarely use	Total
27	15	7	7	24	80

2.3. Method of estimation

Regression analysis is employed to assess whether telecare use reduces days of treatment and/or medical expenditure. Studies in this field face a number of important methodological issues. First, there is the problem of endogenous explanatory variables. One method of solving this is by using system GMM, which allows treatment of not only endogenous explanatory variables but also of the dynamic relationships among the variables that arise due to the chronic time-lagged effect of chronic diseases on patients. Moreover, system GMM is able to deal with the reverse correlation between outpatient medical expenditure and telecare use. In this context, we attempted to demonstrate causality between telecare use and decreased medical expenditures, or to show that the relationship is not seemingly correlated. Some previous studies have successfully attempted to handle endogeneity problems in telemedicine and telecare evaluation as described [3], [5], and [6].

A second methodological problem is related to sample selection bias. System GMM is not necessarily suitable when there is sample selection bias, but we attempted to reduce this bias by sampling the data as much as possible within the system GMM framework. Previously (for example [2]), we successfully managed sample selection bias by using propensity score matching, but the present study does not focus on how to reduce sampling bias.

3. Results

3.1. Model for estimation

In the estimation, the dependent variables were (1) days of treatment of outpatients, all diseases, (2) medical expenditure for outpatients, all diseases, (3) days of treatment of outpatients, chronic diseases, and (4) medical expenditure for outpatients, chronic diseases. The explanatory variables were telecare use (if users, 1; otherwise, 0), age, income, and the presence of any of the four main chronic diseases such as heart disease, hypertension, diabetes, and stroke (if treated, 1; otherwise, 0). In addition, other factors were added as instrumental variables such as dummy variables for sex or year dummies. System GMM estimators developed by Arellano–Bond, Arellano–Bover, and Blundell–Bond are general estimators for coping with data with "small T, large N" panels. System GMM can be used in models in which the independent variables are not strictly exogenous, namely, those correlated with past and possibly current realizations of the error. System GMM can also be used to treat data with heteroskedasticity. The Arellano–Bond test for AR (2) (second stage autocorrelation), the test of weak instruments, and the Hansen test for over-identifying restrictions were used.

3.2. Estimation results, all diseases

Tables 7 and 8I show the results of estimation using system GMM. The coefficient of telecare use is negatively significant for days of treatment ($p<0.10$) and medical expenditure ($p<0.05$). These findings imply that telecare contributed to reducing days of treatment and medical expenditure. However, the Arellano–Bond test for AR (2) for the model of medical expenditure (see Table 8) owed that there was autocorrelation under the 1% significance level, which means that serial correlation of the error terms cannot be denied, and accordingly, the estimates still have small biases. The test of weak instruments showed that instruments and endogenous variables used are correlated significantly, which cannot suffer from a problem of weak instruments. Furthermore, the Hansen test for over-identifying restrictions showed that the instrumental variables were properly chosen. This means that the model specification was adequate and that the parameters were significant and robust. In addition, age is positively significant for both days of treatment and medical expenditure ($p< 0.01$), which is natural considering that days of treatment and medical expenditure increase with age. Finally, the coefficients of three chronic diseases (heart disease, hypertension, and diabetes) are positively significant for both days of treatment and medical expenditure. According to the estimations, telecare use reduces days of treatment for all diseases by 7.9 days per user per year, and medical expenditure for all diseases by approximately JPY 106,904 per user per year. However, the latter may contain biases due to serial correlation, and therefore the result may not be creditable.

Table 7. Result of System GMM (1): Days for Treatment (outpatients, all diseases)

	Coeff.	SD	*t* value	*p* value	
Telecare use	–7.89	4.08	–1.93	0.053	*
Age	0.13	0.02	5.66	0.000	***
Income	–0.00	0.01	–0.43	0.664	
Heart disease	16.03	8.88	1.81	0.071	*
Hypertension	15.69	1.96	8.00	0.000	***
Diabetes	11.81	5.20	2.27	0.023	**
Stroke	–3.66	8.40	–0.44	0.663	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.109	
Test of weak instruments (*p* value)				< 0.01	
Hansen test for over-identifying restrictions (*p* value)				0.144	

Note: ***, **, and * indicate significance of 1%, 5%, and 10%.

3.3. Estimation results, chronic diseases

The same models were applied for patients with chronic diseases. The other variables were the same as in the previous estimations. Tables 9 and 10 summarize the results of these estimations. Both the Arellano–Bond test for autocorrelations, the test of weak instruments, and the Hansen test for over-identifying restrictions were satisfied, since they were not significant ($p =0.692$). Thus, the instrumental variables were selected appropriately. The coefficients for telecare use were negatively significant for both days of treatment ($p<0.05$) and medical expenditure ($p<0.05$). Age was again positively significant for both outcomes ($p<0.01$). In contrast to the previous estimation, only hypertension was positively significant for days of treatment ($p<0.01$) and medical expenditure ($p<0.01$). This means that hypertension is a main contributing factor for days of treatment and medical expenditure. The coefficients indicate that telecare use reduces days of treatment for chronic diseases by 4.2 days per user per year, and medical expenditure for chronic diseases by JPY 64,944 per user per year.

4. Conclusions

In this study, we analyzed the long-term effects of telecare use, and found that it reduces days of treatment

and medical expenditure for patients with chronic diseases by 4.2 days and JPY 64,944 per user per year, respectively. Table 11 summarizes the results from our previous study of the five-year period between 2002 and 2006 [1], [2], and [3]. The results obtained in the current study are larger than those reported previously, which means that telecare use produces both long-term and short-term effects. Therefore, the longer patients use telecare, the larger the reductions in days of treatment and medical expenditure

Table 8. Result of system GMM (2): Medical expenditure (outpatients, all diseases).

	Coeff.	SD	*t* value	*p* value	
Telecare use	–10690	5232	–2.04	0.041	**
Age	134.5	30.2	4.46	0.000	***
Income	–5.82	7.61	–0.76	0.444	
Heart disease	31937	10054	3.18	0.001	***
Hypertension	17968	2279	7.89	0.000	***
Diabetes	13426	6352	2.11	0.035	**
Stroke	–20273	13780	–1.47	0.141	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.005	
Test of weak instruments (*p* value)				< 0.010	
Hansen test for over-identifying restrictions (*p* value)				0.563	

Note: ***, **, * indicate significance of 1%, 5%, 10%.

Table 9. Result of system GMM (3): Days of treatment (outpatients, chronic diseases).

	Coeff.	SD	*t* value	*p* value	
Telecare use	–4.22	1.96	–2.16	0.031	**
Age	0.05	0.01	4.50	0.000	***
Income	0.00	0.00	0.47	0.637	
Heart disease	1.76	3.87	0.45	0.649	
Hypertension	9.06	1.11	8.16	0.000	***
Diabetes	3.37	2.47	1.36	0.173	
Stroke	–3.86	4.62	–0.83	0.404	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.415	
Test of weak instruments (*p* value)				< 0.01	
Hansen test for over-identifying restrictions (*p* value)				0.231	

Note: ***, **, * indicate significance of 1%, 5%, 10%.

The results obtained in this study show the importance telemedicine. Japanese local governments implementing this system currently do not charge users to use the service; instead, they use tax money raised from local residents. For the initial investment for the in-home devices, servers, and network, local governments receive subsidies from the central government; in Nishi-aizu, the local government received funds from three different ministries. However, due to the current poor economic situation in Japan, local governments can no longer rely on such subsidies, which means that the sustainability of telecare or e-Health is an issue that urgently needs to be addressed [8]. From a financial point of view, a new framework is required. Reimbursement through the medical insurance system, for example, is one possibility for increasing the use of telecare systems. Here, we provide an important basis for evidence-based public health policies. The analyses conducted in this study provide a theoretical foundation for government policy-making as well as for designing business models for the implementation of e-Health.

Table 10. Result of system GMM (4): Medical expenditure (outpatients, chronic diseases).

	Coeff.	SD	*t* value	*p* value	
Telecare use	–6494	3216	–2.02	0.043	**
Age	70.83	19.37	3.66	0.000	***
Income	–3.11	8.25	–0.38	0.707	
Heart disease	6885	4904	1.40	0.160	
Hypertension	9715	1467	6.62	0.000	***
Diabetes	5606	4453	1.26	0.208	
Stroke	–6857	6448	–1.06	0.288	
Number of observations				1820	
Arellano–Bond test for AR (2) (*p* value)				0.165	
Test of weak instruments (*p* value)				< 0.01	
Hansen test for over-identifying restrictions (*p* value)				0.692	

Note: ***, **, and * indicate significance of 1%, 5%, and 10%. .

Table 11. Previous results on five-year data.

	OLS[1]	System GMM[2]	PSM[3]
Medical expenditure	JPY 15,302 (US$ 191.28)	-	JPY 25,538–39,936 (US$ 319.23–499.20)
Days of treatment	1.6 days	2.0 days	2.6–4.0 days

Note: [1]Akematsu and Tsuji (2009), [2]Minetaki, Akematsu, and Tsuji (2011), [3]Akematsu and Tsuji (2012).

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