Service for Decreasing Elderly Care Levels and Supply System*

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Abstract: We set a model with ordinary elderly care service and service to reduce elderly care levels and to ascertain how these supplies of services are determined. Our paper presents derivation by which, if two services are provided by different providers, then the supply of service to reduce the elderly care level is greater than for the case in which the services are provided by the same provider. Moreover, our paper presents derivation of the reward of services to reduce the elderly care level to minimize the total reward of elderly care services supported by government funding.

Keywords: aging population, elderly care demand, elderly care level, elderly care supply, government expenditure
JEL Classification: J14, J18

1. Introduction

In OECD countries, the ratios of elderly people to the total population are rising. Especially, the ratio of elderly people in Japan is the highest in the world. As a result, the total cost of elderly care is high and increasing. It has reached ten trillion JPY[1)]. The elderly care cost should be controlled because increased costs require increased taxes and premiums. Households can be adversely affected by the burdens of increased taxes and premiums.

In Japan, services intended to reduce the levels of elderly care are provided to decrease the total amount of elderly care which must be provided. The Japanese government aims to im-

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1) Ministry of Health, Labour and Welfare (MHLW, Japan), "Recent Situation in the Long-Term Care Insurance System (Kaigohokenseido wo Meguru Saikin no Doukou ni tsuite)," (in Japanese) Data are for 2018.

prove the level of care for elderly people while controlling the total costs of care services. Seon (2018) explains that some local governments provide incentive rewards for decreasing elderly care levels. By virtue of that benefit for prevention, the elderly care level is decreased. Moreover, elderly people can live independently without care. In fact, demand for elderly care services decreases. Total costs for elderly care can also be decreased.

Our paper presents an examination of whether services to reduce elderly care levels reduce the total elderly care cost, or not, using a model that includes elderly care services of two types: ordinary elderly care services and services to reduce elderly care levels. Results demonstrate that, if the reward of the service to reduce the elderly care level is small for these two services provided by different providers, the total elderly care cost (total reward of elderly care paid by the government) is lower than in a case in which these services are provided by the same provider. Moreover, we derive the rewards obtained from the services to reduce the elderly care level and to minimize the total elderly care cost.

Many reports of the related literature, such as those by Lundholm and Ohlsson (1998), Tabata (2005), Mizushima (2009), and Cremer and Roeder (2013) describe that a subsidy for elderly care services raises demand for such services. They derive the optimal subsidy level in terms of welfare. White-Means and Rubin (2004), Korn and Wrede (2013), Mou and Winer (2015), and Yasuoka (2019) examine elderly care of two types: formal care and informal care or family care. They also derive how these services' levels are determined. They examine substitution between the two types of elderly care. Yasuoka (2020) examines determination of the wage rate and the labor share in the elderly care service labor market.

As explained above, studies of many types have been reported. Nevertheless, few related papers describe how a service to reduce elderly care level decreases total elderly care costs. In Japan, reduction of the total elderly care cost is under consideration. The subject warrants examination for this study.

The remainder of this paper is arranged as follows. Section 2 sets the model. Section 3 presents examination of the case before separating services of two types. Section 4 elucidates the case after separating services of two types. Section 5 compares the results presented in sections 3 and 4. Section 6 discusses the model setting. The final section concludes this paper.

2. Model

This model economy includes elderly care services of two types: ordinary elderly care service (Service 1) and a service to reduce the elderly care level (Service 2).

This model economy includes low and high elderly care levels. The unit reward from the low and high elderly care levels are defined respectively as q^L and q^H, where $q^H > q^L$. This reward is set by the government.

Only elderly people need Service 2. The Service 2 provider can reduce the elderly care level from high to low with probability $p(e)$[2]. Therein, e denotes the input of the service to reduce the elderly care level. The cost function of Service 2 is assumed by $\frac{1}{2}\gamma e^2$, $(0<\gamma)$[3]. Probabili-

2) Concretely, we consider home support services, nutritional support, health checkups and promotion programs support (e.g., exercise intervention), and others as Service 2.

3) For simplicity, we assume a quadratic cost function. We can consider other cost function as γe^{ε}, $(1<\varepsilon)$. If the cost for

ty $p(e)$ is assumed as shown below.

$$p(e) = ae, \quad 0 < a \tag{1}$$

In that equation, $p(e)$ represents the share of the low elderly care level; $0 \leq p(e) \leq 1$ is assumed. Also, $p(e)$ stands for the probability of a lower level of care, and also denotes the share relative to the total number of people receiving care. If $p(e)$ increases by a unit, then the Service 2 provider can gain reward β, which the government sets.

3. Before Separating Service 1 and Service 2

In this case, we examine the case in which one provider provides Service 1 and Service 2. We define x as the quantity of supply of Service 1. The cost function of Service 1 is assumed by $\frac{1}{2}mx^2(0<m)$. Then, the profit function is presented below.

$$\pi = (p(e)q^L + (1-p(e))q^H)x - \frac{1}{2}mx^2 + p(e)\beta - \frac{1}{2}\gamma e^2 \tag{2}$$

In that equation, $(p(e)q^L + (1-p(e))q^H)x - \frac{1}{2}mx^2$ and $p(e)\beta - \frac{1}{2}\gamma e^2$ respectively represent the profits of Service 1 and Service 2. With maximization of profit function (2), one can obtain x as

$$x = \frac{1}{m}(p(e)q^L + (1-p(e))q^H). \tag{3}$$

In that equation, x depends on e. By substituting (3) into (2), one can obtain the following profit function:

$$\pi = \frac{1}{2m}(p(e)q^L + (1-p(e))q^H)^2 + p(e)\beta - \frac{1}{2}\gamma e^2. \tag{4}$$

With maximization of profit function (4), one obtains e as

$$e = \frac{a\beta - q^H(q^H - q^L)\frac{a}{m}}{\gamma - (q^H - q^L)^2\frac{a^2}{m}}. \tag{5}$$

4. After Separating Service 1 and Service 2

In this case, we consider the case in which Service 1 and Service 2 are made available by different providers. Then, the profit function of Service 1 can be shown as

$$\pi = (p(e)q^L + (1-p(e))q^H)x - \frac{1}{2}mx^2. \tag{6}$$

Optimal x is given as (3). The profit function of Service 2 can be presented as shown below.

$$\pi = p(e)\beta - \frac{1}{2}\gamma e^2 \tag{7}$$

Optimal e to maximize (7) can be represented as[4)]

Service 2 is large for any input, we can consider the case of large γ and ε.

$$e = \frac{a\beta}{\gamma}. \tag{8}$$

5. Comparison of Cases Before and After Separating Services

This section presents a comparison of the case before separating services and that after separating services. With (5) and (8), if the following inequality holds, then the service to reduce the elderly care level after separating services shown by (8) is greater than the service shown by (5).

$$\beta < \frac{\gamma q^H}{a^2(q^H - q^L)} \tag{9}$$

The following inequality holds. The supply of the service to reduce the elderly care level before separating services is greater than in the case after separating services.

$$\beta > \frac{\gamma q^H}{a^2(q^H - q^L)} \tag{10}$$

Generally, the total profit of Service 1 and Service 2 before separating services is greater than the case after separating services because the externality by which Service 2 negatively affects Service 1 exists. Also, the case before separating services considers the externality in profit maximization.

If e is given as (8), then the probability that the service can reduce the elderly care provided from a high level to low level is given as $p_1 \equiv p(e) = \frac{a^2}{\gamma}\beta$. The conditions to have $p_1 \leq 1$ can be expressed as shown below[5].

$$\beta \leq \gamma / a^2 \tag{11}$$

If reward β is given as shown in (11), then the following proposition can be established.

Proposition 1　With $\beta \leq \gamma/a^2$, the inequality (10) cannot hold.

Proof　We prove the proposition by contradiction. If β holds (10), then we would be able to obtain the following inequality.

$$\frac{\gamma q^H}{a^2(q^H - q^L)} < \beta \leq \gamma/a^2 \Rightarrow q^H + q^L < q^H \Leftrightarrow q^L < 0$$

However, this inequality contradicts $0 < q^L$[6]. (Q.E.D.)

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4) Because of $0 \leq p(e) \leq 1$, $0 \leq a \dfrac{a\beta - q^H(q^H - q^L)\frac{a}{m}}{\gamma - (q^H - q^L)^2 \frac{a^2}{m}} \leq 1$ and $0 \leq \dfrac{a^2\beta}{\gamma} \leq 1$ must hold.

5) (9) is given as $\frac{a}{\gamma}\beta > \dfrac{a\beta - q^H(q^H - q^L)\frac{a}{m}}{\gamma - (q^H - q^L)^2 \frac{a^2}{m}}$. The probability given as (8) can be expressed as $p_1 \equiv p(e) = \frac{a^2}{\gamma}\beta$.
Also, $\frac{a}{\gamma}\beta < \dfrac{a\beta - q^H(q^H - q^L)\frac{a}{m}}{\gamma - (q^H - q^L)^2 \frac{a^2}{m}}$ is given. The probability given as (5) can be shown as $p_2 \equiv p(e) = \dfrac{a^2\beta - q^H(q^H - q^L)\frac{a^2}{m}}{\gamma - (q^H - q^L)^2 \frac{a^2}{m}}$. Then one can verify that $p_2 < p_1$ and $0 \leq p_2 \leq 1$ hold.

Proposition 1 shows that it is necessary that β always hold (9). Then, the supply of services to reduce the elderly care level after separating services is greater than that before separating services: separating Service 1 and Service 2 is desirable to raise the supply of the service and to reduce the elderly care level. Then, because of (3), the ordinary elderly care service (Service 1) in the case after separating services is less than that before separating services.

Moreover, after separating services, the service to reduce the elderly care level (Service 2) can reduce the total reward for elderly care paid by the government. We define the total reward for elderly care paid by the government after separating services and that before separating services respectively as G_1 and G_2. If $p(e)$ is given, then the total reward for elderly care paid by the government $G(p(e))$ is

$$\begin{aligned} G(p(e)) &= \frac{1}{m}(q^H - p(e)(q^H - q^L))^2 + p(e)\beta \\ &= \frac{(q^H - q^L)^2}{m}\left\{(p(e) - b)^2 + \left(\frac{q^H}{q^H - q^L}\right)^2 - b^2\right\}, \end{aligned} \tag{12}$$

where $b \equiv \left(\frac{q^H}{q^H - q^L} - \frac{m\beta}{2(q^H - q^L)^2}\right)$. Defining $p_1 = \frac{a^2}{\gamma}\beta$ and $p_2 = \frac{a^2\beta - q^H(q^H - q^L)\frac{a^2}{m}}{\gamma - (q^H - q^L)^2\frac{a^2}{m}}$, one can obtain $G_1 = G(p_1)$ and $G_2 = G(p_2)$ because of (12). Then, because of $p_1 > p_2$ and (12), the following proposition can be established.

Proposition 2 If reward $\beta < \beta^*$, then one can obtain $G_1 < G_2$. If the reward $\beta > \beta^*$, then one can obtain $G_1 > G_2$. β^* is defined as shown below.

$$\beta^* \equiv \frac{2\frac{q^H}{q^H - q^L} + \frac{q^H(q^H - q^L)\frac{a^2}{m}}{\gamma - (q^H - q^L)^2\frac{a^2}{m}}}{2\frac{m}{2(q^H - q^L)^2} + \frac{a^2}{\gamma} + \frac{a^2}{\gamma - (q^H - q^L)^2\frac{a^2}{m}}}. \tag{13}$$

Proof $G(p(e))$ is a quadratic function of $p(e)$ and is a convex downward parabola. Therefore, the symmetry axis of this parabola is given as $p(e) = b$ and $p_1 > p_2$. The following can be obtained.

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6) Proposition 1 is generalized to nonlinear $p(e)$. One can assume that $p(e)$ is weakly increasing and not too convex, because $p'(e) \geq 0$ and $p''(e) < \frac{\gamma}{\beta}$. It is noteworthy that $p(e) \in [0,1]$ always holds. Equation (4) is maximized when

$$\frac{1}{m}(p(e)q^L + (1 - p(e))q^H)p'(e)(q^L - q^H) + p'(e)\beta - \gamma e = 0 \tag{a}$$

holds. Also, Equation (7) is maximized when

$$p'(e)\beta - \gamma e = 0 \tag{b}$$

holds. Because $\frac{1}{m}(p(e)q^L + (1 - p(e))q^H)p'(e)(q^L - q^H) < 0$ holds and $p'(e)\beta - \gamma e$ is decreasing with e, optimized e in equation (a) is always less than that in equation (b).

$$\begin{cases} \text{If } b > p_1, G_1 < G_2. \\ \text{If } p_2 < b < p_1 \text{ and } b > \dfrac{p_1+p_2}{2}, G_1 < G_2. \\ \text{If } p_2 < b < p_1 \text{ and } b < \dfrac{p_1+p_2}{2}, G_1 > G_2. \\ \text{If } b < p_2, G_1 > G_2. \end{cases} \Leftrightarrow \begin{cases} \text{If } b > \dfrac{p_1+p_2}{2}, G_1 < G_2. \\ \text{If } b < \dfrac{p_1+p_2}{2}, G_1 > G_2. \end{cases}$$

Because of this condition and simple calculation, we can obtain Proposition 2. (Q.E.D.)

The total profit of Service 1 and Service 2 before separating services is greater than the total profit after separating services. The supply of ordinary elderly care service x after separating services is smaller than the supply before separating services. The supply of service to reduce elderly care level e before separating services is less than the supply after separating services. These results are attributed to the externality[7]. As long as the firm considers the negative externality by which Service 2 decreases the profit of Service 1, the total profit is maximized at the case before separating services. Therefore, it is not good to separate services of two types.

However, if one considers the total reward of elderly care paid by the government, then the case after separating services is desirable. In Japan, slowing or decreasing the total reward of elderly care paid by the government is necessary. With $\beta<\beta^*$, the total reward of elderly care after separating services is less than in the case before separating services. A government seeking to reduce the total reward of elderly care should separate the services, depending on the value of β.

The total reward of elderly care services supported by the government after separating services can be represented as shown below.

$$H=(p(e)q^L+(1-p(e))q^H)x+p(e)\beta=\frac{\left(q^H-\dfrac{(q^H-q^L)a^2}{\gamma}\beta\right)^2}{m}+\frac{a^2\beta^2}{\gamma} \tag{14}$$

The value of β to minimize the total reward of elderly care service can be derived as $\beta=\dfrac{\gamma(q^H-q^L)q^H}{\gamma m+(q^H-q^L)^2a^2}$ because of $\dfrac{\partial H}{\partial \beta}=0$ [8]. An increase in m and a or a decrease in γ reduces β such that $\dfrac{\partial H}{\partial \beta}=0$ holds. An increase in m means an increase in cost for Service 1. An increase a raises the population share of low level of elderly care. If the population share of low level of elderly care is large, the larger level of β is inefficient in terms of a decrease in the population share of high level of elderly care. An increase in (q^H-q^L) does not always raise β such that $\dfrac{\partial H}{\partial \beta}=0$ holds[9]. If γ is large or m is small, then β to hold $\dfrac{\partial H}{\partial \beta}=0$ is large. That is, if the cost

7) Integration of each service sector internalizes the externality. The total profit of service sectors is maximized. However, even if the service sector is separated, then one can obtain the result that a decrease in the reward after separating service sector β makes e reach the level before separating the service sector.

8) If we consider the case of integrated service, we can obtain $\beta=\dfrac{(q^H-q^L)q^H\left(1+2\left(1+\dfrac{(q^H-q^L)^2a^2}{\gamma m-(q^H-q^L)^2a^2}\right)\right)}{2m\left(1+\dfrac{(q^H-q^L)^2a^2}{\gamma m-(q^H-q^L)^2a^2}\right)}$ as $\dfrac{\partial H}{\partial \beta}=0$.

of elderly care of Service 1 is small or that of Service 2 is large, then the subsidy for Service 2 can be efficient to cut the total reward of elderly care service.

6. Discussion

This section provides a precise description of the model setup and other details. For these analyses, production is determined so that "Price=Marginal Cost," as in a perfectly competitive market for the provision of care services. According to data from the Ministry of Health, Labour and Welfare (MHLW, Japan), "the average accruing source retained earnings per special care facility is approximately JPY 310 million and the average actual retained earnings per special care facility is approximately JPY 160 million," which means that profits are accrued and retained[10]. In reality, each provider maximizes its profit margin, given the official price of care fees set by the government. The remainder, which pays the salaries of care staff and other costs, is saved by the provider[11].

Because the price is set by the government, the price does not change depending on the supply of services in an oligopolistic market instead of a perfectly competitive one. Therefore, the profit maximization problem is solved in the same way as it is solved in a perfectly competitive market, with the price as a given.

Next, we consider whether it is better to provide care services by integrating sectors or separating them with regard to care service providers. As the analyses presented herein show, when care services are provided by sector-integrated providers, the supply of Service 2 that reduces the level of care required is smaller than that provided by sector-separated providers. The total cost of care (G or H) is higher. Therefore, the implication of the results of this paper is that separate provision is desirable in terms of reducing the total cost of elderly care paid by the government. However, as presented herein, the total cost of elderly care can be reduced even in a case with providers who integrate the sectors by setting the reward for Service 2 as β[12].

7. Conclusion

First, a model with elderly care services of two types is set: an ordinary elderly care service and a service to reduce the elderly care level. Then we examine determination of the supply of services of two types before and after separating the two services. Results show that the sup-

9) With differentiation of $\dfrac{\partial \dfrac{\gamma(q^H-q^L)q^H}{\gamma m+(q^H-q^L)^2a^2}}{\partial(q^H-q^L)}$, we can obtain $\dfrac{\gamma q^H(\gamma m-(q^H-q^L)^2a^2)}{(\gamma m+(q^H-q^L)^2a^2)^2}$.

10) Ministry of Health, Labour and Welfare (MHLW, Japan), "Retained Earnings in Special Care Homes (Tokubetsu Yogo Roujin Houmu no Naibu Ryuho ni tsuite (in Japanese))".

11) Because social welfare and medical corporations are not for-profit corporations, it could be considered as the quantity supplied under zero profit conditions rather than profit maximizing behavior, in which case the quantity supplied would be determined according to "Price =Average Cost." However, given that the actual data show profits and the resulting retained earnings, profit-maximizing behavior is considered for the analyses presented herein.

12) There exists a reward for the supply of services which reduces the care level, for instance, that of the Tokyo Metropolitan Government, Japan. Tokyo Metropolitan Government, "Improvement of Care and Promotion of Business (Youkaigodotou Kaizen Sokushin Jigyo (in Japanese))".

ply of services to reduce the elderly care level *after* separating services is greater than in the case *before* separating services. The ordinary elderly care service level is lower than in the case before separating services. The total profit of the two services *before* separating services is greater than that *after* separating services.

However, the total cost of elderly care services after separating services is less than in the case before separating services if the reward for a unit of service to reduce the elderly care level is smaller than a certain level. This result demonstrates that a government can control the total cost of elderly care services. Taken together, the results obtained from this study indicate that the government must set a reward system of elderly care services and must devote consideration to how elderly care services should be managed.

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