Article title: Technical Efficiency of Prevention Services for Functional Dependency in Japan's Public Long-term Care Insurance System: An Ecological Study

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Supplementary file 2. The Details of Stochastic Frontier Analysis With a True Fixed Effects Model

For technical efficiency estimation, we used stochastic frontier analysis because it accounts for random error and is more robust to variable changes and outliers than nonparametric data envelopment analysis.[26-29] However, technical efficiency estimation with stochastic frontier analysis is confounded by sample heterogeneity. Greene proposed the true fixed effects model (TFEM),[28,29] which can distinguish unobserved time-invariant heterogeneity from estimated technical efficiency. The TFEM assumes that technical efficiency varies over time without any time function, and therefore should better reflect the actual technical efficiency of insurers. Based on the results of the F-test in the pooled ordinary least squares model ($P < 0.001$) and the Hausman test ($P < 0.001$), a TFEM was selected to estimate technical efficiency in this study.

The conventional Cobb–Douglas production form was used, as shown in equation (1):

$$\ln Y_{it+1} = \alpha_i + \beta_1 \ln X_{it} + \beta_2 \ln Z_{it} + v_{it} - u_{it}, \qquad (1)$$

$$v_{it} \sim N\left[0, \sigma^2{}_v\right],\ u_{it} = \left|U_{it}\right|,\ U_{it} \sim N\left[0, \sigma^2{}_u\right].$$

Y, X, and Z are outcome, explanatory variables, and covariate factors, respectively. Long-term care insurance (LTCI) insurer is denoted by i, year is denoted by t, and the random error term is denoted by v_{it}. u_{it} is the inefficiency term, which is assumed to be half-normally distributed. α_i is the time-invariant insurer-specific fixed effect (heterogeneity), which may represent unobserved potential confounders that vary across local regions and is unlikely to change over the studied period (e.g., local culture and social norms regarding the family provision of informal long-term care and the substitutional use of formal long-term care). Y, X, and Z were naturally log-transformed. We assumed a 1-year time lag because changes in functional dependency status may occur within a year after preventive interventions.[35-38] The parameters were estimated using the maximum likelihood method. The efficiency score was estimated as $\exp[-E(u_{it}|v_{it} - u_{it})]$ based on the estimator proposed by Jondrow et al.[39,40] We used the "sfpanel" command with the "model (tfe)" option in Stata 16.0 (StataCorp, College Station, TX, USA).

In health economics, production function is classified into two categories: production function of *health care* and production function of *health*. The former produces health care services with inputs of labor and capital, and the latter produces health with inputs of health care services.[32-34] In this study, we used the production function of *health* because public LTCI insurers are expected to maximize the functional independency of older people with a limited amount of preventive services.

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