Evolutionary game analysis of building a sustainable intelligent elderly care service platform

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Appendix

Proof of Proposition 1

The stability analysis of the digital technology company's strategy indicates that when $y < \frac{\Delta C_d \beta - L_d - \alpha IQ\lambda\zeta + IQ\lambda(\alpha-1)z}{R_d z + (\beta-1)\Delta C_d + IQ\lambda(1-\alpha\zeta-(1-\alpha)\zeta z)}$ and $z < z_1^*$, $x = 0$ represents the evolutionary equilibrium strategy. When $y > \frac{\Delta C_d \beta - L_d - \alpha IQ\lambda\zeta + IQ\lambda(\alpha-1)z}{R_d z + (\beta-1)\Delta C_d + IQ\lambda(1-\alpha\zeta-(1-\alpha)\zeta z)}$ and $z > z_1^*$, $x = 1$ becomes the evolutionary equilibrium strategy. Thus, as the probabilities y and z increase, the stable strategy of the digital technology company evolves from $x = 0$ (non-participation in value co-creation) to $x = 1$ (participation in value co-creation). □

Proof of Proposition 2:

Keeping other parameters constant and given $z_1^* = \frac{\Delta C_d((1-y)\beta + y) - L_d - IQ\lambda(\alpha\zeta(1-y)+y)}{R_d y + IQ\lambda\zeta(y-1)(\alpha-1)}$, it can be observed that as R_d, λIQ and L_d increase, z_1^* decreases. As shown in Figure 2, the cross-section shifts downward, leading to an increase in volume A_2, which in turn increases the probability that the digital technology company will choose to participate in value co-creation. Conversely, as ΔC_d and β increase, z_1^* also increases, causing the cross-section to shift upward, resulting in a decrease in volume A_2. Therefore, the probability of the digital technology company choosing not to participate increase. □

Proof of Proposition 3:

The first derivative of $H(z)$ with respect to z is obtained as

$$\frac{\partial H(z)}{\partial z} = IQ\zeta(1-\alpha) + \left(\left(IQ(1-\lambda) - IQ\right)(1-\alpha)\zeta - R_s\right)x$$

(1) When $\left(IQ(1-\lambda) - IQ\right)(1-\alpha)\zeta - R_s > 0$, we can derive $\frac{\partial H(z)}{\partial z} > 0$.

(2) When $\left(IQ(1-\lambda) - IQ\right)(1-\alpha)\zeta - R_s < 0$:

- If $\frac{R_s}{(1-\lambda)(1-\alpha)\zeta} < IQ$, it can be deduced that $\frac{IQ\zeta(1-\alpha)}{IQ(1-\alpha)\zeta + R_s - IQ(1-\lambda)(1-\alpha)\zeta} > 1 > x$ and $\frac{\partial H(z)}{\partial z} = IQ\zeta(1-\alpha) + \left(\left(IQ(1-\lambda) - IQ\right)(1-\alpha)\zeta - R_s\right)x > 0$;

- If $\frac{R_s}{(1-\lambda)(1-\alpha)\zeta} > IQ$ and $\frac{IQ\zeta(1-\alpha)}{IQ(1-\alpha)\zeta + R_s - IQ(1-\lambda)(1-\alpha)\zeta} > x$, we obtain $\frac{\partial H(z)}{\partial z} > 0$; If $\frac{R_s}{(1-\lambda)(1-\alpha)\zeta} > IQ$ and $\frac{IQ\zeta(1-\alpha)}{IQ(1-\alpha)\zeta + R_s - IQ(1-\lambda)(1-\alpha)\zeta} < x$, we derive $\frac{\partial H(z)}{\partial z} < 0$.

Summarizing the above, it can be concluded that when $R_s > IQ(1-\lambda)(1-\alpha)\zeta$ and $x > x_1^* = \frac{IQ\zeta(1-\alpha)}{IQ(1-\alpha)\zeta + R_s - IQ(1-\lambda)(1-\alpha)\zeta}$ are met, $\frac{\partial H(z)}{\partial z} < 0$; otherwise, $\frac{\partial H(z)}{\partial z} > 0$. When $\frac{\partial H(z)}{\partial z} < 0$, the stable strategy of the social organization evolves from $y = 0$ (non-participation in value co-creation) to $y = 1$ (participation in value co-creation) as z increases. When $\frac{\partial H(z)}{\partial z} > 0$, the stable strategy of the social organization evolves from $y = 1$ to $y = 0$ as z increases. □

Proof of $\frac{\partial J(x)}{\partial x} < 0$:

It can be deduced $\frac{\partial J(x)}{\partial x} = \Delta R_{pL} - \Delta R_{pH} + (\Delta R_p - \Delta R_{pL})y$. Because $\frac{\Delta R_{pH} - \Delta R_{pL}}{\Delta R_p - \Delta R_{pL}} > 1 > y$, we can obtain $y(\Delta R_p - \Delta R_{pL}) < \Delta R_{pH} - \Delta R_{pL}$. Then it is easy to have

$$\frac{\partial J(x)}{\partial x} = \Delta R_{pL} - \Delta R_{pH} + (\Delta R_p - \Delta R_{pL})y < 0$$ □

Proof of Proposition 4

The stability analysis of the digital technology company's strategy indicates that when $x < x^*$ and $y < \frac{-C_{pL} + C_{pH} - R_{pH} + R_{pL} - x(\Delta R_{pH} - \Delta R_{pL})}{(\Delta R_{pL} - \Delta R_p)x + \Delta R_p + G_p - C_p}$, $z = 0$ represents the evolutionary equilibrium strategy. Otherwise, $z = 1$ represents the evolutionary equilibrium strategy. Therefore, the stable strategy of the service provider evolves from $z = 0$ (non-participation in value co-creation) to $z = 1$ (participation in value co-creation) as the probabilities x and y increase. □

Proof of Proposition 5

Keeping other parameters constant and given $x^* = \frac{-C_{pL} + C_{pH} - R_{pH} + R_{pL} - (\Delta R_p + G_p - C_p)y}{\Delta R_{pH} - \Delta R_{pL} + (\Delta R_{pL} - \Delta R_p)y}$, it can be derived that x^* decreases as $R_{pH} - R_{pL}$, $\Delta R_{pH} - \Delta R_{pL}$ and G_p increase. As observed from Figure 4, the cross-section moves toward the origin, resulting in an increase in volume of C_2, which increases the probability that the service provider will choose to participate in value co-creation. When $C_{pH} - C_{pL}$ and C_p increase, x^* and the volume of C_1 increase, leading to a higher probability of the service provider choosing not to participate. □