Supplementary Material

By investigating 30 firms of a kind of a plastic product in Hebei Province of China, including 10 manufacturers, 10 retailers and 10 3PL firms, the corresponding values were obtained, i.e., $c_M = 4$, $c_L = 2$, $c_R = 3$, $p = 40$, $\alpha = 100$, $\beta = 100$, $m = 25$, $\gamma = 50$, $\mu = 200$, $\sigma = \frac{100}{\sqrt{3}}$.

The corresponding decision values can be obtained by substituting the values in the paper into Eqs. (7), (8), (9) ,(10) and (11).The specific computer program of numerical analysis for Figures 2 to 6 with Maple is as follows:

For Fig. 2:

$$\pi_r := (p-(w+s+c_R))\cdot q - p\cdot\int_{-\infty}^{q}(q-y)\cdot\frac{1}{2\sqrt{3}\sigma}\,dy$$

$$\pi_m := (w-c_M)\cdot q$$

$$\pi_l := (s-c_L)\cdot q - m\cdot x^2$$

$$w := c_M + \frac{\left(4\cdot\beta\cdot m-\gamma^2\right)\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma)}$$

$$s := c_L + \frac{\left(p-2\cdot c_R-2\cdot c_M-2\cdot c_L\right)\cdot\beta\cdot\alpha\cdot m}{2\cdot\alpha\cdot m+2\cdot(4\cdot\beta\cdot m-\gamma^2)}$$

$$x := \frac{\alpha\cdot\gamma\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma)}$$

$$q := \frac{\alpha\cdot\beta\cdot m\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma}$$

$c_M := 4$

$c_R := 3$

$c_L := 2$

$p := 40$

$\mu := 200$

$unprotect('\gamma')$

$\gamma := 50$

$\alpha := 100$

$$\beta := 100$$

$$\sigma := \frac{100}{\sqrt{3}}$$

$$e1 := plot(\pi_m, m = 25..50, color = black, linestyle = 1):$$

$$e2 := plot(\pi_l, m = 25..50, color = black, linestyle = 2):$$

$$e3 := plot(\pi_r, m = 25..50, color = black, linestyle = 3):$$

$$plots[display](e1, e2, e3)$$

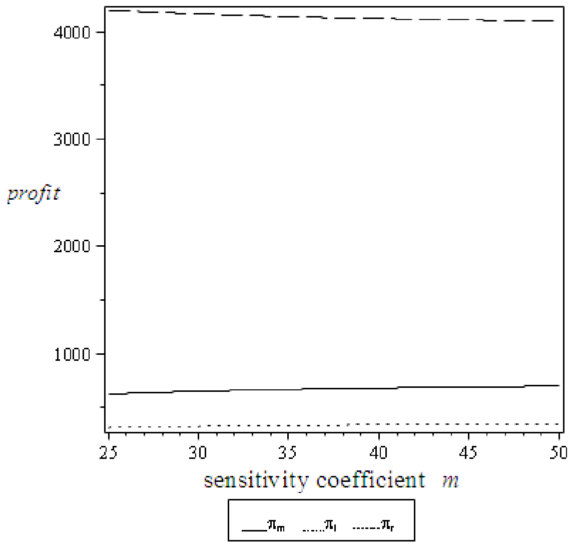

Fig. 2: The effect of the logistics investment cost on the supply chain members' profit

For Fig. 3:

$$\pi_r := (p - (w + s + c_R)) \cdot q - p \cdot \int_{-\infty}^{q} (q - y) \cdot \frac{1}{2\sqrt{3}\sigma} dy$$

$$\pi_m := (w - c_M) \cdot q$$

$$\pi_l := (s - c_L) \cdot q - m \cdot x^2$$

$$w := c_M + \frac{\left(4 \cdot \beta \cdot m - \gamma^2\right)\left(\sqrt{3} \cdot \mu \cdot p + 3 \cdot \left(p - 2(c_R + c_M + c_L)\right) \cdot \sigma\right)}{2(\alpha \cdot \beta \cdot m \cdot p\sqrt{3} + 6 \cdot \left(2 \cdot \alpha \cdot m + 4 \cdot \beta \cdot m - \gamma^2\right) \cdot \sigma)}$$

$$s := c_L + \frac{\left(p - 2 \cdot c_R - 2 \cdot c_M - 2 \cdot c_L\right) \cdot \beta \cdot \alpha \cdot m}{2 \cdot \alpha \cdot m + 2 \cdot (4 \cdot \beta \cdot m - \gamma^2)}$$

$$x := \frac{\alpha \cdot \gamma \cdot \left(\sqrt{3} \cdot \mu \cdot p + 3 \cdot \left(p - 2(c_R + c_M + c_L) \right) \cdot \sigma \right)}{2(\alpha \cdot \beta \cdot m \cdot p\sqrt{3} + 6 \cdot \left(2 \cdot \alpha \cdot m + 4 \cdot \beta \cdot m - \gamma^2 \right) \cdot \sigma)}$$

$$q := \frac{\alpha \cdot \beta \cdot m \cdot \left(\sqrt{3} \cdot \mu \cdot p + 3 \cdot \left(p - 2(c_R + c_M + c_L) \right) \cdot \sigma \right)}{\alpha \cdot \beta \cdot m \cdot p\sqrt{3} + 6 \cdot \left(2 \cdot \alpha \cdot m + 4 \cdot \beta \cdot m - \gamma^2 \right) \cdot \sigma}$$

$c_M := 4$

$c_R := 3$

$c_L := 2$

$p := 40$

$\mu := 200$

$unprotect('\gamma')$

$m := 25$

$\alpha := 100$

$$\sigma := \frac{100}{\sqrt{3}}$$

$\beta := 100$

$e1 := plot(\pi_m, \gamma = 50..75, color = black, linestyle = 1):$

$e2 := plot(\pi_l, \gamma = 50..75, color = black, linestyle = 2):$

$e3 := plot(\pi_r, \gamma = 50..75, color = black, linestyle = 3):$

$plots[display](e1, e2, e3)$

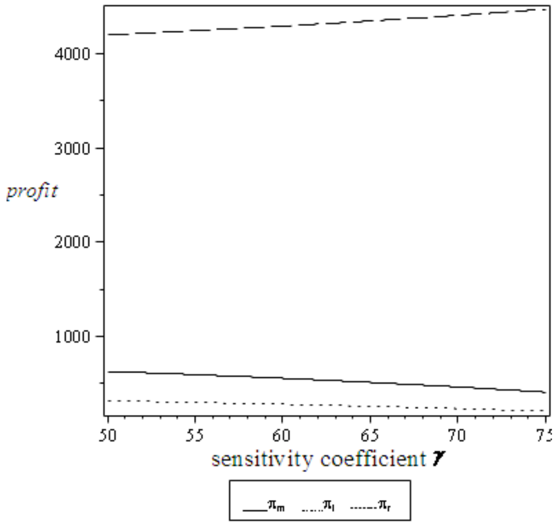

Fig. 3: The effect of the sensitivity coefficient of the order quantity to the logistics service level on the supply chain members' profit

For Fig. 4:

$$\pi_r := (p-(w+s+c_R))\cdot q - p\cdot\int_{-\infty}^{q}(q-y)\cdot\frac{1}{2\sqrt{3}\sigma}\,dy$$

$$\pi_m := (w-c_M)\cdot q$$

$$\pi_l := (s-c_L)\cdot q - m\cdot x^2$$

$$w := c_M + \frac{(4\cdot\beta\cdot m-\gamma^2)\left(\sqrt{3}\cdot\mu\cdot p+3\cdot(p-2(c_R+c_M+c_L))\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2)\cdot\sigma)}$$

$$s := c_L + \frac{(p-2\cdot c_R-2\cdot c_M-2\cdot c_L)\cdot\beta\cdot\alpha\cdot m}{2\cdot\alpha\cdot m+2\cdot(4\cdot\beta\cdot m-\gamma^2)}$$

$$x := \frac{\alpha\cdot\gamma\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot(p-2(c_R+c_M+c_L))\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2)\cdot\sigma)}$$

$$q := \frac{\alpha\cdot\beta\cdot m\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot(p-2(c_R+c_M+c_L))\cdot\sigma\right)}{\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2)\cdot\sigma}$$

$$c_M := 4$$

$$c_R := 3$$

$$c_L := 2$$

$$p := 40$$

$\mu := 200$

$\sigma := \frac{100}{\sqrt{3}}$

$unprotect('\gamma')$

$\gamma := 50$

$m := 25$

$\beta := 100$

$e1 := plot(\pi_m, \alpha = 100..150, color = black, linestyle = 1):$

$e2 := plot(\pi_l, \alpha = 100..150, color = black, linestyle = 2):$

$e3 := plot(\pi_r, \alpha = 100..150, color = black, linestyle = 3):$

$plots[display](e1, e2, e3)$

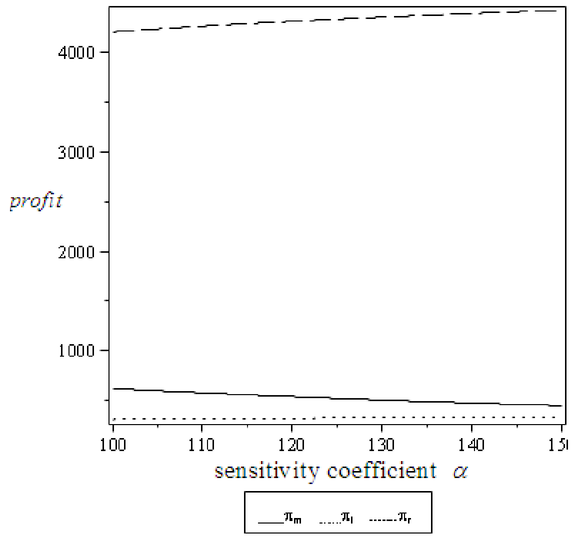

Fig. 4: The effect of the sensitivity coefficient of the order quantity to the wholesale price on the supply chain members' profit

For Fig. 5:

$\pi_r := (p-(w+s+c_R))\cdot q - p\cdot\int_{-\infty}^{q}(q-y)\cdot\frac{1}{2\sqrt{3}\sigma}\,dy$

$\pi_m := (w-c_M)\cdot q$

$\pi_l := (s-c_L)\cdot q - m\cdot x^2$

$$w := c_M + \frac{\left(4\cdot\beta\cdot m-\gamma^2\right)\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma)}$$

$$s := c_L + \frac{\left(p-2\cdot c_R-2\cdot c_M-2\cdot c_L\right)\cdot\beta\cdot\alpha\cdot m}{2\cdot\alpha\cdot m+2\cdot(4\cdot\beta\cdot m-\gamma^2)}$$

$$x := \frac{\alpha\cdot\gamma\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma)}$$

$$q := \frac{\alpha\cdot\beta\cdot m\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma}$$

$c_M := 4$

$c_R := 3$

$c_L := 2$

$p := 40$

$\mu := 200$

$$\sigma := \frac{100}{\sqrt{3}}$$

$unprotect('\gamma')$

$\gamma := 50$

$m := 25$

$\alpha := 100$

$e1 := plot(\pi_m, \beta = 100..150, color = black, linestyle = 1):$

$e2 := plot(\pi_l, \beta = 100..150, color = black, linestyle = 2):$

$e3 := plot(\pi_r, \beta = 100..150, color = black, linestyle = 3):$

$plots[display](e1, e2, e3)$

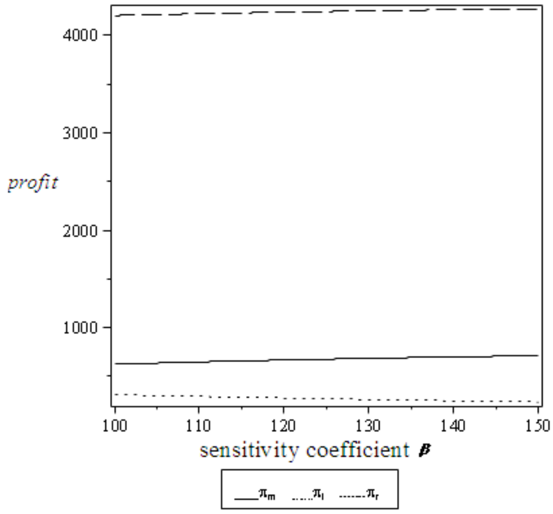

Fig. 5: The effect of the sensitivity coefficient of the order quantity to the logistics service price on the supply chain members' profits

For Fig. 6:

$$\pi_r := (p-(w+s+c_R))\cdot q - p\cdot\int_{-\infty}^{q}(q-y)\cdot\frac{1}{2\sqrt{3}\sigma}\,dy$$

$$\pi_m := (w-c_M)\cdot q$$

$$\pi_l := (s-c_L)\cdot q - m\cdot x^2$$

$$w := c_M + \frac{\left(4\cdot\beta\cdot m-\gamma^2\right)\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma)}$$

$$s := c_L + \frac{\left(p-2\cdot c_R-2\cdot c_M-2\cdot c_L\right)\cdot\beta\cdot\alpha\cdot m}{2\cdot\alpha\cdot m+2\cdot(4\cdot\beta\cdot m-\gamma^2)}$$

$$x := \frac{\alpha\cdot\gamma\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{2(\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma)}$$

$$q := \frac{\alpha\cdot\beta\cdot m\cdot\left(\sqrt{3}\cdot\mu\cdot p+3\cdot\left(p-2(c_R+c_M+c_L)\right)\cdot\sigma\right)}{\alpha\cdot\beta\cdot m\cdot p\sqrt{3}+6\cdot\left(2\cdot\alpha\cdot m+4\cdot\beta\cdot m-\gamma^2\right)\cdot\sigma}$$

$$c_M := 4$$

$$c_R := 3$$

$$c_L := 2$$

$$p := 40$$

$\mu := 200$

$\alpha := 100$

$unprotect('\gamma')$

$\gamma := 50$

$m := 25$

$\beta := 100$

$$e1 := plot(\pi_m, \sigma = \frac{100}{\sqrt{3}} .. \frac{200}{\sqrt{3}}, color = black, linestyle = 1):$$

$$e2 := plot(\pi_l, \sigma = \frac{100}{\sqrt{3}} .. \frac{200}{\sqrt{3}}, color = black, linestyle = 2):$$

$$e3 := plot(\pi_r, \sigma = \frac{100}{\sqrt{3}} .. \frac{200}{\sqrt{3}}, color = black, linestyle = 3):$$

$plots[display](e1, e2, e3)$

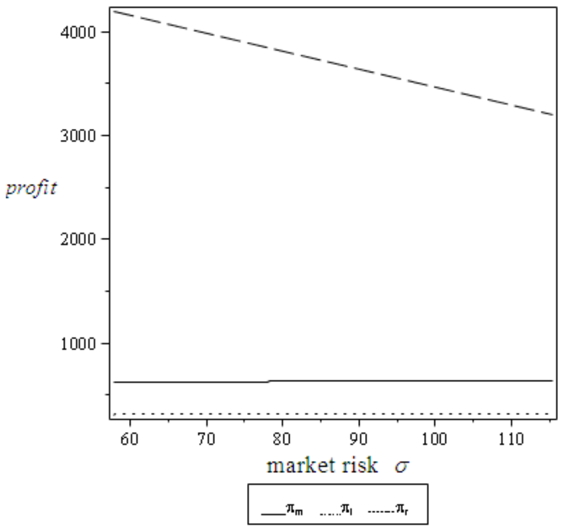

Fig. 6: The effect of the market risk parameter on the supply chain members' profits