

International R&D formations and strategic environmental policy

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ONLINE APPENDIX

Here, we show equilibrium values in model extension.

1 Equilibrium values in model extension

1.1 Case A: $p_i = 1 - q_{i1} - q_{i2}$, $i = 1, 2, 3$

In the case of RJV competition, we obtain the equilibrium values for $i, j = 1, 2$ as follows:

$$q_{ij}^{NJ} = q_{3j}^{NJ} = \frac{3(2\eta + 1)(2\gamma + \eta)}{9\gamma(2\eta^2 + 5\eta + 2) + \eta(13\eta + 9)}, \quad x_i^{NJ} = \frac{9\gamma(2\eta + 1) - 5\eta}{9\gamma(2\eta^2 + 5\eta + 2) + \eta(13\eta + 9)},$$

$$t_i^{NJ} = \frac{\eta(9\gamma(2\eta + 1) - 5\eta)}{9\gamma(2\eta^2 + 5\eta + 2) + \eta(13\eta + 9)},$$

$$\pi_i^{NJ} = \frac{3(18\gamma(6\eta^2 + 11\eta + 4)\eta + 9(9\eta + 8)(2\gamma\eta + \gamma)^2 + (72\eta^2 + 97\eta + 18)\eta^2)}{2(9\gamma(2\eta^2 + 5\eta + 2) + \eta(13\eta + 9))^2},$$

$$SW_i^{NJ} = \frac{\gamma(324\eta^3 + 1224\eta^2 + 1151\eta + 360)\eta + 9(27\eta + 40)(2\gamma\eta + \gamma)^2 + 5(36\eta^2 + 49\eta + 18)\eta^2}{2(9\gamma(2\eta^2 + 5\eta + 2) + \eta(13\eta + 9))^2},$$

$$GW^{NJ} = \frac{\gamma(324\eta^3 + 1512\eta^2 + 1439\eta + 432)\eta + 27(9\eta + 16)(2\gamma\eta + \gamma)^2 + (252\eta^2 + 317\eta + 108)\eta^2}{(9\gamma(2\eta^2 + 5\eta + 2) + \eta(13\eta + 9))^2}.$$

In the case of RJV cartels, we obtain the equilibrium values for $i, j = 1, 2$ as follows:

$$q_{ij}^{CJ} = q_{3j}^{CJ} = \frac{6(\eta + 1)(4\gamma + \eta)}{18\gamma(\eta^2 + 5\eta + 4) + \eta(13\eta + 18)}, \quad x_i^{CJ} = \frac{36\gamma(\eta + 1) - 10\eta}{18\gamma(\eta^2 + 5\eta + 4) + \eta(13\eta + 18)},$$

$$t_i^{CJ} = \frac{\eta(18\gamma(\eta + 1) - 5\eta)}{18\gamma(\eta^2 + 5\eta + 4) + \eta(13\eta + 18)},$$

$$\pi_i^{CJ} = \frac{216\gamma^2(\eta + 1)^2(3\eta + 8) + 72\gamma(7\eta^2 + 19\eta + 12)\eta + 2(54\eta^2 + 133\eta + 54)\eta^2}{(18\gamma(\eta^2 + 5\eta + 4) + \eta(13\eta + 18))^2},$$

$$SW_i^{CJ} = \frac{2(36\gamma^2(\eta+1)^2(9\eta+4) + \gamma(81\eta^3 + 702\eta^2 + 1241\eta + 720)\eta + 5(9\eta^2 + 22\eta + 18)\eta^2)}{(18\gamma(\eta^2 + 5\eta + 4) + \eta(13\eta + 18))^2},$$

$$GW^{CJ} = \frac{4(108\gamma^2(\eta+1)^2(3\eta+16) + \gamma(81\eta^3 + 846\eta^2 + 1529\eta + 864)\eta + (63\eta^2 + 146\eta + 108)\eta^2)}{(18\gamma(\eta^2 + 5\eta + 4) + \eta(13\eta + 18))^2}.$$

1.2 Case B: $p_i = 1 - 4(q_{i1} + q_{i2})$, $i = 1, 2$, and $p_3 = 2 - 2(q_{31} + q_{32})$

In the case of RJV competition, we obtain the equilibrium values for $i, j = 1, 2$ as follows:

$$q_{ij}^{NJ} = \frac{\gamma(-2\eta^2 + 21\eta + 36) + \eta(13\eta + 18)}{12(\gamma(4\eta^2 + 30\eta + 36) + 9\eta(\eta + 2))}, \quad q_{3j}^{NJ} = \frac{\gamma(2\eta^2 + 51\eta + 72) + 2\eta(11\eta + 18)}{6(\gamma(4\eta^2 + 30\eta + 36) + 9\eta(\eta + 2))},$$

$$x_i^{NJ} = \frac{\gamma(6\eta + 9) - 4\eta}{\gamma(4\eta^2 + 30\eta + 36) + 9\eta(\eta + 2)}, \quad t_i^{NJ} = \frac{\eta(\gamma(6\eta + 9) - 4\eta)}{\gamma(4\eta^2 + 30\eta + 36) + 9\eta(\eta + 2)},$$

$$\pi_i^{NJ} = \frac{\gamma^2(2\eta + 3)^2(2\eta^2 + 267\eta + 720) + 18\gamma(2\eta^3 + 87\eta^2 + 366\eta + 360)\eta + (653\eta^2 + 2484\eta + 1620)\eta^2}{18(\gamma(4\eta^2 + 30\eta + 36) + 9\eta(\eta + 2))^2},$$

$$SW_i^{NJ} = \frac{12\gamma^2(2\eta + 3)^2(\eta^2 + 81\eta + 288) + \gamma(1231\eta^3 + 12144\eta^2 + 33732\eta + 31104)\eta + 24(67\eta^2 + 288\eta + 324)\eta^2}{72(\gamma(4\eta^2 + 30\eta + 36) + 9\eta(\eta + 2))^2},$$

$$GW^{NJ} = \frac{4\gamma^2(2\eta + 3)^2(4\eta^2 + 291\eta + 1440) + \gamma(1583\eta^3 + 21696\eta^2 + 61092\eta + 51840)\eta + 8(443\eta^2 + 1656\eta + 1620)\eta^2}{36(\gamma(4\eta^2 + 30\eta + 36) + 9\eta(\eta + 2))^2}.$$

In the case of RJV cartels, we obtain the equilibrium values for $i, j = 1, 2$ as follows:

$$q_{ij}^{CJ} = \frac{\eta(13\eta + 36) - 2\gamma(\eta^2 - 21\eta - 72)}{12(4\gamma(\eta^2 + 15\eta + 36) + 9\eta(\eta + 4))}, \quad q_{3j}^{CJ} = \frac{\gamma(\eta^2 + 51\eta + 144) + \eta(11\eta + 36)}{3(4\gamma(\eta^2 + 15\eta + 36) + 9\eta(\eta + 4))},$$

$$x_i^{CJ} = \frac{12\gamma(\eta + 3) - 8\eta}{4\gamma(\eta^2 + 15\eta + 36) + 9\eta(\eta + 4)}, \quad t_i^{CJ} = \frac{2\eta(3\gamma(\eta + 3) - 2\eta)}{4\gamma(\eta^2 + 15\eta + 36) + 9\eta(\eta + 4)},$$

$$\pi_i^{CJ} = \frac{8\gamma^2(\eta + 3)^2(\eta^2 + 186\eta + 1440) + 36\gamma(\eta^3 + 111\eta^2 + 804\eta + 1440)\eta + (653\eta^2 + 4680\eta + 6480)\eta^2}{18(4\gamma(\eta^2 + 15\eta + 36) + 9\eta(\eta + 4))^2},$$

$$SW_i^{CJ} = \frac{48\gamma^2(\eta+3)^2(\eta^2+108\eta+1152) + \gamma(1231\eta^3 + 27744\eta^2 + 145296\eta + 248832)\eta + 24(67\eta^2 + 528\eta + 1296)\eta^2}{72(4\gamma(\eta^2+15\eta+36) + 9\eta(\eta+4))^2},$$

$$GW^{CJ} = \frac{64\gamma^2(\eta+3)^2(\eta^2+105\eta+1440) + \gamma(1583\eta^3 + 46848\eta^2 + 254736\eta + 414720)\eta + 8(443\eta^2 + 3168\eta + 6480)\eta^2}{36(4\gamma(\eta^2+15\eta+36) + 9\eta(\eta+4))^2}.$$