Model and Analysis (10): Tables and Figures of each game's scenario

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Contents

1 Model overview

A segment of timeline:

Cropt profit or payoff player i gains from crop production:

$$\max \pi_i^C(t) = 1 - P_i(t+1) - \mathbf{1}_\phi c$$

wrt the pest dynamics as following:

$$P_i(t+1) - P_i(t) = \mathbf{1}_{Crop} g P_i(t)(1 - P_i(t)) - d(P_i(t) - P_j(t)) - \mathbf{1}_{\phi_i} \phi P_i(t) - \alpha P_i(t) N(t)$$

A payoff table for land-use decision in which each crop profit (π^C) depends on not only land-use decision (NCH or Crop) but also the pest density on the two adjacent properties:

$\frac{i\rightarrow}{j\downarrow}$	i: NCH	i: Cropland
j: NCH	π_j^{NCH}; π_i^{NCH}	π_j^{NCH}; π_i^{C}
j: Crop	π_j^{C}; π_i^{NCH}	π_j^{C}; π_i^{C}

2 Best response of individual in case of full information

Result 1 *Pesticide-use decision depends only on the local pest population.*

$$\text{If } P_i(T) \leq \frac{c}{\phi} \quad \text{then } \pi_i^{C}(T) \geq \pi_i^{CP}(T)$$

$$\text{If } P_i(T) \geq \frac{c}{\phi} \quad \text{then } \pi_i^{C}(T) \leq \pi_i^{CP}(T)$$

Discussion on the threshold $\frac{c}{\phi}$*:* one small paragraph, trade-off, constraint the value and the rationale.

2.1 "If the neighbor j follows NCH, what do "i" do?"

Figure 1: crop at almost pest density level and at every period.
Nash equilibria in this case for (i,j) are (Crop, NCH) and (Crop-Pesticide, NCH).

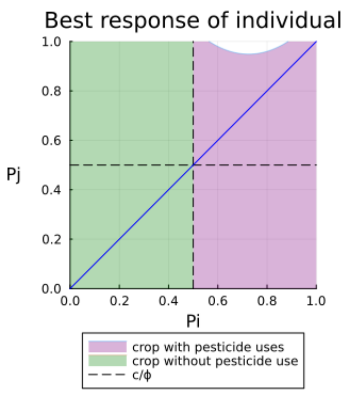

Figure 1: *
Best response of i when j does NCH

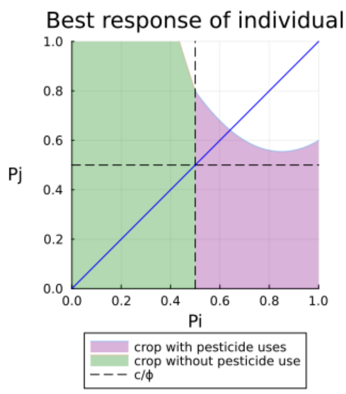

Figure 2: *
Best response of i when j does Cropland

2.2 "If neighbor j does cropland, what do i do?"

Figure 2 and Figure 3: in the scenario of no public goods, there will be NE: (i) (C,C) represents crop-crop for (i,j); (ii) (C,P) represents crop and crop-pesticides for (i,j) and vice versa for (P,C); (iii) A and B represents for NCH and Crop-Pesticides for (j,i) and (i,j), respectively. One undetermined region in which it is unclear who does either crop with pesticide or NCH.

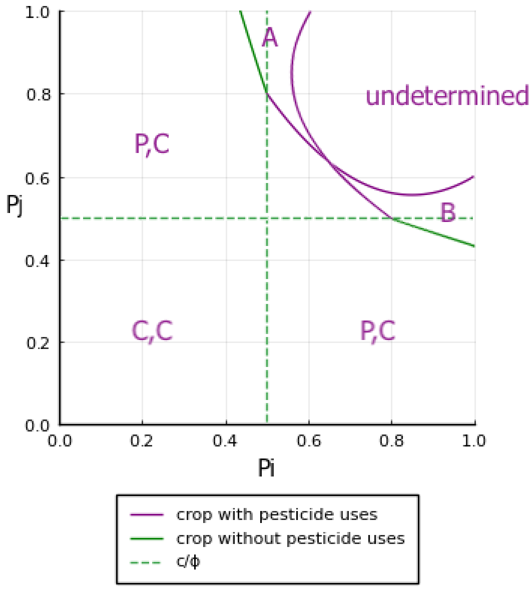

Figure 3: *
Strategic interaction between agents in case of full info and NO public goods

Result 2 *In the scenario of the public goods absence, subject to the level of pest density, Nash equilibria in this case for (i,j) are (Crop, Crop); (Crop-Pesticide, Crop); (Crop-Pesticides, NCH) is an undetermined who-do-what equilibrium as presented in Figure 3.*

Total benefit would be defined as the total payoffs of all farmers (players). We have the W, total benefit of the benchmark case, is given by:

$$W = \sum_{i=1,2} \pi_i = \pi_1 + \pi_2$$

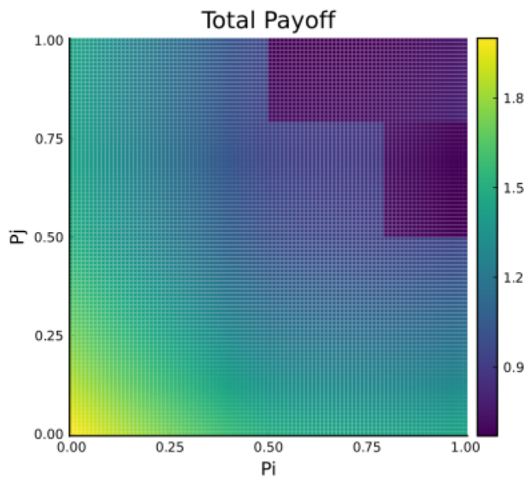

Figure 4: *
Total payoffs with full information

please CLICK to see code for total payoff, please note that the interval value of x and y in the corner of undetermined is defined by two inequalities.

3 Best response of individual in case of incomplete information...

3.1 ... on public goods

Pest dynamic of agent i *when* i *do not account for public goods existence*:

$$\tilde{P}_i(t+1) - P_i(t) = gP_i(t)(1-P_i(t)) - d(P_i(t) - P_j(t)) - \mathbf{1}_{\phi_i}\phi P_i(t)$$

Comparison between Cropland profit and NCH:

$$\pi_i^{NCH}(T) \leq \pi_i^C(T)$$
$$\iff \pi^{NCH} \leq 1 - \tilde{P}_i^C(T+1) - \mathbf{1}_{\phi_i} c$$
$$\iff P_j(T) \leq \frac{1}{d}\Big(1 - \pi^{NCH} - c\Big) - \frac{1}{d}\Big(1 + g - d - \phi\Big)P_i(T) + \frac{g}{d}P_i^2(T)$$

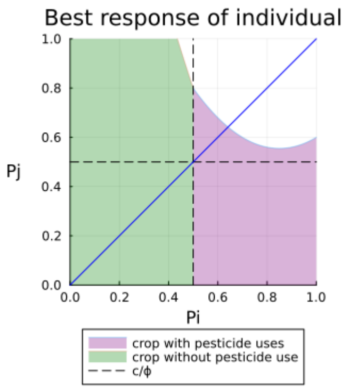

Figure 5: *
Incomplete info of public goods

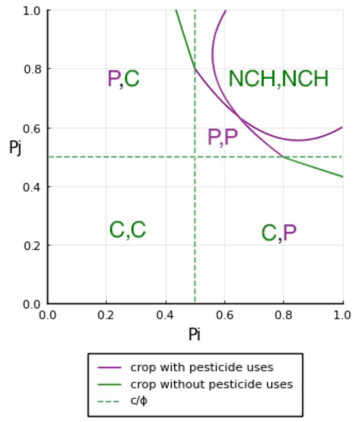

Figure 6: *
Strategic interactions in case of lacking info of public goods

The social loss is defined as the difference between the total payoff in the benchmark case and the total payoff in this incomplete info on public goods. The difference in the total payoff is given by:

$$\text{gap } = W^{\text{info}} - W^{\text{ overlook public goods}}$$

Social loss, defined as the difference between the total payoff in the benchmark case and the total payoff in this incomplete info on public goods and pest movement, is shown by:

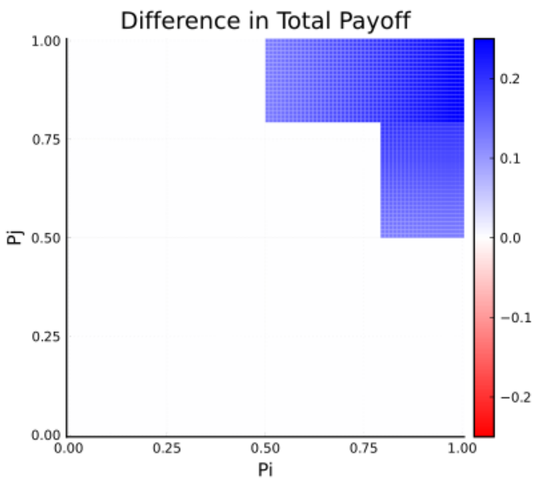

Figure 7: Gap due to knowledge/info gap on public goods

Neighbor j follows NCH, but agent i doesn't account for the positive effect of public goods, then i will lose the profitable opportunity to do crop production. Thus, it leads to inefficient outcome. We call the result is:

Result 3 *In the incomplete scenario of public goods, despite the existence of public goods, one anticipates to follow NCH and then it could lead to the Nash equilibrium is (NCH,NCH) and this outcome is not optimal.*

3.2 ... on public goods and local pest growth

Pest dynamic of agent i *when i do not account for public goods and local pest growth*:

$$P_i(t+1) - P_i(t) = -d(P_i(t) - P_j(t)) - \mathbf{1}_{\phi_i}\phi P_i(t)$$

Comparison between Cropland profit and NCH:

$$\pi_i^{NCH}(T) \leq \pi_i^{C}(T)$$

$$\iff \pi^{NCH} \leq 1 - \tilde{P}_i^{C}(T+1) - \mathbf{1}_{\phi_i} c$$

$$\iff P_j(T) \leq \frac{1}{d}\Big(1 - \pi^{NCH} - c\Big) - \frac{1}{d}\Big(1 - d - \phi\Big)P_i(T)$$

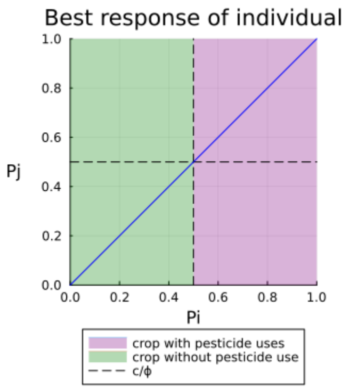

Figure 8: *
Incomplete info of pest growth

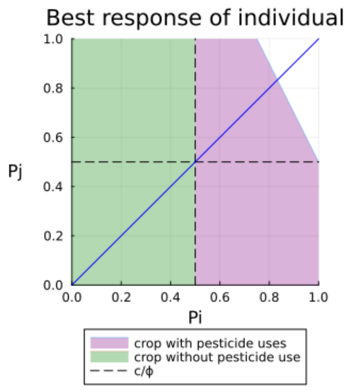

Figure 9: *
Incomplete info of pest growth and public goods

In the scenario of incomplete info on public goods and pest growth, even though there are less profitable ability from anticipation, but it contains larger ability to do cropland as agent doesn't account for the pest growth.

3.3 ... on public goods and pest dispersal rate:

Pest dynamic of agent i *when i do not account for public goods and pest disperal*:

$$\tilde{P}_i(t+1) - P_i(t) = gP_i(t)(1 - P_i(t)) - \mathbf{1}_{\phi_i}\phi P_i(t)$$

Comparison between Cropland profit and NCH:

$$\pi_i^{NCH}(T) \leq \pi_i^{CP}(T)$$

$$\iff \pi^{NCH} \leq 1 - \tilde{P}_i^{CP}(T+1) - c$$

$$\iff 0 \leq \Big(1 - \pi^{NCH} - c\Big) - \Big(1 + g - \phi\Big)P_i(T) + gP_i^2(T)$$

Consider the solution of this above inequality, we have conditions:

- $\Delta = (1+g-\phi)^2 - 4g(1-\pi^{NCH}-c) \geq 0$, we have the threshold pest density in which the crop profit is less than subsidy. In our benchmark case, under the particular benchmarck parameters, this condition is satisfied and represented by figure 9.
- $\Delta = (1+g-\phi)^2 - 4g(1-\pi^{NCH}-c) < 0$, it means that in the anticipation of agent, there is always profitable for crop production. In our benchmark case with particular parameters setup, this is not our consideration for this condition.

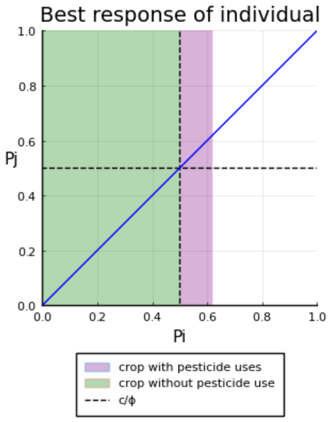

Figure 10: *
Incomplete info of pest spatial movement and public goods

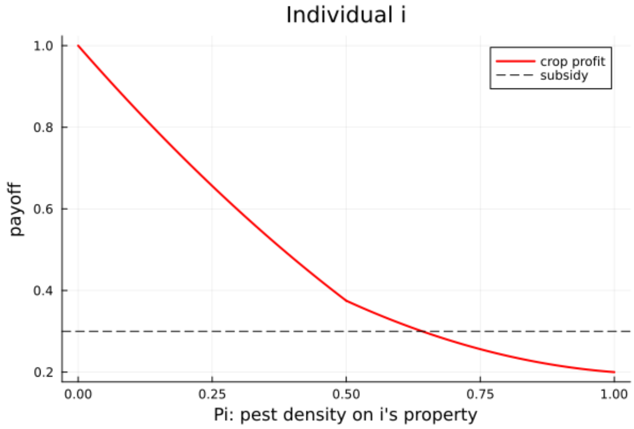

Figure 11: *
Payoff of individual i

3.4 ... on all ecological information and public goods existence

Pest dynamic of agent i *when i do not account for NCH, pest growth and dispersal*:

$$\tilde{P}_i(t+1) - P_i(t) = -\mathbf{1}_{\phi_i}\phi P_i(t)$$

Comparison of between Cropland profit and NCH:

$$\pi_i^{NCH}(T) \leq \pi_i^{CP}(T)$$

$$\Longleftrightarrow \pi^{NCH} \leq 1 - \tilde{P}_i^{CP}(T+1) - c$$

$$\Longleftrightarrow 0 \leq \Big(1 - \pi^{NCH} - c\Big) - \Big(1-\phi\Big)P_i(T)$$

$$\Longleftrightarrow P_i(T) \leq \frac{1-\pi^{NCH}-c}{1-\phi}$$

Result 4 *In the scenario of lacking all ecological information and public goods, ...*

figures on next page...

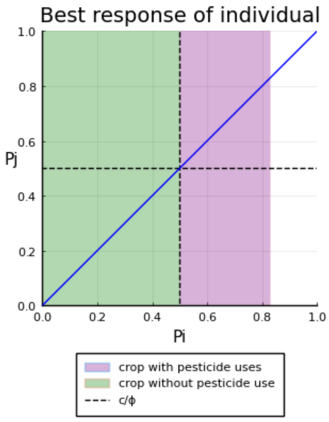

Figure 12: *
Incomplete info of all ecological info and public goods

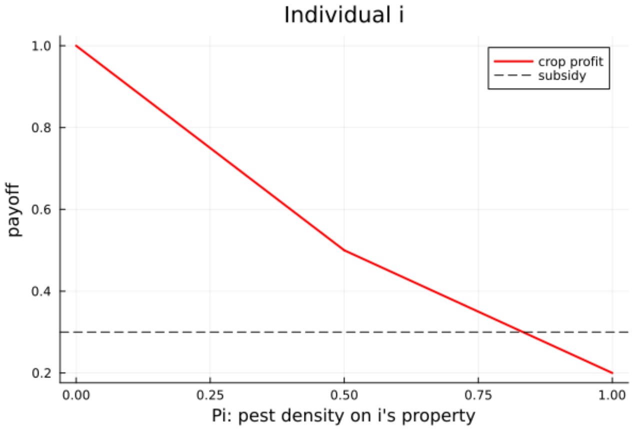

Figure 13: *
Payoff of individual i

The difference between the total payoff in the benchmark case and the total payoff in this incomplete all ecological info and public goods are shown in the following figure. The difference in the total payoff is given by:

$$\text{gap } = W^{\text{info}} - W^{\text{ no info}}$$

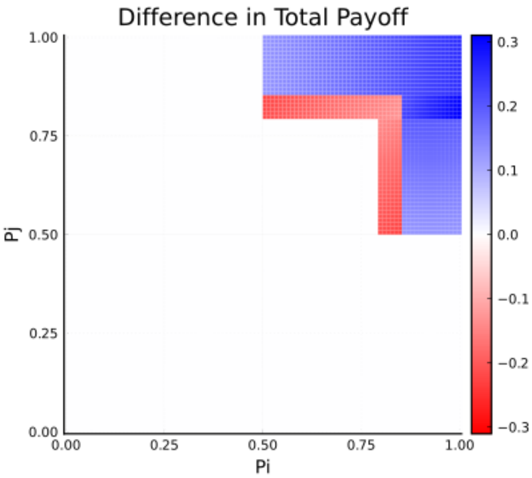

Figure 14: Gap due to knowledge gap on all ecological information and public goods

Remarkably, shows the negative in social loss. Comment: red for negative value in the social loss, as they ignore the important info of all ecological info on both local and the entire landscape level.

4 Sensitive Analysis

Objective of this section: How changing the parameters can affect the best response as well as NE of each scenario. One remark case is when less efficiency of pesticide use is (or c/ϕ close to 1), then the public goods and its efficiency play an important role in pest control and cropland.

- one (group of) figure with benchmark case where $c/\phi = 1/2$, ... as normal ... large growth less profitable ability for cropland
- one (group of) figure with $c/\phi = 1/5$ represents very efficient pesticides use, and the trade-off of cost-benefit is low (pay less but gain more benefit). In that case, one could do cropland at every pest density level (figure 17).
- one (group of) figure with $c/\phi = 2/3$ represents less efficient pesticides use, and the cost-benefit trade-off is high (pay more but gain less), profit of cropland is negative when pest density is closed to 1 (full invaded)

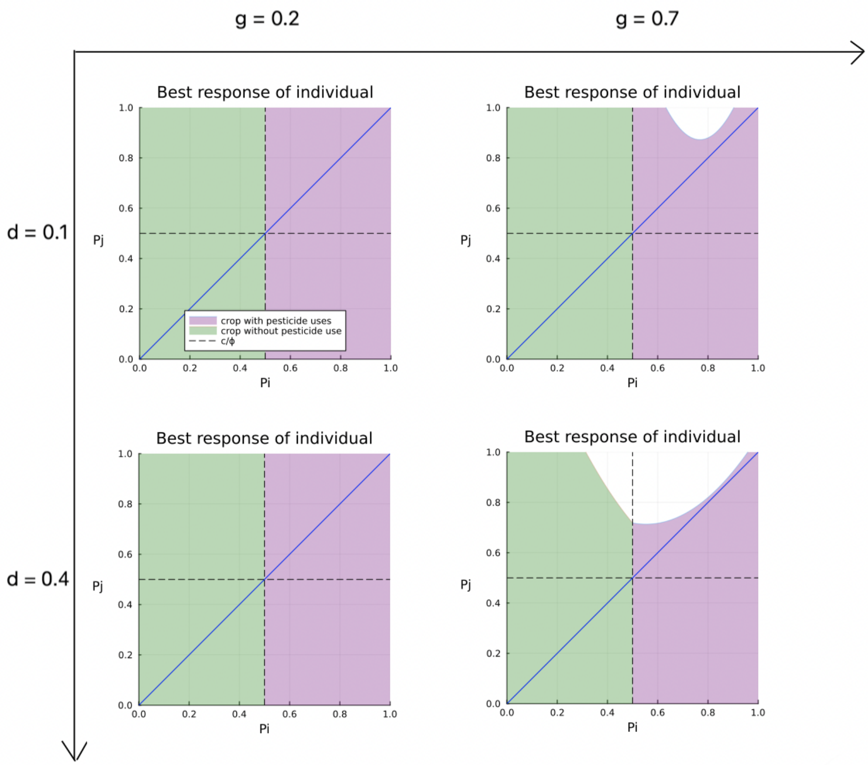

Figure 15: Sensitive analysis with threshold $\frac{c}{\phi} = \frac{1}{2}$

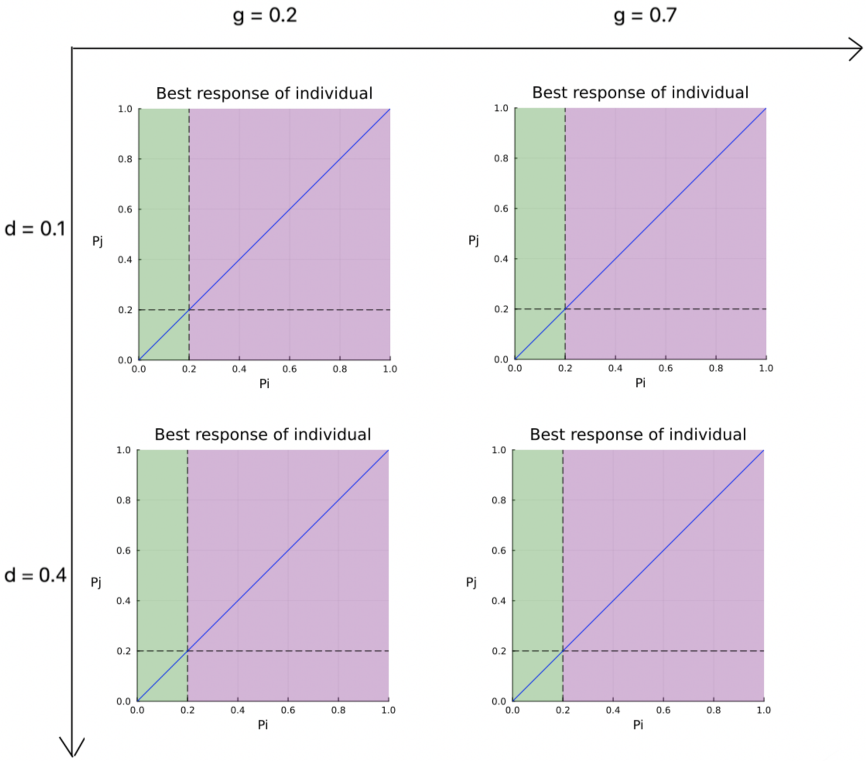

Figure 16: Sensitive analysis with threshold $\frac{c}{\phi} = \frac{1}{5}$

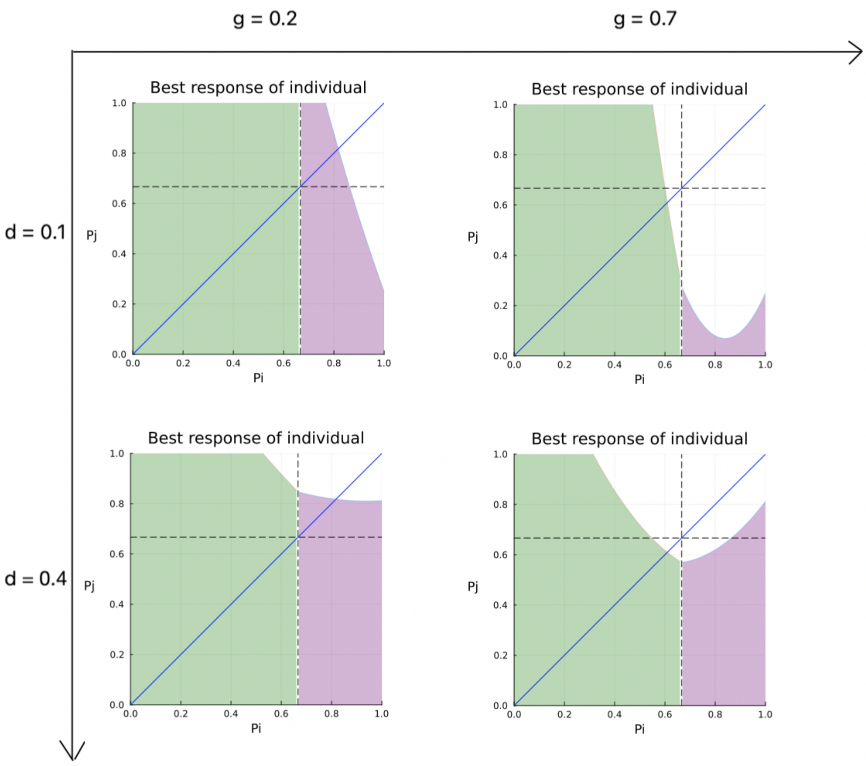

Figure 17: Sensitive analysis with threshold $\frac{c}{\phi} = \frac{2}{3}$