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Innovation incentives for electricity networks to enable grid edge transformation

Rahmat Poudineh

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Introduction

- The operating environment of electricity distribution networks is changing.
  - Distributed generation, electricity vehicles, interaction of end-users with the grid, active network management, smart grid and smart meters.
- Traditionally regulatory regime of network companies emphasised on cost reduction.
- To enable transformation of the electricity sector regulation needs to focus also on innovation
  - Innovation activities are not only costly but also risky.
  - How to incentivise firms to undertake efficient innovation given the costly and ***risky*** nature of this activity?

Incentive regulation and innovation

- Two further questions:
  - How to share costs and risks of innovation activity between customers and the firm?
  - What happens if both innovation and normal efficiency gain are treated similarly and incentivised through an output-led, ex ante price controls mechanism?
- When effort of the firm is unobservable and firm is risk averse, remuneration needs to be linked to performance.
- Lets consider the following linear contract mechanism

$$z = \beta + \alpha_1 x_1 + \alpha_2 x_2$$

  - Z: is the allowed revenue for the firm for its innovation and efficiency gain efforts
  - β is costs that are directly transferred to the consumers
  - x_1 is gain from its efficiency improvement
  - x_2 is gain of firm from its innovation effort

Incentive regulation and innovation (2)

$$z = \beta + \alpha_1 x_1 + \alpha_2 x_2$$

- $x_1 = e_1 + \varepsilon_1$ $\quad \varepsilon_1 \sim N(0, \sigma_1^2)$ normal efficiency gain
- $x_2 = e_2 + \varepsilon_2$ $\quad \varepsilon_2 \sim N(0, \sigma_2^2)$ innovation gain
- σ_{12} correlations of risks between two activities

- Firm preferences are represented by $u(z) = -\exp(-rz)$
- The cost of firm is: $c(e_1, e_2) = \frac{1}{2}\rho(e_1^2 + e_1^2) + \theta e_1 e_2$ where $|\theta| < \rho$

Incentive regulation and innovation (2)

- As there are two channels through which two activities (innovation and efficiency gain) can interact(risk and cost structure) four different possibilities exist:
  - The risk of two activities is independent
    - there is synergy between two tasks
    - there is no synergy between two tasks
  - The risk of two activities is correlated.
    - there is synergy between two tasks
    - there is no synergy between two tasks
- We solve the model and then :
  - plot the optimal share of firm from both outputs (innovation and normal efficiency) against variance of innovation.
  - plot the attention of firm (reflected in its effort) to two tasks (innovation and normal efficiency gain) when risk of innovation increases compared to normal efficiency gain.

The risk of two activities is uncorrelated-----there is synergy

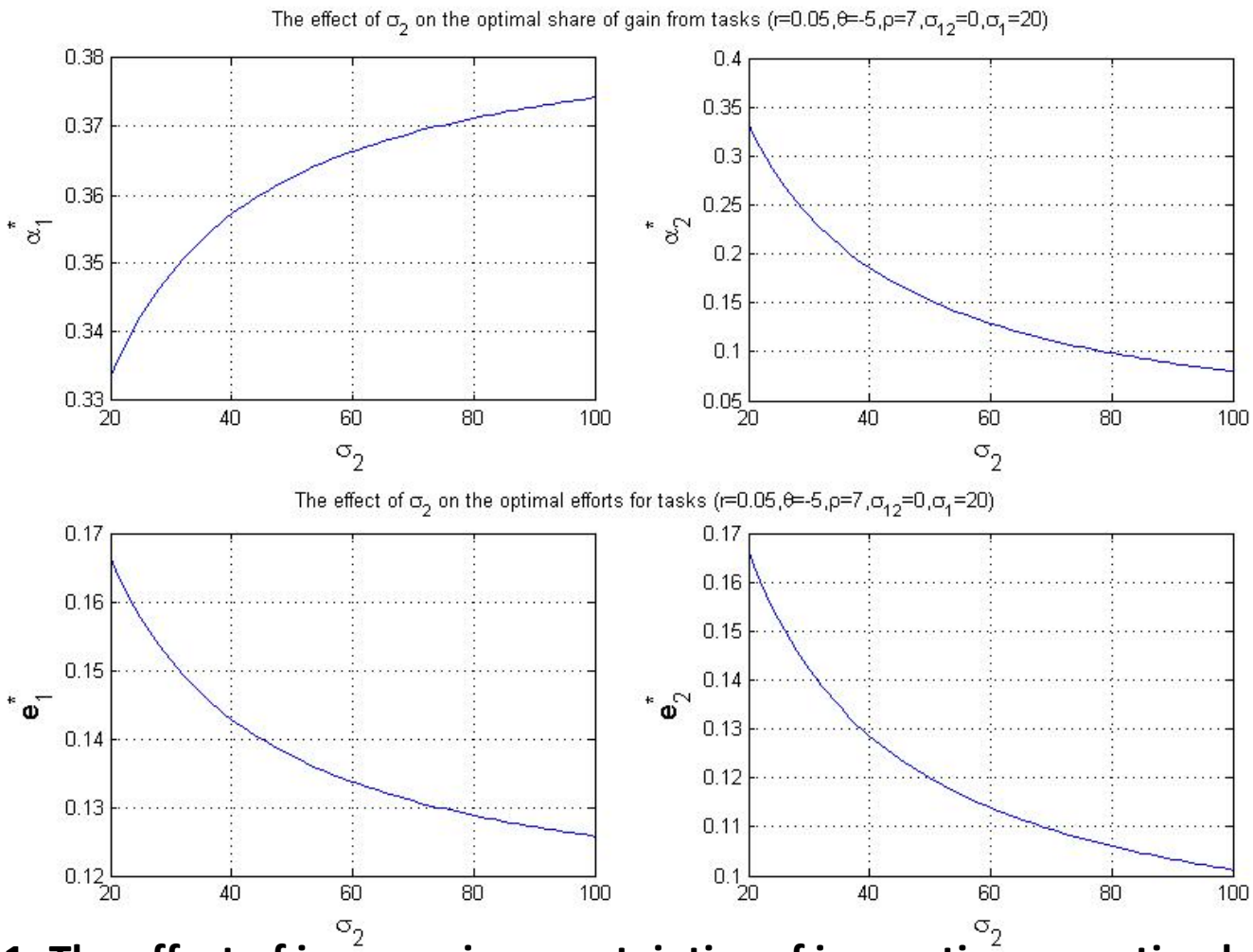

Figure 1: The effect of increase in uncertainties of innovation on optimal share of firm and its effort (when there is synergy between tasks-i.e., $\theta < 0$)

The risk of two activities is uncorrelated-----there is synergy (2)

- Optimum regulation:
  - Regulator needs to increase the reliance of efficiency incentive on the performance of firm
  - Regulator needs to reduce the reliance of the innovation incentive to outcome (transfer a higher share of costs to the consumer through fixed part).
- Effort of the firm
  - Given the assumption about risk correlation and synergy between two activities, an increase in risk of innovation reduces the optimal effort of firm on both activities.

The risk of two activities is uncorrelated -----there is no synergy

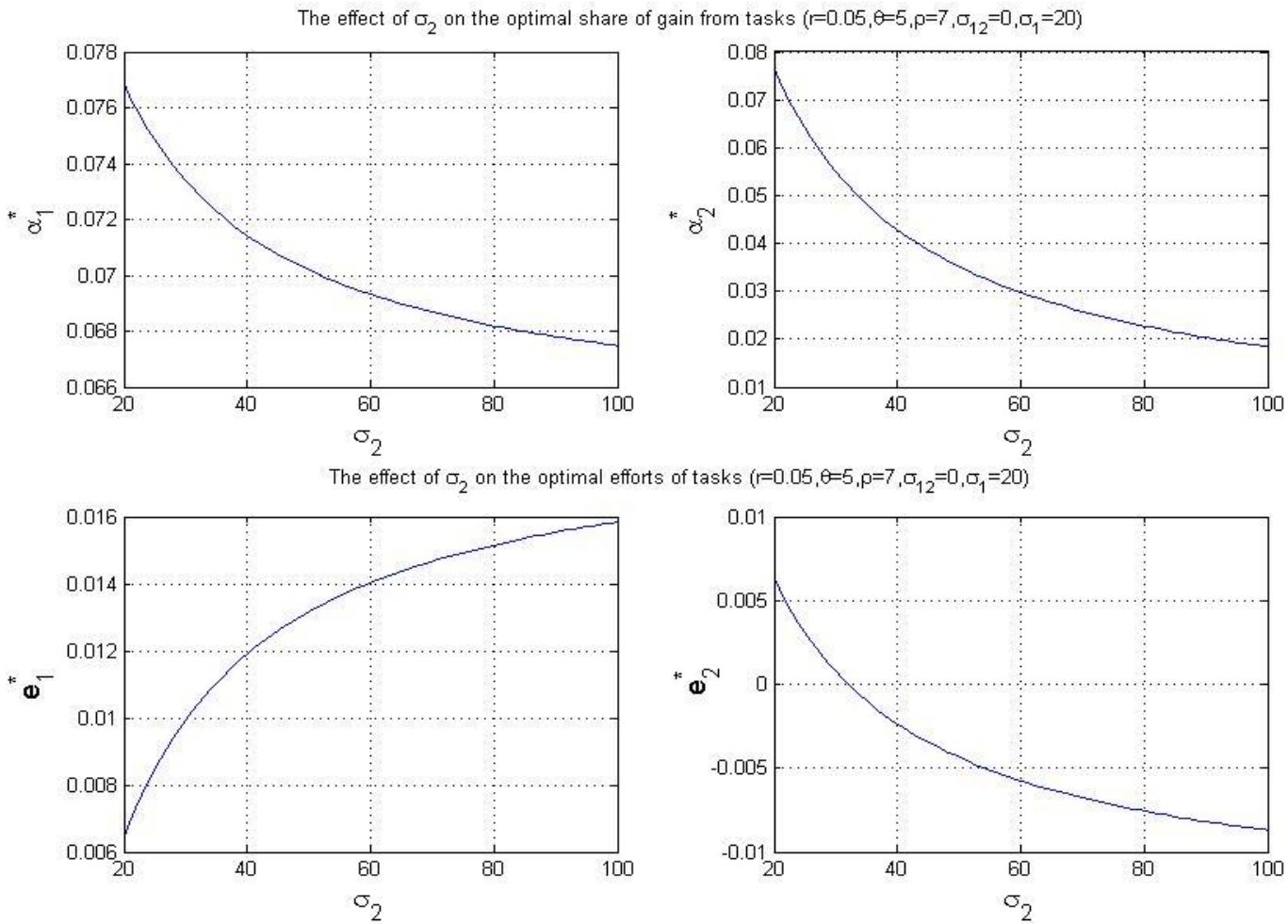

Figure 2: the effect of increase in uncertainties of innovation on the optimal share of firm and its effort (when there is no synergy between tasks-i.e., θ>0)

The risk of two activities is uncorrelated -----there is no synergy

- Optimum regulation:
  - Regulator needs to reduce the reliance of efficiency incentive to the performance
  - Regulator needs to reduce the reliance of the innovation incentive to outcome (transfer a higher share of costs to the consumer through fixed part).
- Effort of the firm
  - Given the assumption about risk correlation and lack of synergy between two activities, an increase in the risk of innovation activities diverts the attention of firm from innovation to normal efficiency gain.

The risk of two activities is correlated ----there is synergy

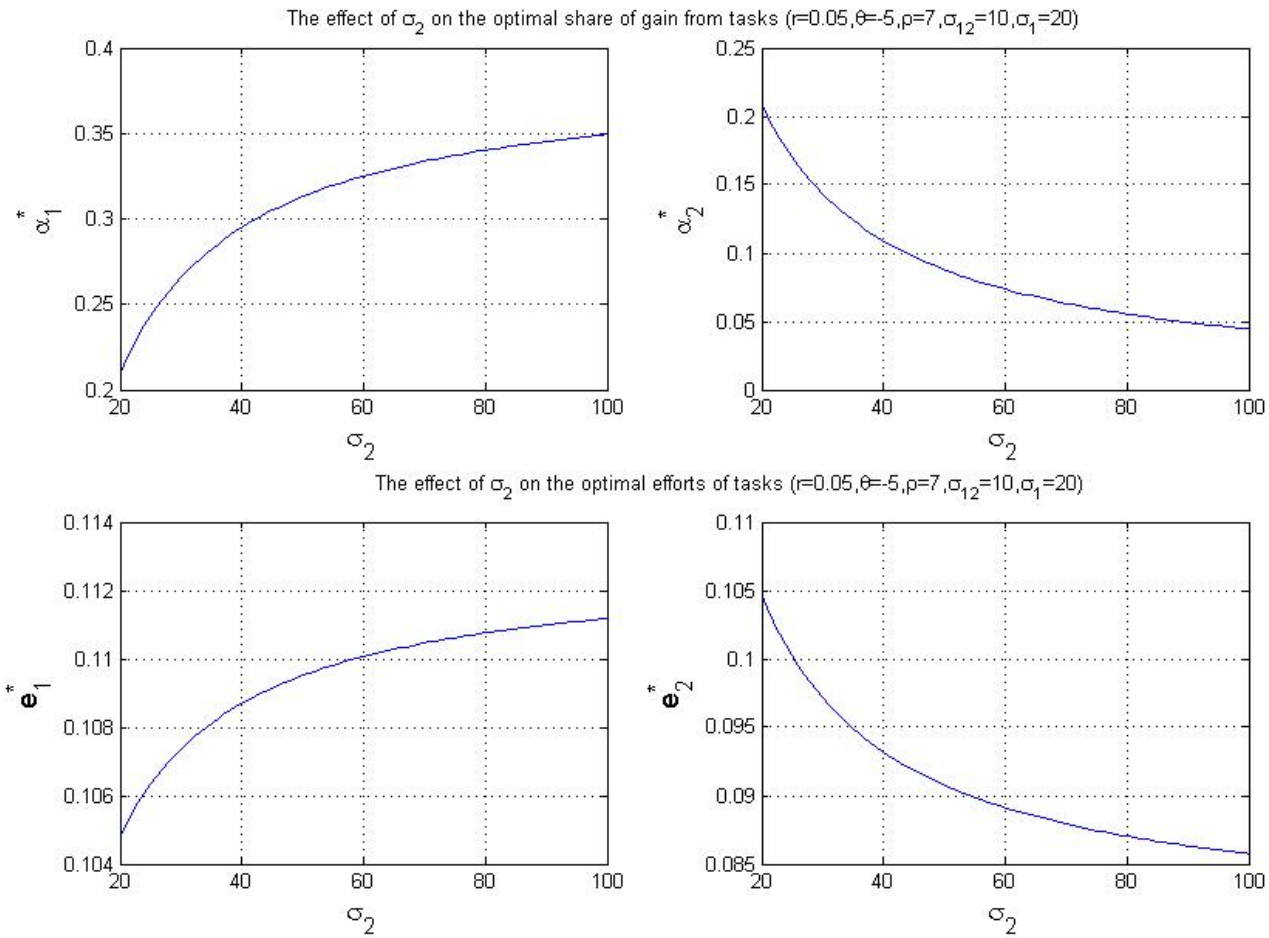

Figure 3: the effect of increase in uncertainties of innovation on the optimal share of firm and its effort (synergy between tasks)

The risk of two activities is correlated ----there is synergy (2)

- Optimum regulation:
  - Regulator needs to increase the reliance of efficiency incentive to the performance of firm
  - Regulator needs to reduce the reliance of the innovation incentive to the outcome (transfer a higher share of costs to the consumer through fixed part).
- Effort of the firm
  - Given the assumption about risk correlation and presence of synergy between two activities, an increase in the risk of innovation activities diverts the attention of firm from innovation to normal efficiency gain.

The risk of two activities is correlated ----there is no synergy

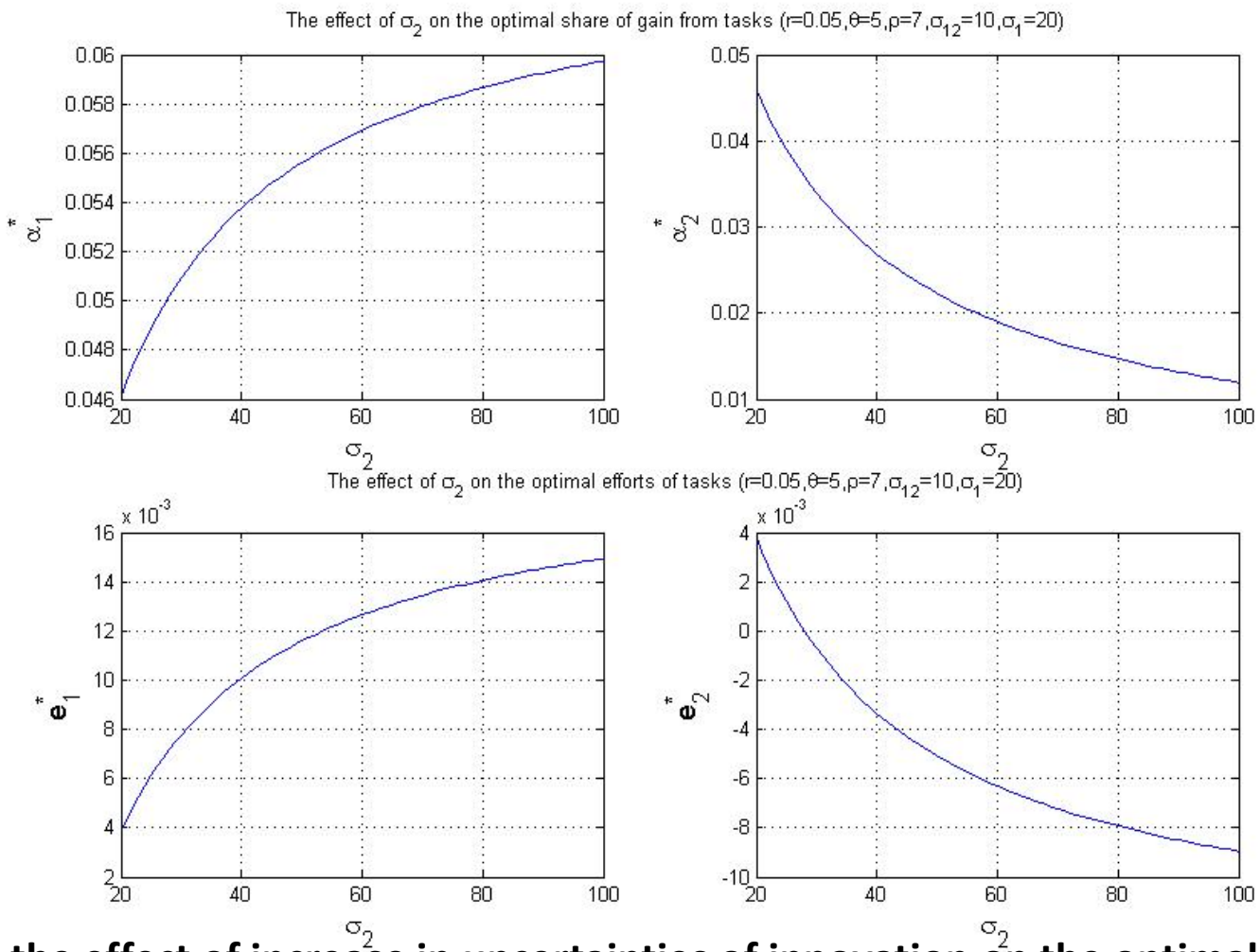

Figure 4: the effect of increase in uncertainties of innovation on the optimal share of firm and its effort (when there is no synergy between tasks-i.e., $\theta > 0$)

The risk of two activities is correlated ----there is no synergy

- Optimum regulation:
  - Regulator needs to increase the reliance of efficiency incentive to the performance of firm
  - Regulator needs to reduce the reliance of the innovation incentive to outcome (transfer a higher share of costs to the consumer through fixed part).
- Effort of the firm
  - Given the assumption about risk correlation and lack of synergy between two activities, an increase in the risk of innovation activities diverts the attention of firm from innovation to efficiency gain.

Conclusions

- In designing regulation, regulator must differentiate between normal efficiency gain and innovation - These two activities have different cost/risk profile
- Regulator should reduce the reliance of innovation cost to the outcome when they are risky (R&D and piloting)
- For those activities that are less risky (introduction of established technologies) remuneration can be linked to the performance.
- In an output-oriented performance based scheme, an increase in the risk of innovation activity either reduces the efforts of firms on both normal efficiency gain and innovation activity or diverts the attention of firm from innovation to normal efficiency gain.

Competitive innovation funds

- In recent years there has been a growing interest in competitive schemes in order to incentivise innovation.
- An example of regulatory model with such a scheme is the UK RIIO model.
- In this part we investigate whether competitive innovation fund is the silver bullet? (does it necessarily lead to the selection of project with highest potential value?)

Competitive innovation funds (2)

- Suppose two firms compete for innovatin fund w which will be allocated to the project with higher potential value (only one firm wins).
- The value of project is a linear function of firm's effort (e_i) and its characteristics (λ_i) (coefficient of value potential)

$$f_i(e_i) = \lambda_i e_i \quad i \in \{1,2\}$$

- The probability of being successful in the competition is

$$p_i = \frac{f_i(e_i)}{f_1(e_1)+f_2(e_2)} \quad i \in \{1,2\}$$

  - when $e_1 = e_2 = 0$ $p_i = \frac{\lambda_1}{\lambda_1+\lambda_2}$.

- Firm risk preference is: $u_i(z_i) = -\exp(-r_i z_i)$ where $z_i = I_i + w_i - e_i$
- I_i is the initial resource of the firm

Competitive innovation funds (3)

- This is a simultaneous game of complete information in the sense that each firm knows its own as well as its rival's characteristics. The firm exert effort in order to maximise its expected utility of gain from competition. Given above, player i expected utility:

$$E(u_i) = p_i u_i(I_i + w_i - e_i) + (1 - p_i) u_i(I_i - e_i)$$

$$E(u_i) = -[\frac{\lambda_i e_i}{\lambda_1 e_1 + \lambda_2 e_2} \exp\left(-r_i(I_i + w_i - e_i)\right) + \left(\frac{\lambda_i e_j}{\lambda_1 e_1 + \lambda_2 e_2}\right) \exp\left(-r_i(I_i - e_i)\right)]$$

- $i, j \in \{1,2\}$

- The first order condition for the firm would yield:

$$p_i' = \frac{r_i}{1 - e^{-r_i w}} (p_i e^{-r_i w} + 1 - p_i)$$

Competitive innovation funds (4)

- $\frac{p_2}{p_1} = \sqrt{\frac{\lambda_2 s(r_1)e^{-r_1 w}}{\lambda_1 s(r_2)e^{-r_2 w}} + \left(\frac{\lambda_1 s(r_2) - \lambda_2 s(r_1)}{2s(r_2)e^{-r_2 w}}\right)^2} - \left(\frac{\lambda_1 s(r_2) - \lambda_2 s(r_1)}{2\lambda_1 s(r_2)e^{-r_2 w}}\right)$

- where $s(r_i) = \frac{r_i}{1 - e^{-r_i w}}$

Competitive innovation funds (5)

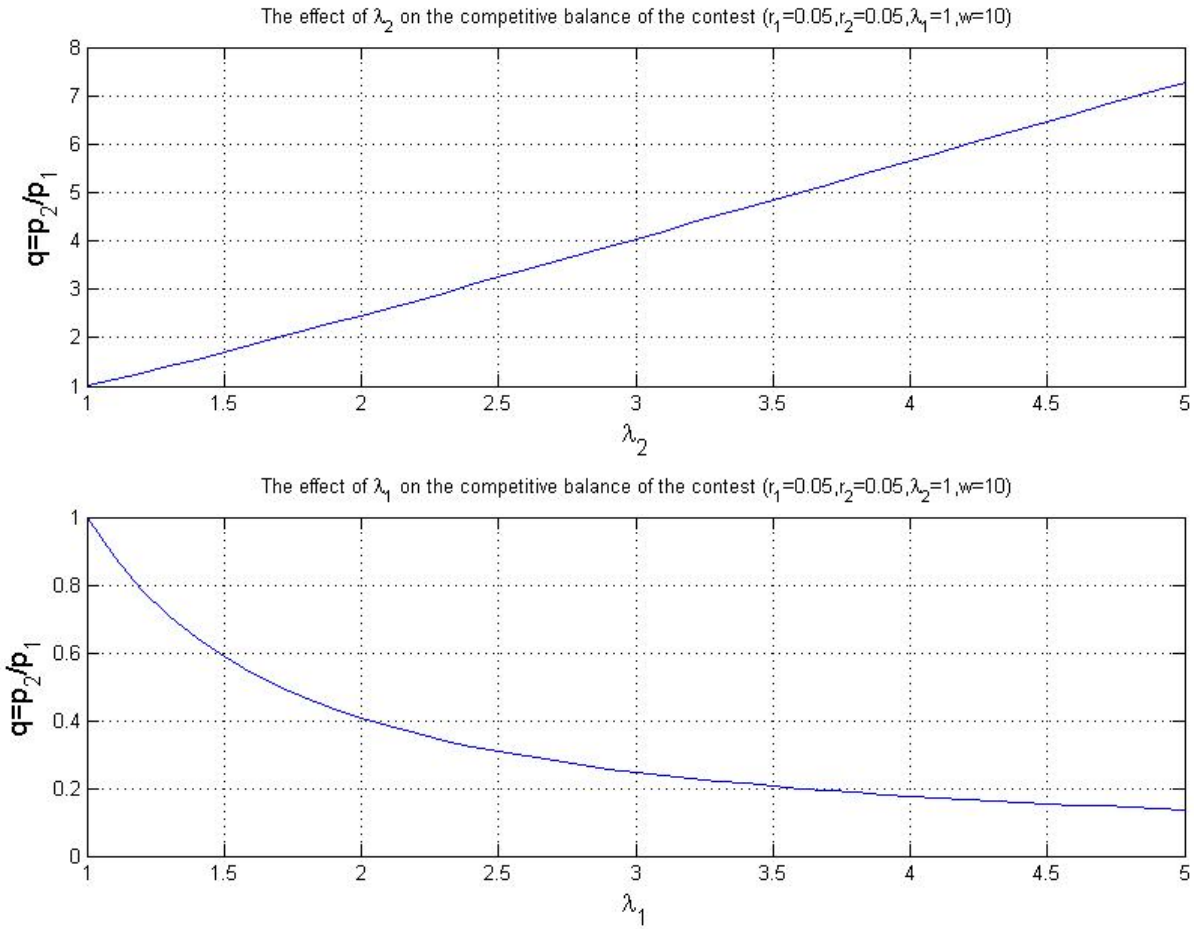

Figure 6: The effect of coefficient of value potential (λ) on the competitive balance of the contest (two parties have the same level of risk aversion)

Competitive innovation funds (6)

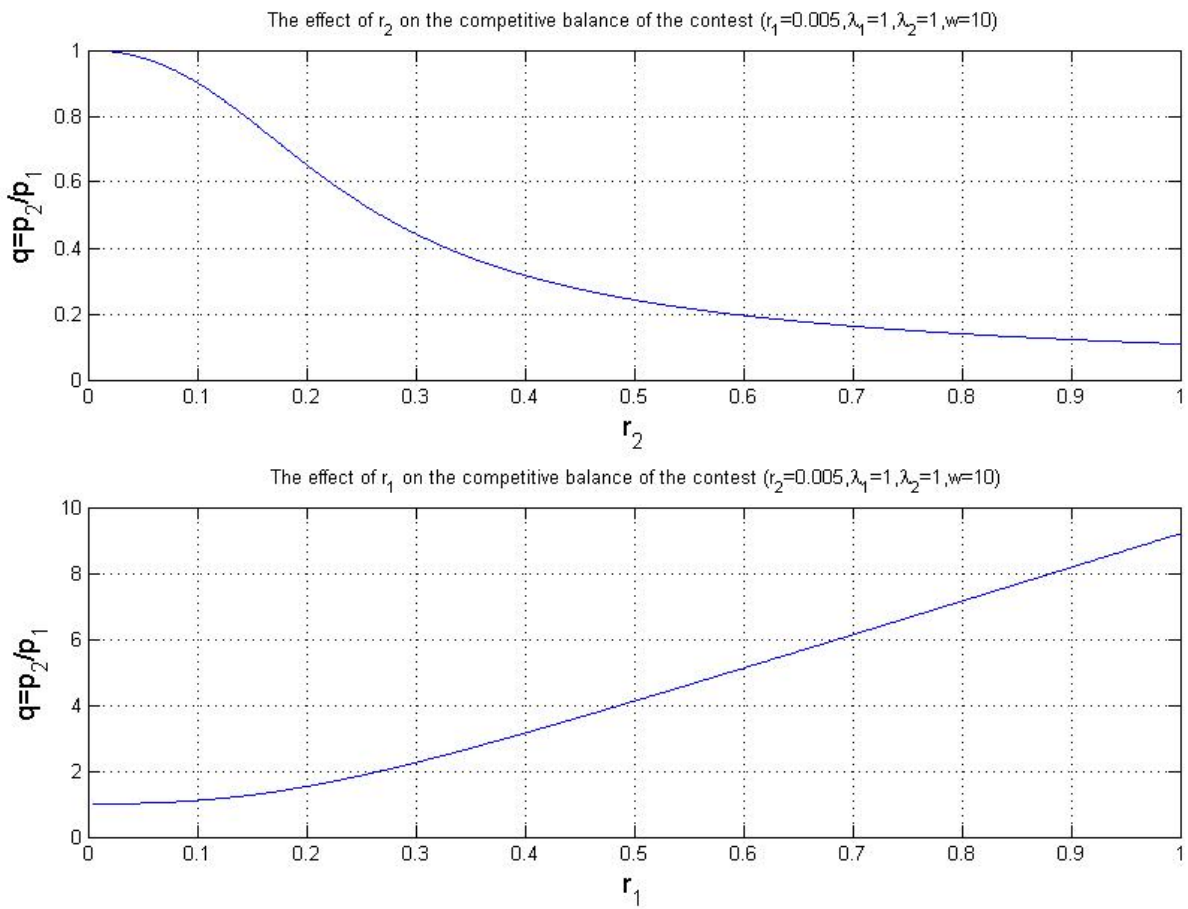

Figure 7: The effect of risk aversion of parties (r) on the competitive balance of the contest (two projects have the same potential value coefficient)

Competitive innovation funds (7)

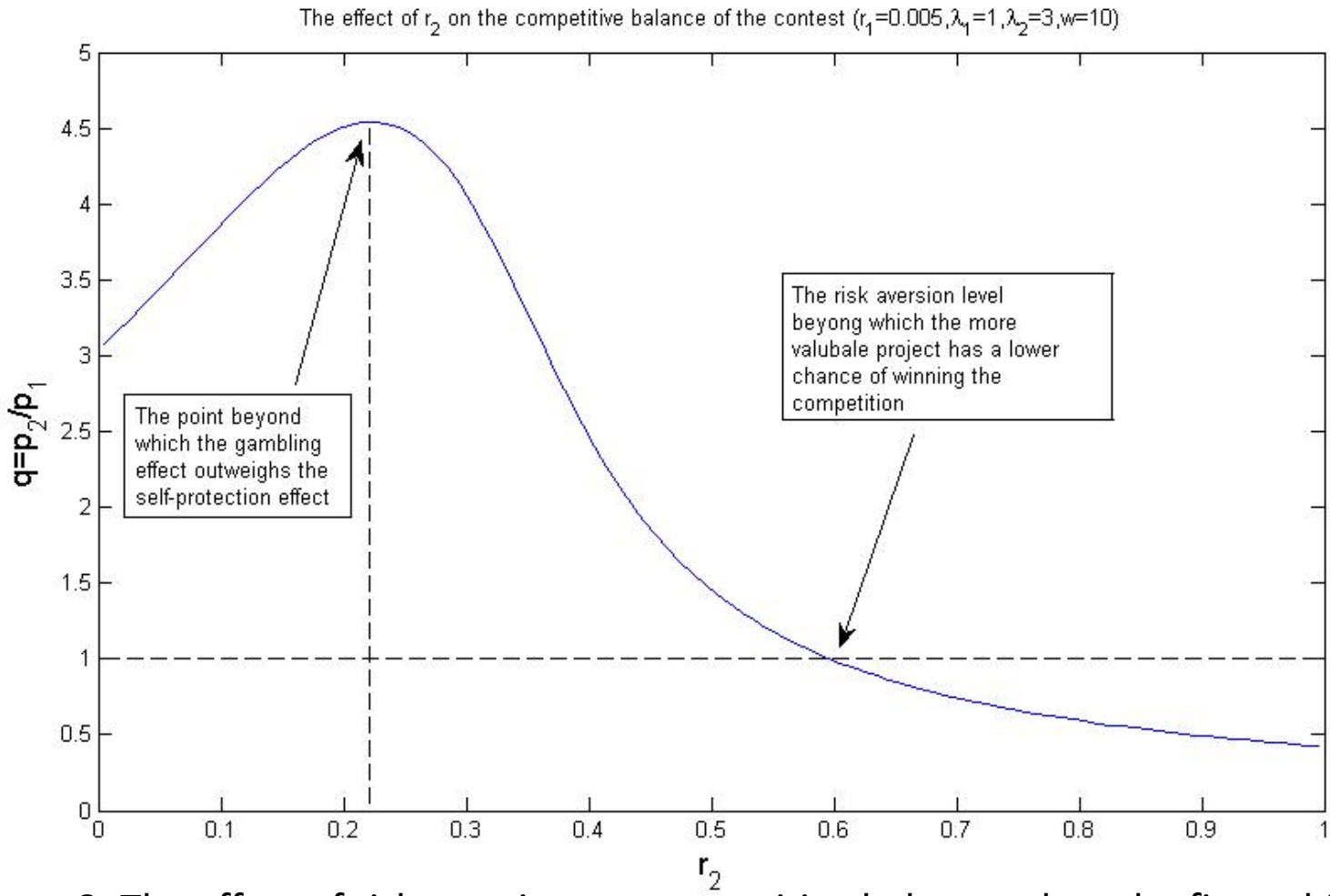

Figure 8: The effect of risk aversion on competitive balance when the firm which has the project with higher potential value is also more risk averse

Conclusions

- Although competitive schemes may seem like a cure to incentivise innovation in natural monopoly environment however:
  - The risk attitude of parties is critical in the contest.
  - Competitive innovation funds do not necessarily lead to selection of the project with highest potential value.
  - A firm with a more valuable innovation idea can lose the context because of risk aversion.
  - A two stage mechanism probably can solve this issue.

Thank you for your attention