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# Analyzing the Impact of Government Policies towards Product Innovation on Firms Using Evolutionary Game Theory

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## 1. Introduction

Innovation is a key determinant of economic growth and an important source of social benefits. Current government policies that would encourage innovation are much the same in all countries. They often focus on two aspects. One, governments encourage firms to develop innovative and safer products by providing financial support such as: R&D subsidies or tax credits. On the other hand, they rely on strict regulation of product liability to assure that these advances do not pose harm to public.

In these circumstances, a firm decision making on product innovation is affected by the risk of tort liability, the risk of failure and high R&D expenditures. Therefore, when an innovator cannot reduce this liability by improving the quality of her innovation, the effect of the law of torts on the incentive to innovate is perverse [1]. Effective policies call for a balancing of the incentives for improved product safety using product liability laws, and the benefits from innovation for both firms and society on the other.

Like any business plan, a firm decision of R&D spending on innovation is acted under private benefit-maximizing constraint while government policy planner seeks to maximize social value from that innovation. Under the contrasting differences these two decision criteria, the interaction between governments and firms is happened as two competing interest groups of the game. In this game, each individual chooses among alternative actions or behaviors whose payoff depends on the choices of others [2]. By analyzing this strategic game interaction, our study attempts to identify effectiveness and impact of investments from the government on the innovation incentive of manufacturing firms.

In order to analyze this strategic game interaction, we assume a simple model as shown in Fig.1. In this model, the government intervenes into the innovation process in two ways, by financial support for innovation and by regulation policy from safety and environmental considerations.

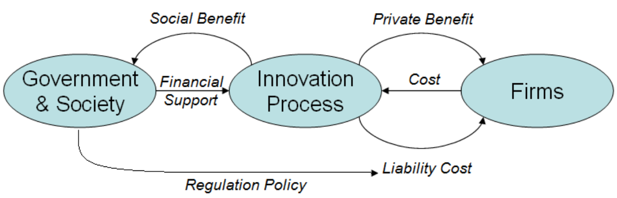


*Fig.1: Innovation model*

## 2. Objectives and Methodology

Evolutionary Game Theory (EGT) is a different approach to the classic analysis of games. First, game players are assumed to have an incomplete information and limited rationality. Secondly, games agents must be simulated with population of players that use different strategies and a process similar to natural selection of playing members of the populations is used to determine how the population evolves. The basic idea is that actions (or behaviors) which are more "fit", given the current distribution of behaviors, tend over time to displace less fit behaviors [2]. Ideally, under the dynamical process, the evolution would converge to some stable value for each population, which would represent a best response for each agent.

In this research, we use this theoretical background to model and simulate the interaction dependent strategy evolution between governments and firms as two populations. The limited rationality assumption of EGT is suitable for our model where both the government and the firm are working under uncertain and risky process of innovation. Individual strategies are converging through the dynamic process under the social mechanism of learning and imitation. Based on the results of the evolution of the game, we analyze the role of factors such as government's financial support, social value and private value in affecting the new product development decisions of firms. The objective of this study is to find the optimal strategy for the implementation of government policies and its effects on the incentive for product innovation of firm.

## 3. Model of evolutionary game between the government and the firm

### *3.1. Basic assumptions and parameters of the game model*

Evolution process of firms and governments is represented by a two-population evolutionary game, where the population of firms strategically interacts with that of governments.

For the case of manufacturing firms, they might adopt strategy of developing product innovation (strategy $F_1$) or not developing product innovation (strategy $F_2$). If they decide to develop a new innovative product, we suppose that the production cost is $C$, product liability risk is $\theta$, and the expected liability cost is $L$. However, from the results of other empirical studies, it is clear that many attempted innovations fail in large firms as well as in small firms [3]. For this reason, we call $u$ as the success rate of firm's product innovation project; specifically, $u_1$, $u_2$ are the success rate in case with and without the support of government respectively $(u_1>u_2)$. If a firm is successful in developing product innovation, of course, it can gain the benefit $B$ from this innovative product, such as revenue, competitive advantage in the market.

For governments, they may choose to financially support firms' innovation process (strategy $G_1$) or not (strategy $G_2$). The reason that governments encourage and support firm's innovation is because of the benefit $S$ it can bring for society. The gap between private and social returns to R&D activities has traditionally been used as a theoretical justification for government support to private R&D through subsidies or tax credits [4]. Therefore, to encourage those who innovate, government gives firms the financial support $F$, suppose that $F<S$.

*Table 1: Relevant variables of the model*

| Variables | Definitions |
|---|---|
| $C$ | Cost of innovation |
| $\theta$ | Product liability risk |
| $L$ | Expected liability cost |
| $u_1$ | Innovation success rate with the support of government |
| $u_2$ | Innovation success rate without the support of government |
| $B$ | Benefit for firm from innovation product |
| $S$ | Benefit for society from innovation product |
| $F$ | Government financial support |

*3.2. Establish of game model*

| Governments \ Firms | $F_1$: Do Innovation (y) | $F_2$: Not Do Innovation (1-y) |
|---|---|---|
| $G_1$: Support (x) | $u_1S - F$; $u_1B - C - \theta L + F$ | 0; 0 |
| $G_2$: Not Support (1-x) | $u_2S$; $u_2B - C - \theta L$ | 0; 0 |

*Fig.2: Game matrix*

*3.3. Equilibrium analysis and results*

We assume that the proportion of the government choosing strategy $G_1$ is $x$ and that of the government choosing strategy $G_2$ is $1\text{-}x$. The proportion of firm deciding to pursue $F_1$ strategy is $y$ and then that of firm deciding $F_2$ strategy is $1\text{-}y$. Here, $x$ and $y$ are functions of time $t$. We have:

- Expected payoff of the government choosing *"Support"* strategy is:

$$E_G(G_1) = y(u_1S - F) + (1-y)0 = y(u_1S - F)$$

- Expected payoff of the government choosing *"Not Support"* strategy is:

$$E_G(G_2) = y(u_2S) + (1-y)0 = yu_2S$$

- The average payoff of the government is:

$$\overline{E_G} = xE_G(G_1) + (1-x)E_G(G_2) = xy(u_1S - F) + (1-x)yu_2S$$

- The expected payoff of the firm choosing *"Do Innovation"* strategy is

$$E_F(F_1) = x(u_1B - C - \theta L + F) + (1-x)(u_2B - C - \theta L)$$

- The expected payoff of the firm choosing *"Not Do Innovation"* strategy is:

$$E_F(F_2) = x0 + (1-x)0 = 0$$

- The average payoff of the firm is:

$$\overline{E_E} = yE_F(F_1) + (1-y)E_F(F_2)$$

- Replicator dynamics equation of government *"Support"* strategy is:

$$\frac{dx}{dt} = x(E_G(G_1) - \overline{E}_G) = x(1-x)y\left[(u_1 - u_2)S - F\right]$$

After analysis the replicator dynamics equation of government using the stability theory, we have:

When $\Delta u = u_1 - u_2 < \frac{F}{S}$, we have $x=0$ is the evolutionary stable strategy (ESS).

When $\Delta u = u_1 - u_2 > \frac{F}{S}$, we have $x=1$ is ESS.

- Replicator dynamics equation of firm *"Do Innovation"* strategy is:

$$\frac{dy}{dt} = y(E_F(F_1) - \overline{E}_F) = y(1-y)\{x[(u_1 - u_2)B + F] + u_2B - C - \theta L\}$$

After analysis the replicator dynamics equation of firm using the stability theory, we also have:

When $C + \theta L > u_1B + F$, we have $y=0$ is ESS.

When $u_2B > C + \theta L$, we have $y=1$ is ESS.

**4. Discussion**

These results show that for firms, when innovation production cost and liability cost is higher than all the benefits that firm getting from innovation, even in case they receive support from government, they do not want to do innovation. However, when firm is strong enough with their own technological capability to succeed in innovation and benefits that firm may gain from innovation is greater than the product innovation cost and liability cost, all firm will choose to do innovation.

The social value of innovation is one very important factor that leads government to the decision of investment for firm. For an innovation having high desirable social benefit, even though firm has a low technology intensity to achieve it successfully, government should raise the level of financial support for firm.

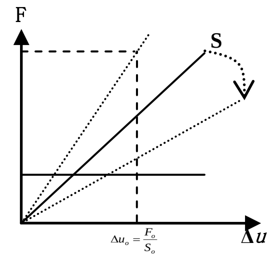


*Fig.3: Relation between F and S*

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