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# Competition, Patent Protection, and Innovation in an Endogenous Market Structure\*

Keishun Suzuki<sup>†</sup>

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## Abstract

This study revisits the relationship between competition and innovation by incorporating an endogenous market structure (EMS) in a dynamic general equilibrium model. We consider that both innovative and non-innovative followers engage in Cournot competition with free entry. A competition-enhancing policy, which reduces entry cost, can stimulate the entry of innovative followers when the entry cost is high. However, when the entry cost is sufficiently low, the entry of non-innovative followers crowd-out innovative followers from the market. As a result, there is a non-monotonic relationship (inverted-V shape) between competition and innovation. Furthermore, we show that, while strengthening patent protection positively affects innovation when competition is sufficiently intense, the effect may be negative under milder competition. This suggests that a competition policy could complement a patent policy.

**JEL-Classification:** O30, O40.

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# 1 Introduction

Over the years, many researchers have attempted to explore how intensifying product market competition (PMC) affects innovation. [Schumpeter \(1950\)](#) considers monopolistic profit as the most powerful engine driving technological progress. In pure Schumpeterian growth models, competition mostly discourages firms from innovation because post-innovation profit shrinks under harsh PMC (also known as the “Schumpeterian effect”).

However, the results of empirical analyses are mixed and do not necessarily show such clear trade-off between competition and innovation. [Aghion et al. \(2005\)](#), the most influential study in the field, show an inverted-U relationship between competition and innovation using data for the United Kingdom. They also extend a Schumpeterian growth model and demonstrate non-monotonicity between the two. [Hashmi \(2013\)](#) demonstrates a negative relationship between PMC and innovation in the United States and that the relationship may differ across countries. On the other hand, using the same data, [Corera and Ornaghi \(2014\)](#) indicate that PMC positively impacts innovation when control variables are changed. More recently, [Blazsek and Escribano \(2016\)](#) also suggest that PMC enhances innovation in the United States. In sum, the relationship between PMC and innovation remains controversial.<sup>1</sup>

Many theoretical studies have examined the relationship between PMC and innovation assuming a fixed number of incumbents in the product market. Using an oligopolistic model, [Aghion et al. \(1997, 2001, 2005\)](#) show that strong PMC may enhance economic growth since it stimulates the neck-and-neck firms’ incentive to innovate (“escape competition effect”) and this outweighs the Schumpeterian effect. However, needless to say, the interrelationship between the number of firms and status of PMC is intrinsic to investigate the competition–innovation relationship more precisely. In fact, [Etro \(2007\)](#) point out that the escape competition effect completely disappears under the assumption of free entry. In this case, the non-monotonicity between PMC and innovation also vanishes. Hence, it is necessary to consider this issue in a more general framework, which is an endogenous market structure (EMS), where the number of firms in the product market is endogenously determined.<sup>2</sup>

Using an EMS model, some studies have recently analyzed the relationship between PMC and innovation. [Denicolò and Zanchettin \(2010\)](#) extend a quality-ladder growth model in which the total number of asymmetric incumbents is endogenously determined. In their model, several efficient incumbents can remain in the market, even if further innovation occurs, since their model assumes that patent length is infinite and firms do

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<sup>1</sup>For a comprehensive survey of empirical studies, see [Cohen \(2010\)](#).

<sup>2</sup>See [Etro \(2007, 2009\)](#) for EMS models.

not engage in Bertrand competition. Then, strong PMC excludes inefficient incumbents from the market and increases the market share of an efficient incumbent. They also demonstrate that intense PMC may stimulate the incentive to innovate through this market selection process. [Bento \(2014\)](#) incorporates the uncertainty of quality-improvement size in a Schumpeterian growth model, wherein the incumbent's markup is endogenously determined. In his model, a fortunate potential firm that draws the best quality among all firm becomes the monopolist. When an innovator's market entry cost is low, the number of firms that draws the lottery increases. The increase in the number of firms decreases the probability that one firm wins (this discourages each firm's research by the Schumpeterian effect), but increases the winner's quality level and innovation value (he labels this as the "Hayekian effect"). He further shows that these opposite effects generate an inverted-U relationship between PMC and research per firm.

This study investigates the relationship between PMC and innovation by developing a dynamic equilibrium (DGE) model with EMS. Unlike other studies that consider R&D activities by potential firms as the key driver of growth, we consider a situation in which only active firms in the product markets engage in R&D as in [Aghion et al. \(2005\)](#). This is inspired by some empirical findings that existing firms' quality improvement, rather than creative destruction by the entrant, is a major source of growth.<sup>3</sup> In the model, firms can enter the product market as innovative or non-innovative followers without infringing the leader's patent and engage in Cournot competition with the leader. Innovative followers also conduct R&D activities and the successful researcher becomes the new leader in the market. A competition-enhancing policy, which reduces entry cost, stimulates the entry of innovative followers when the level of PMC is low. However, when PMC is sufficiently tough, the policy hinders innovation since non-innovative followers crowd-out innovative followers from the market. As a result, a competition-enhancing policy has a non-monotonic effect on innovation. Furthermore, our model shows that strengthening patent protection does not always enhance innovation. We find that the pro-patent policy always has a positive effect on innovation when PMC is sufficiently intense. This result suggests a complementarity between a competition policy and patent policy, which is consistent with the empirical findings in [Aghion et al. \(2015\)](#).

It is also worthwhile to note the differences between the present study and existing literature. As [Etro \(2007\)](#) argue, our model does not have an escape competition effect in [Aghion et al. \(2005\)](#) because of free entry. Nonetheless, we can demonstrate a non-monotonic relationship between competition and growth using another mechanism mentioned previously. [Bento \(2014\)](#) also obtain an inverted-U relationship between PMC

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<sup>3</sup>See [Bartelsman and Doms \(2000\)](#) and [Garcia-Macia et al. \(2016\)](#). In particular, [Garcia-Macia et al. \(2016\)](#) report that 87.2% of TFP growth for 2003-2013 in the United States can be attributed to existing firms' innovation.

and innovation in a partial equilibrium framework that keeps both the interest rate and economic growth rate constant. However, he does not explicitly examine this using a general equilibrium model owing to the complexity.<sup>4</sup> Our DGE model has an advantage in the point. Furthermore, the model in [Bento \(2014\)](#) consists of a monopolist in each intermediate goods market because of Bertrand competition and potential firms conduct all research. In contrast, our Cournot competition model under free entry in the product market allows imitators to enter and a part of these producing firms engage in R&D activities. As a parameter for PMC level, [Aghion et al. \(2005\)](#) use an exogenous degree of collusion in neck-and-neck industries in which duopolistic firms have the same level of technology. However, such a proxy for PMC not only lacks a micro-foundation but also captures a somewhat industry-specific competition policy because it has no impact on PMC in industries comprising firms with differing technology levels. [Denicolò and Zanchettin \(2010\)](#) use a parameter of conjectural variations as a measure of competition level, which has been criticized by many theorists. Unlike these studies, we use entry cost as a parameter for PMC degree, which allows us to easily highlight the policy implications.<sup>5</sup>

This study also revisits the relationship between intellectual property rights (IPR) and innovation, for which many related works have been published.<sup>6</sup> In particular, [Chu et al. \(2016\)](#) study the effect of strengthening patent protection on economic growth in a model with EMS. They develop a hybrid model of variety expansion and quality improvement, where the introduction of a new variety is considered a market entry and the number of firms (varieties) is endogenously determined. Their model shows that strict patent protection enhances growth in the short run but hinders it in the long run because it expands the number of entrants and decreases the market share per firm.<sup>7</sup> By contrast, we find that strong patent protection may have a positive effect even in the long run. Furthermore, our study considers a competition-patent policy mix by examining the comparative statics of

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<sup>4</sup>Also, in the context of industrial organization, many studies have dealt with the relationship between competition and innovation using partial equilibrium models. For example, [Boone \(2001\)](#) shows a non-monotonic relationship between competition intensity and R&D incentive.

<sup>5</sup>In addition to these recent studies, [Van de Klundert and Smulders \(1997\)](#) investigate the effect of competition on economic growth using an endogenous growth model with EMS. They use the distinction between Cournot and Bertrand competition to denote competition intensity and show that tougher PMC always yields a higher innovation rate.

<sup>6</sup>See, for example, [Cysne and Turchick \(2012\)](#), [Furukawa \(2007\)](#), [Futagami and Iwaisako \(2007\)](#), [Horii and Iwaisako \(2007\)](#), and [Suzuki \(2015\)](#). In particular, [Suzuki \(2015\)](#) extends a quality-ladder model in which the monopolist's markup size is endogenously determined, as in this study, by his optimal choice of several IPR protections (patent and trade secret). His model shows that, depending on the risk of trade secret leakage, the effect of strengthening patent protection on economic growth can be negative, U-shaped, or positive.

<sup>7</sup>This trade-off between the number of firms (varieties of differentiated goods) and innovation is a common feature in models where the introduction of a new variety is considered a market entry. See also [Van de Klundert and Smulders \(1997\)](#), [Peretto \(1999\)](#), and [Minniti \(2009\)](#).

patent protection under several PMC levels.

The remainder of this paper is structured as follows. Section 2 describes the model and Section 3 solves the equilibrium. Section 4 discusses the effects of competition-enhancing and patent policies on innovation and welfare. Section 5 concludes.

## 2 The model

This section develops a DGE model with EMS. The model is based on quality-ladder type endogenous growth model in [Grossman and Helpman \(1991, Ch.4\)](#).

### 2.1 Households

We consider an economy consisting of  $L$  identical and infinitely lived households. Each household supplies a unit of labor inelastically and earns wage  $w$  in every period. Their intertemporal utility function is as follows:

$$U_t = \int_0^{\infty} \exp(-\rho t) \ln C_t dt, \quad (1)$$

where  $\rho$  is the subjective discount rate and  $C_t$  is an index of consumption at time  $t$ . In the economy, there is a continuum of industries indexed by  $i \in [0, 1]$ . The households consume final goods across all industries. The period utility is,

$$\ln C_t = \int_0^1 \ln \left( \sum_{k=0}^{\tilde{k}(i)} \lambda^k X_{kt}(i) \right) di, \quad (2)$$

where  $X_{kt}(i)$  is the consumption of the good whose quality is  $k$  in industry  $i$  at time  $t$ . The quality of each good is represented as an integer  $k$  power of  $\lambda > 1$ , which means that the quality of the new good is  $\lambda$  times higher than that of the previous one. In industry  $i$ , there are  $\tilde{k}(i)$  types of goods and the quality of the latest good is  $\lambda^{\tilde{k}(i)}$ . We can show that, in equilibrium, households buy only the highest quality good in each industry.

Under the logarithmic utility function, households spend their budget equally across the industries. Therefore, the demand of a good in the industry  $i$  is  $X_{\tilde{k}}(i) = E/p_{\tilde{k}}(i)$ , where  $E$  is expenditure and  $p_{\tilde{k}}$  is the price of the good whose quality is  $\tilde{k}(i)$ .

In this setting, the ideal price index associated with the consumption index  $C$  is

$$P = \exp \left[ \int_0^1 \ln \left( \frac{p_{\tilde{k}}(i)}{\lambda^{\tilde{k}(i)}} \right) di \right]. \quad (3)$$

Given the aggregate price index, households spend to maximize their intertemporal utility. From the maximization result, household's optimal time path for spending is represented by  $\dot{E}/E = r - \rho$ . Using aggregate expenditure as the *numéraire*, we get  $E = 1$  and  $r = \rho$ . Hereinafter, we omit  $i$  from the notations if there is no risk of misunderstanding.

## 2.2 Industries

Consider an industry that consists of a leader and  $N$  followers. All of them engage in Cournot competition, where their unit production costs are asymmetric. While the leader can produce a good using one unit of labor, followers must devote  $\lambda\chi > 1$  units of labor to produce a unit of the same good. We assume that patent protection is imperfect and followers can partially imitate the leader's good without infringing the patent. Parameter  $\chi \in (1/\lambda, 1)$  indicates the degree of patent breadth.<sup>8</sup> As we derived, the inverse demand function for goods in an industry is  $p = 1/X$ . In the market equilibrium,  $X$  equals the aggregate output in the industry. Given the inverse demand function and wage rate of one unit of labor,  $w$ , producer  $j$  maximizes her own profit,  $\pi(j)$ . Accordingly, the profit maximization problem is

$$\max_{x(j)} \pi(j) = \frac{1}{X} \cdot x(j) - c(j) \cdot w \cdot x(j), \quad (4)$$

where  $x(j)$  is output level and  $c(j)$  is production cost.<sup>9</sup> By solving this, we obtain the output of producer  $j$  as follows:

$$\begin{aligned} \frac{\partial \pi(j)}{\partial x(j)} = 0 &\Leftrightarrow \frac{1}{X} - \frac{x(j)}{X^2} - c(j) \cdot w = 0 \\ &\Leftrightarrow x(j) = X - c(j) \cdot w \cdot X^2. \end{aligned} \quad (5)$$

We denote  $x_L$  and  $x_F$  as the output of the leader and followers in the industry. Assume that all followers are symmetric. Then, the aggregate output in the industry is written as  $X = x_L + N \cdot x_F$ . Then, we can derive the market equilibrium price as follows:

$$\begin{aligned} X &= X - wX^2 + N \cdot (X - \lambda\chi wX^2) \\ &\Leftrightarrow p = \left( \frac{1 + N\lambda\chi}{N} \right) w. \end{aligned} \quad (6)$$

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<sup>8</sup>Patent breadth is the extent to which patent holders can legally prevent imitators from copying their patented technologies. In our model, patent breadth is the broadest when  $\chi = 1$  and narrowest when  $\chi = 1/\lambda$ . The same specification of patent breadth was applied in [Iwaisako et al. \(2011\)](#).

<sup>9</sup>Note that  $c(j) = 1$  when producer- $j$  is the leader and  $c(j) = \lambda\chi$  when she is a follower.

The aggregate output in the industry is

$$X = \left( \frac{N}{1 + \lambda\chi N} \right) \frac{1}{w}. \quad (7)$$

It is well-known that the ratio between  $x_L$  and  $x_F$  is equal to that of the markup under Cournot competition. Then, we have

$$\begin{aligned} \frac{x_L}{x_F} &= \frac{p - w}{p - \lambda\chi w} = 1 + (\lambda\chi - 1)N \\ \Leftrightarrow x_L &= [1 + (\lambda\chi - 1)N]x_F(i). \end{aligned} \quad (8)$$

Using this, we obtain the equilibrium output of each producer as follows:

$$x_F = \left[ \frac{N}{(1 + \lambda\chi N)^2} \right] \left( \frac{1}{w} \right), \quad (9)$$

$$x_L = \left[ \frac{N}{(1 + \lambda\chi N)^2} \right] [1 + (\lambda\chi - 1)N] \left( \frac{1}{w} \right). \quad (10)$$

Then, the follower's and leader's profit are

$$\pi_F(N) = \left( \frac{1}{1 + \lambda\chi N} \right)^2, \quad (11)$$

$$\pi_L(N) = \left( 1 - \frac{N}{1 + \lambda\chi N} \right)^2. \quad (12)$$

These functions are decreasing in  $N$ .

### 2.3 Followers: Imitators and Research Firms

Following [Etro \(2007\)](#), in this section, we incorporate the concept of EMS in the model.

There are two types of followers in the model. First is the non-innovative firms who only imitate a state-of-the-art good. We label this type of followers as “imitators” in a narrow sense. Second is the type of firms that not only produces an imitated good but also conducts R&D activities. We label them as “research firms.” We assume that all R&D activities are conducted by research firms; therefore, there is no potential researcher in the model.<sup>10</sup>

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<sup>10</sup>In most R&D-based growth models, only potential firms engage in R&D activities, while incumbents do not because of the Arrow's replacement effect. By contrast, in our model, R&D activities can be performed for only producing firms. This assumption can be justified when the research productivity of existing firms is lower than that of potential ones because manufacturing experience gives the producer essential clues about further innovations.

The success of R&D activities follows a Poisson process. By employing a worker, a research firm can draw a lottery that may succeed to create a high-quality good with a small probability of  $a$ . In the model, there is no decision regarding the amount of R&D investment by research firms. Therefore, the total number of research firms is equal to that of workers employed by research firms.<sup>11</sup> Let  $R$  denote the total number of research firms in an industry. Then, the probability of an innovation occurring in the industry at the interval of  $dt$  is  $(Ra)dt$ . In addition, we denote  $M$  as the total number of imitators in the industry. In this case,  $N = M + R$  holds.

We assume that all  $N$  followers must pay a cost of  $e > 0$  in each period.<sup>12</sup> Since this cost can prevent potential firms from entering the industry, in our model, we consider it an entry cost.<sup>13</sup> This assumption simplifies the analyses of comparative statistics. The leader does not pay this cost because entry cost is a barrier that protects incumbent.

Then, the free-entry condition for imitators is,

$$\pi_F(N) \leq e \text{ equality holds when } M > 0. \quad (13)$$

Similarly, the free-entry condition for research firm is,

$$\pi_F(N) + aV_t - w \leq e \text{ equality holds when } R > 0, \quad (14)$$

where  $V_t$  is the value of innovation. In the equilibrium,  $M$  and  $R$  are determined by these conditions.

## 3 The Steady State

### 3.1 Equilibrium

In labor market equilibrium, aggregate labor demand  $X + n$  must be equal to labor supply  $L$ . The labor market clearing condition is

$$\left( \frac{N}{1 + \lambda\chi N} \right) \left( \frac{1}{w} \right) + R = L. \quad (15)$$

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<sup>11</sup>We can interpret research firms as non-production workers who set up their enterprise and engage in R&D activities. [Hori and Iwaisako \(2007\)](#) also considered a similar R&D process specification. Note that free-entry condition (14) also holds in this interpretation because wage is an opportunity cost.

<sup>12</sup>Alternatively, we can consider that all entrants borrow some money when they enter and constantly repay or all followers' projects are completed instantaneously.

<sup>13</sup>In a narrow sense, entry cost is a fixed cost that all entrants must pay when they enter the market. However, entrants must regularly pay several other costs, which also serve as an effective entry cost in a broad sense (e.g., advertisement and patent license fee).

The equilibrium wage rate  $w$  is determined to satisfy this condition.

Consider the evolution of innovation value  $V_t$ . A leader earns  $\pi_L$  in every period, unless a certain research firm successfully innovates. The leader loses her position and must exit from the market with the probability of  $Ra$ . We assume that there is a perfectly risk-free asset market. Therefore, the following equation holds as a no-arbitrage condition in the asset market:

$$rV_t = \pi_L(N) + \dot{V}_t - RaV_t. \quad (16)$$

### 3.2 The Steady State

In the equilibrium, depending on the magnitude of  $e > 0$ , there are two possible cases. First, there is no imitator ( $M = 0, N = R$ ) in the industry when  $e$  is sufficiently large. Second, imitators and research firms coexist in the same industry ( $M > 0, N = M + R$ ) when  $e$  is sufficiently small. In the subsection, we solve the steady state for each case.

**Case 1:**  $M = 0, N = R$

From the no-arbitrage condition, normalization, and profit, we obtain

$$\dot{V}_t = 0 \Leftrightarrow V_t = \frac{[1 - R/(1 + \lambda\chi R)]^2}{\rho + Ra}. \quad (17)$$

By substituting the free-entry condition for research firms (14) with the labor market clearing condition (15), we get

$$V_t = \frac{1}{a} \left[ e + \left( \frac{R}{(1 + \lambda\chi R)(L - R)} \right) - \left( \frac{1}{1 + \lambda\chi R} \right)^2 \right]. \quad (18)$$

These two equations reveal that the steady state is unique and unstable as in Panel (a) of Fig.1. To guarantee the existence, we suppose an additional condition for parameters:

**Assumption 1.**

$$e < \frac{a}{\rho} + 1 \equiv e^{\max}. \quad (19)$$

Since there is only jumpable variables in the dynamics, to satisfy the transversality condition,  $V_t$  must immediately jump to its steady-state value at  $t = 0$ . There is no transitional dynamics in our model as in [Grossman and Helpman \(1991, Ch.4\)](#). Therefore, the comparative statics between different steady states are applicable.

**Case 2:**  $M > 0, N = M + R$

The free-entry condition for imitators (13) determines the total number of followers:

$$N = \frac{1}{\lambda\chi} \left( \frac{1}{\sqrt{e}} - 1 \right) \equiv \bar{N}(e). \quad (20)$$

Then, by substituting equations (12) and (20) with equation (16), we have

$$\dot{V}_t = 0 \Leftrightarrow V_t = \frac{[1 - (1 - \sqrt{e})/(\lambda\chi)]^2}{\rho + Ra}. \quad (21)$$

This is a decreasing function in  $R$ . Using equations (13) and (14), we obtain  $aV_t = w_t$ . From this, (20), and labor market clearing condition (15), we can derive

$$V_t = \frac{1}{a} \left[ \frac{1 - \sqrt{e}}{\lambda\chi(L - R)} \right]. \quad (22)$$

This is an increasing function in  $R$ . Panel (b) of Fig.1 states that the steady-state in case 2 is also unique and unstable and  $V_t$  must jump to its steady-state value immediately at  $t = 0$ . We suppose the following additional condition of parameters for the existence of a steady state:

**Assumption 2.**

$$\sqrt{e} > 1 - \frac{\lambda\chi}{\rho/a + 1}. \quad (23)$$

We define  $e^{\min}$ , the minimum non-negative value that case 2 happens, as follows:

$$e^{\min} = \varepsilon^2, \quad (24)$$

where  $\varepsilon = \max \left[ 0, 1 - \frac{\lambda\chi}{\rho/a + 1} \right]$ .

Under  $e^{\min} < e < e^{\max}$ , the steady-state value of R&D workers,  $R^*$ , is strictly positive.<sup>14</sup> We focus on this range of entry cost in the comparative statics.

## 4 Policy Effects

### 4.1 Competition Policy

This section investigates the impact of competition-enhancing policy on innovation, which lowers entry cost  $e$ . In the model, the implication of a growth effect is same that of innova-

<sup>14</sup>Because  $0 \leq e^{\min} < 1 < e^{\max}$  always holds, the range of  $e$  is not empty.

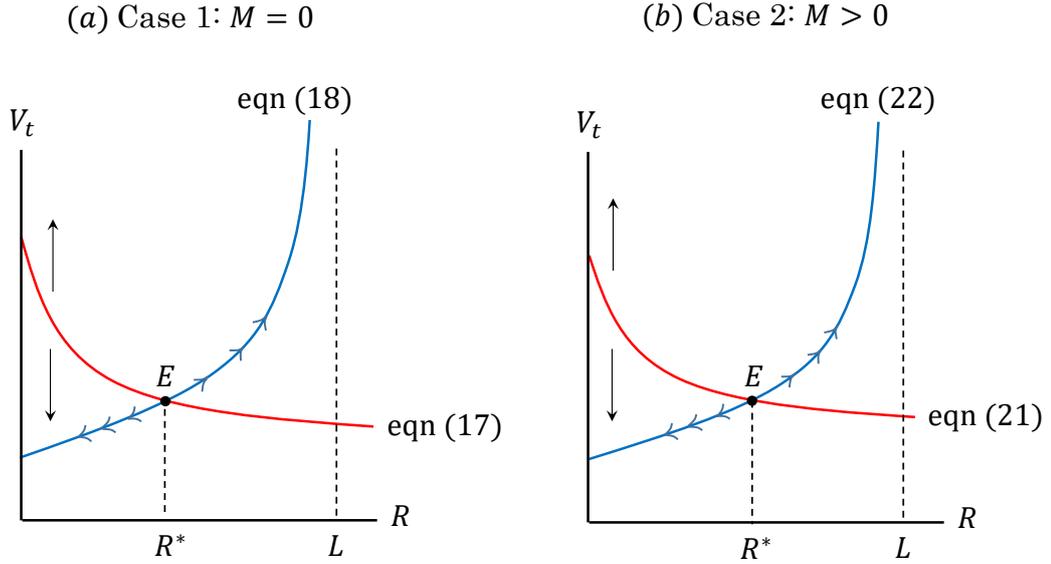


Figure 1: The steady-state.

tion since the economic growth rate  $g^* \equiv \dot{C}/C$  is calculated as  $g^* = R^* a \ln \lambda$ . Therefore, we also interpret the following results as the growth effects of competition-enhancing policy.

**Case 1:**  $M = 0, R > 0$

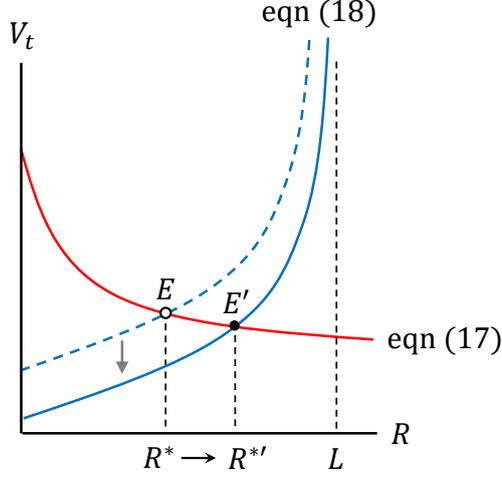
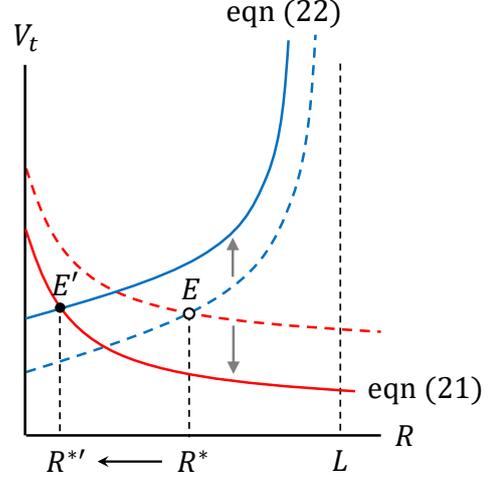
This policy shifts curve of equation (18) downward, as in Panel (a) of Fig.2, and raises  $R^*$  along the curve of equation (17). This means that the competition-enhancing policy has a positive effect on innovation. The intuition is simple: since research firms have to pay entry cost, a smaller entry cost allows many research firms to enter the market.

In the model, research firms have a stronger incentive to enter the market than imitators who do not enter the market when  $\pi_F < e$  because research firms have an expectation of innovation. Therefore, in case 1, the reduction of entry cost only brings in the research firms.

**Case 2:**  $M > 0, R > 0$

However, in case 2, the competition-enhancing policy has a negative effect on innovation caused by two mechanisms.

First, the policy raises the equilibrium wage, which is the cost of R&D activities. According equation (20), the decreasing  $e$  increases the total number of followers,  $\bar{N}(e)$

(a) Case 1:  $M = 0$ (b) Case 2:  $M > 0$ Figure 2: The competition-enhancing policy ( $e \downarrow$ ).

and this increases the labor demand in production. This shifts the curve of equation (22) upward.

Second, stronger competition reduces the expected innovation value. In case 2, entry cost  $e$  disappears under the free-entry condition of research firms since  $\pi_F(N) = e$  holds. This implies that the decision of entry for research firms just depends on the expected innovation value (which declines in  $M^*$ ) and wage (which increases in  $M^*$ ). As a result, the policy shifts the curve of equation (21) downward.

Both shifts work to decrease  $R^*$  as in Panel (b) of Fig. 2. In sum, in case 2, the competition-enhancing policy invites more imitators and the imitators crowd-out research firms. In other words, the research firms' incentive to enter becomes weaker than that of imitators. This is in perfect contrast to case 1.

### Threshold of Entry Cost

In this section, we attempt to determine the threshold of entry cost  $\tilde{e}$  that divides the economy into two cases. We do so by solving  $\bar{N}(e) = R_2^*(e)$ , where  $R_h^*(e)$  is the number of research firms in the steady state in case  $h = 1, 2$ . Although we cannot analytically derive  $\tilde{e}$ , we can easily show that it uniquely exists in  $(e^{\min}, 1)$ .<sup>15</sup> Note that the proxies of

<sup>15</sup> $\bar{N}(e)$  is a strictly decreasing function in  $e$  and we have  $\bar{N} \rightarrow \infty$  when  $e \rightarrow 0$  and  $\bar{N} = 0$  holds when  $e = 1$ . On the other hand,  $R_2^*(e)$  is always a finite positive value  $e \in (e^{\min}, 1)$  and a strictly increasing function in this range. Therefore, the intersection of  $\bar{N}(e)$  and  $R_1^*(e)$  must be uniquely determined.

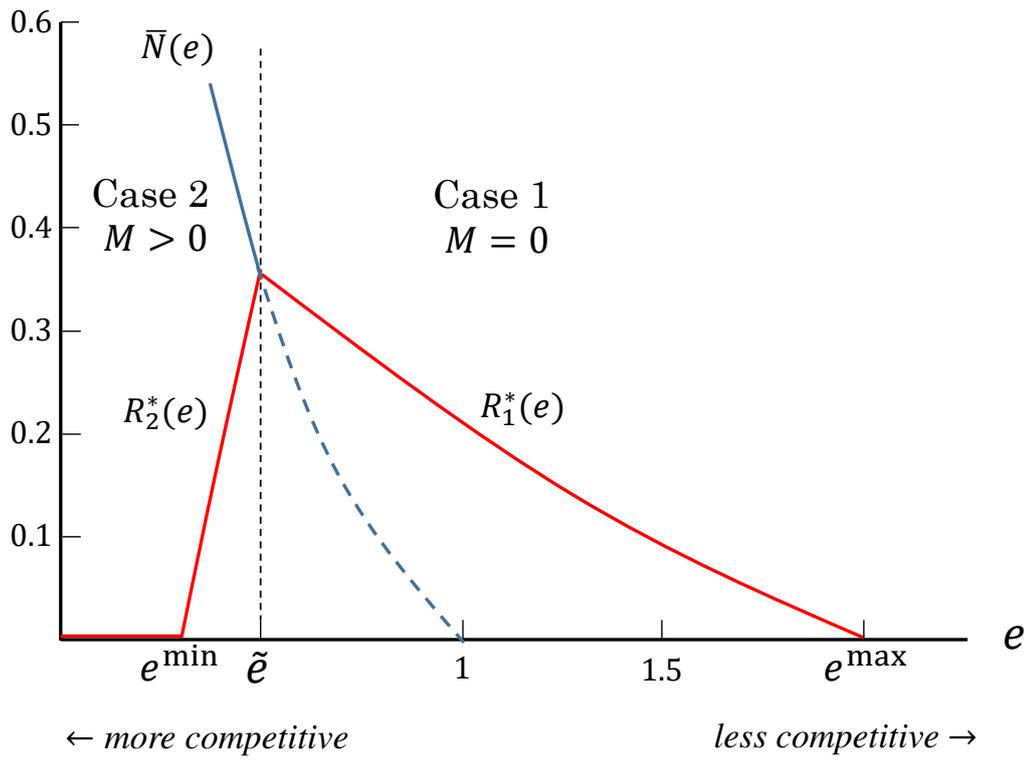


Figure 3: Comparative statics of  $e$ . Calculated numerically by setting  $L = 1$ ,  $\lambda = 1.2$ ,  $\chi = 0.95$ ,  $\rho = 0.01$ , and  $a = 0.01$ . Under these parameters,  $e^{\min} \simeq 0.31$ ,  $\tilde{e} = 0.5$ , and  $e^{\max} = 2$ . All parameter assumptions are satisfied.

PMC often used in empirical studies (e.g., average Lerner's index, Herfindahl-Hirschman Index) have a monotonic relationship with the entry cost in our model since the total number of followers is strictly decreasing in  $e \in (e^{\min}, e^{\max})$ . Therefore, we can state that a decrease in  $e$  is a competition-enhancing policy in the model.

From the above discussion, we obtained the following result:

**Proposition 1.** *There is a non-monotonic relationship between PMC and innovation. When the level of PMC is low ( $\tilde{e} < e < e^{\max}$ ), the competition-enhancing policy ( $e \downarrow$ ) has a positive effect on innovation. On the other hand, when PMC is sufficiently intense ( $e^{\min} < e < \tilde{e}$ ), the competition-enhancing policy ( $e \downarrow$ ) has a negative effect on innovation.*

Fig.3 summarizes the results.

Although the non-monotonic relationship between PMC and innovation is similar to that discussed in earlier studies, the channels are starkly differ. Our model does not have the escape competition effect in the model by [Aghion et al. \(2005\)](#) because we assume that the number of firms is not fixed. In their model, even if the competition-enhancing policy decreases the current profit, two neck-and-neck existing firms have no choice but to increase their R&D efforts. However, in our model with free-entry, research firms are allowed to exit (truly escape) from the market as in case 2. Furthermore, the decrease in current profit distracts potential firms from entering the market. These effects are not considered in [Aghion et al. \(2005\)](#).

### Welfare Implication

Here, we investigate whether the growth-maximizing  $\tilde{e}$  also maximizes households' welfare. To do so, we calculate the welfare evaluated in the case where the economy starts at the steady state.

In the steady state, we have  $\ln C_t = g^* \cdot t - \ln X$  from equation (2). By integrating the lifetime-utility function (1) with respect to time, we obtain welfare:

$$\begin{aligned} W &= \int_0^{\infty} \exp(-\rho t) [g^* \cdot t + \ln X] \\ &= \frac{1}{\rho} \left[ \frac{R^* a \ln \lambda}{\rho} + \ln(L - R^*) \right]. \end{aligned} \quad (25)$$

By differentiating this with respect to  $R^*$ , we obtain

$$\frac{\partial W}{\partial R} > 0 \Leftrightarrow R^* < L - \frac{\rho}{a \ln \lambda}. \quad (26)$$

When this inequality holds, an increase in  $R^*$  also increases welfare. If  $L - \rho/(a \ln \lambda) \leq 0$  holds, the inequality is violated since  $R^* \geq 0$ , and then, a rising  $R^*$  decreases welfare. From this result and Proposition 1, we have the following Proposition:

**Proposition 2.** *The growth-maximizing  $\tilde{e}$  does not always maximize welfare and the welfare implication depends on the value of  $\rho/(a \ln \lambda)$ .*

- *When  $R^*(\tilde{e}) \leq L - \rho/(a \ln \lambda)$ , the welfare and the PMC level have an inverted-V relationship, which is the same as that in Proposition 1.*
- *When  $L - \rho/(a \ln \lambda) \leq 0$ , this relationship becomes V-shaped.*
- *When  $0 < L - \rho/(a \ln \lambda) < R^*(\tilde{e})$ , this relationship is ambiguous.*

From equation (7), we can also write welfare as follows:

$$W = \frac{1}{\rho} \left[ \frac{R^* a \ln \lambda}{\rho} + \ln N - \ln(1 + \lambda \chi N) - \ln w \right]. \quad (27)$$

The competition-enhancing policy affects welfare through the following three channels: a decrease in  $e$  (i) always increases the number of followers  $N$ , (ii) always increases (decreases) innovation  $R$  in case 1 (case 2), and (iii) has a positive (ambiguous) effect on wage rate  $w$  in case 1 (case 2). We cannot analytically derive the total effect in both cases.<sup>16</sup> However, using numerical examples, as in Fig. 4, we can show all patterns are as written in the previous proposition by changing discount rate  $\rho$ . The inequality in (26) is satisfied if  $\rho$  is sufficiently small. This reflects that the first innovation-stimulating effect becomes stronger when  $\rho$  is small because the households consider dynamic gains from quality improvement more important than static distortion by imperfect competition. The large total labor supply  $L$  also works to satisfy the inequality because the market price of goods decreases because the wage rate in the labor market equilibrium decreases.

## 4.2 Patent Policy

Now, we explore the effect of strengthening patent protection on innovation. To do so, we consider the repercussions of a government raising  $\chi$  in both cases.

First, we discuss the effects in case 2. Strengthening patent protection reduces the number of followers  $\bar{N}$ . Then, it shifts the curve of equation (21) in Panel (b) of Fig. 1 upward since  $e < 1$ , and this positively affects innovation. This shift reflects the Schumpeterian effect: strong patent protection increases the post-innovation profit and innovation value. Furthermore, because labor demand in the production sector decreases and this

<sup>16</sup>In case 1, the third effect has a negative impact on welfare, whereas the first and second effect increases welfare. In case 2, the first and second effects are conflicting.

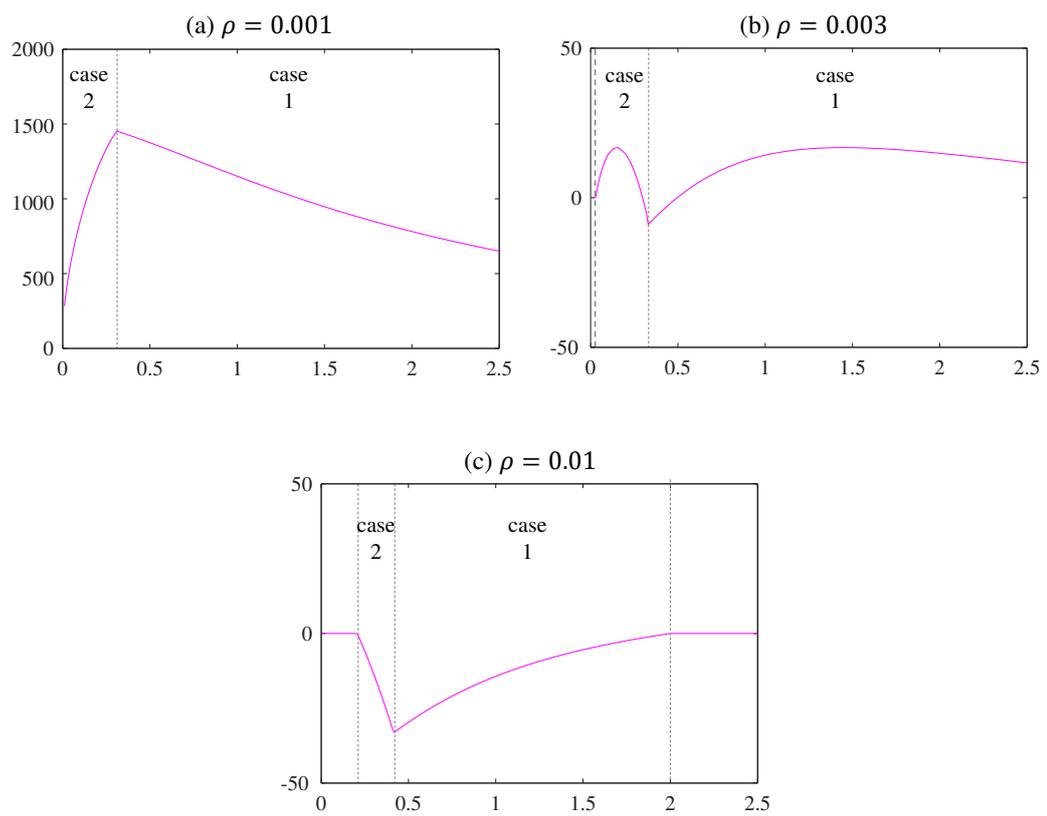


Figure 4: Welfare and entry cost under  $\rho = 0.01, 0.003, 0.0001$ . Parameters are  $L = 1, \lambda = 1.5, \chi = 0.95$ , and  $a = 0.01$ . All assumptions are satisfied.

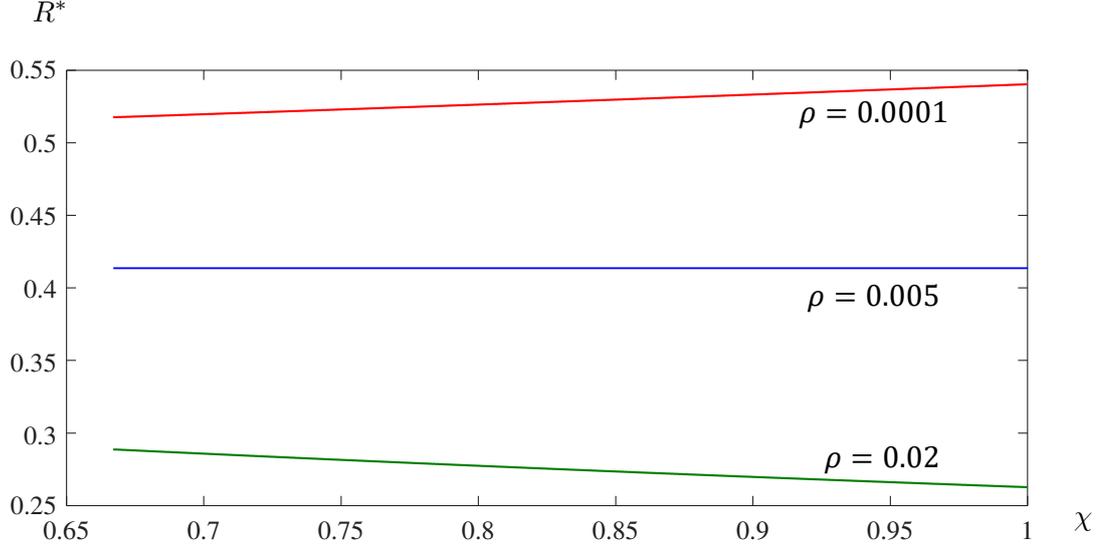


Figure 5: Comparative statics of  $\chi$ . Calculated numerically by setting  $L = 1, \lambda = 1.5, e = 0.55$ , and  $a = 0.01$ . Under these parameters, we investigate the effect on innovation when  $\rho = 0.02, 0.005, 0.0001$ . In these parameter settings, Assumption.1 is satisfied and  $\tilde{e} < 0.55$ .

puts downward pressure on equilibrium wage (R&D cost), the curve of equation (22) in Panel (b) of Fig. 1 moves downward. This also has a positive effect on innovation. Consequently, by the standard Schumpeterian effect and wage decreasing effect, innovation increases in case 2.

**Proposition 3.** *Strengthening patent protection ( $\chi \uparrow$ ) spurs innovation ( $R^* \uparrow$ ) when the PMC level is sufficiently high ( $e^{\min} < e < \tilde{e}$ ).*

In case 1, the effect on innovation is complex. Strengthening patent protection has a positive impact on innovation through the Schumpeterian effect and wage decreasing effect as in case 2. However, in case 1, the policy also decreases current profit  $\pi_F$  and this negatively affects innovation.<sup>17</sup> While the curve of equation (17) in Panel (a) of Fig. 1 moves upward, the direction of the shift of equation (18) is ambiguous.

However, we can anticipate that the sign of the policy effect depends on discounted rate  $\rho$ . Thus, we numerically examine the effect of strengthening patent protection on innovation. Fig. 5 indicates that while stronger patent stimulates innovation when  $\rho$  is low, it discourages innovation when  $\rho$  is high. However, when  $\rho$  is in between, there is an ambiguous relationship.

We summarize the results as follows:

<sup>17</sup>This effect disappears in case 2 because  $\pi_F = e$  holds and then, the decision of entry for research firms depends on  $aV$  and  $w$  (equation (14)).

**Numerical Result 1.** *Strengthening patent protection ( $\chi \uparrow$ ) has any of negative, ambiguous, or positive effect on innovation when the level of PMC is sufficiently low ( $\tilde{e} < e < e^{\max}$ ).*

Our result differs from the findings in [Chu et al. \(2016\)](#), that is, a stricter patent protection deteriorates growth in the long run. In case 2, our model shows that strengthening patent protection enhances innovation through the Schumpeterian effect. It is widely known that empirical findings on the effects of tightening IPR protection on innovation or economic growth are mixed.<sup>18</sup> To this effect, our ambiguous result is more consistent with the findings of these studies. What are the causes of this variance? To answer this question, let us consider the difference in entry between these models. In [Chu et al. \(2016\)](#), an entrant becomes the monopolist in a differentiated intermediate goods industry with her own patents. Strengthening patent protection attracts many entrants over time, and then, expanding the number of firms gradually decreases market share per firm. Because of this “dilution effect,” the incumbents’ cost-reducing R&D is discouraged in the long run. By contrast, in our model, all entrants (imitators and research firms) are initially followers who imitate the leader’s technology and strengthening patent protection decreases their pre-innovation profit. In case 2, this policy reduces the number of imitators and accordingly, attracts many research firms. This implies that the results depend on whether researchers are damaged by strong patent protection.

We find that strengthening patent protection always enhances innovations in case 2, but discourages them in case 1. The results suggest a complementarity with a competition-enhancing policy, which is consistent with the empirical finding in [Aghion et al. \(2015\)](#), who also theoretically explain the complementarity in a model without free-entry. However, since their result depends on the escape competition effect, such complementarity disappears once we consider free entry, as [Etro \(2007\)](#) discussed. A key contribution of our model is that we are able to retain the complementarity even after incorporating EMS in the model.

## 5 Conclusion

This study developed an analytically tractable innovation model to evaluate the effect of a competition policy on innovation. To analyze the effect more realistically, we considered free entry in the product market and a situation in which only existing firms engage in R&D activities.

Our study makes three contributions to the literature. First, we reconciled the result

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<sup>18</sup>For related studies and surveys, see [Falvey et al. \(2006\)](#), [Rockett \(2010\)](#), and [Greenhalgh and Rogers \(2010\)](#).

of [Aghion et al. \(2005\)](#) and EMS proposed by [Etro \(2007\)](#). We found that a competition-enhancing policy has a non-monotonic effect on innovation, which is also in the model comprising a fixed number of firms by [Aghion et al. \(2005\)](#). Nevertheless, while [Etro \(2007\)](#) points out that non-monotonicity disappears once we consider a framework with EMS, we succeeded in retaining it using a DGE model with EMS. Second, we showed that the innovation-maximizing PMC level does not always maximize welfare and it depends on parameters such as a discount rate. Interestingly, there is a case in which the welfare function has two extreme values with respect to entry cost. Finally, we investigated the effect of strengthening patent protection on innovation. The model demonstrates that stronger patent protection does not necessarily enhance innovation because it decreases pre-innovation profit and research firms exit the market. This effect does not exist in the model without free entry.

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