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Income, Endogenous Market Structure and Innovation

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Abstract

We investigate the effect of income distribution on R&D in a dynamic framework. Our model captures both the infinite R&D race among heterogeneous innovators and a market where successful innovators generate revenues. The market structure of successful innovations is endogenous–firms produce vertically differentiated substitute goods and compete in price. Based on firms' equilibrium market revenues, we derive numerical solutions of the Markov perfect equilibrium innovation rate of the dynamic problem. A key insight in our results is that explicitly modeling price competition and the market structure plays an important role in evaluating the impact of rising income inequality on R&D; furthermore, the way aggregate innovation responds to regulatory policies might also depend on the market structure. Contrary to past findings, we show that increasing income inequality has a negative effect on innovation when the market quality gap is large, in which case, price competition leads to lower revenues and diminishes the innovation incentives. Regarding R&D policies, subsidies are found to dampen the innovation efforts; however, under certain market structure conditions, they also encourage entry to the R&D race. Tax incentives that reduce the variable R&D costs are shown to have positive effects on innovation.

1 Introduction

This paper examines a dynamic innovation race that is driven by demand under an endogenous market structure. In a dynamic framework, we embed a microfoundation that endogenizes the number of incumbents and their revenues by consumer income, and we connect income per capita and inequality to competing firms' R&D incentives. Both the driving force

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of and the obstacles to innovation can largely stem from market demand. As Schumpeter stated, "[profit] is the premium which capitalism attaches to innovation" [15]. Consumers' disposable income and purchasing power construct the market that entrepreneurs face. For example, in information technology, gauging market preferences is critical for determining the success of a new gadget; in areas of health care and renewable energy, significant breakthroughs depend heavily on market needs and the affordability of a certain drug or a clean-energy product. Thus, beyond the inherent merits of inventions, new products can only be a success when they are competitive in price and promising in generating profits in the existing market. This reality underscores the role of market structure in incentivizing innovation; our work is distinguished from the previous literature by introducing market structure endogeneity into a dynamic R&D race.

We found that the effect of increasing income inequality on innovation is sensitive to the market structure. The post-innovation rents received by potential innovators are directly linked to income inequality. Without varying the income per capita, our results indicate that higher inequality might reduce the innovation rate, as decreasing low income levels trigger a price reduction of all goods in the market. However, if generations of innovations have narrower quality gaps (i.e., vertically differentiated products are more similar in quality), the corresponding market structure will not lead to a lower innovation rate when inequality increases - in this case, demand shifts take place instead of price reduction, and market profitability remains constant. By endogenizing the market structure, we have obtained findings that contrast with [6], which does not consider the price competition among successfully innovated firms.

Furthermore, understanding the connection between income and innovation is an important precursor to studying the R&D policies. By endogenizing market structure, our work adds an important dimension to past studies on innovation policies, which generally have assumed a specific market structure. The dependence of innovation incentives on market structure could lead to different insights on R&D policies when market segmentation and profitability vary. We show that R&D subsidies, modeled by reducing the fixed R&D cost, in fact shift firms' innovation rates differently under market structures characterized by higher competition intensity and/or more concentrated income distribution.

The rest of the paper is organized as follows. Section 2 reviews the related studies. We describe the price competition game and analyze the endogenous market structure in Section 3. Then we present the innovation race and analyze the firm's innovation decisions using computation in Section 4. Section 5 discusses the comparative statics results and our findings on the equilibrium innovation rate under different income shocks and the impact of regulatory policies. Section 6 concludes.

2 Literature Review

We characterize the market of generations (qualities) of goods using a vertically differentiated market, based on the static setting introduced by Shaked and Sutton [17]. We relax the assumption of uniform income distribution in [17] by generalizing the distribution, and incorporate a taste shock into the model for consumers at each income level. Thus, within each income segment, consumers are heterogeneous in their preferences for product quality difference. This setting captures an innovative market, where a successful innovator arrives with the latest generation (highest quality) product and engages in price competition with the incumbents. The endogenized market structure depends on the income distribution, consumer taste parameters, and firms' quality gaps. Extending [17], we embed this endogenous market structure in a dynamic model, which formulates the R&D race in an infinite horizon framework.

Studies in the industrial organization literature have examined the connection between market structure and R&D. However, this line of work has primarily focused on a static model that limits the analysis to a single or finite-period model [11] [12]. Innovation is inherently a dynamic process. A new product will eventually be challenged and succeeded by another innovation; the rate of such turnover under economic forces is the interest of this study. Thus, we contribute to this body of literature by formulating a dynamic study.

Vives [18] focuses on the connection between competition and innovation efforts. The study reports that the number of firms increases as the entry cost decreases (implying higher competitive pressure), but R&D efforts per firm decrease [18]. It models an endogenous (exogenous) market structure based on free (restricted) entry. Our paper offers a different insight on the relationship between competition and innovation by endogenizing market structure according to consumer income and preferences. Under our setup, the R&D subsidies do not immediately lead to an increase in the number of innovating firms. When the number of innovating firms is not affected, the R&D efforts per firm decrease as well; however, when the number of firms increases (extensive margin), the higher competitive pressure actually stimulates the R&D efforts (intensive margin). The latter parallels the "escape-competition effect" of the inverted-U relationship discussed in [1]. The "escape-competition effect" occurs when both the extensive margin and the intensive margin exist: the high-type innovators are facing new entrants to the R&D race, and thus innovate more intensively.

On innovation policies, Segal and Whinston provide a dynamic model for analyzing antitrust policy and innovation [16]. We offer an additional dimension by endogenizing the market structure. Without assuming a monopolistic market,[1] we consider a vertically differentiated market where incumbents' profits are determined by the price competition. Moreover, several interesting studies have investigated simultaneously the effect of subsidies on innovative and imitative technologies using growth models [14] [3]. These works consider horizontally differentiated innovative goods [8] [14] [3], whereas we treat generations of innovations as vertically differentiated based on the setting in [17]. The two different perspectives allow for a more in-depth understanding of the role of R&D subsidies. Interestingly, our framework and past studies all show both positive and negative effects of subsidies on innovation.

Our work targets a question that is most closely related to that raised by Foellmi and Zweimuller, which is on the effect of income inequality on innovation and growth [6]. They find that greater income inequality is beneficial for innovation incentives and growth: The effect of the higher price that results from greater income inequality dominates the effect of the larger market size induced by lesser income inequality [6]. Our results contrast sharply with theirs by showing that greater income inequality either does not affect or lowers the innovation rate, depending on the market structure. In Foellmi and Zweimuller's work, firms set monopolistic prices, and consumers purchase a continuum of the differentiated goods subject to a budget constraint [6]; in the absence of price competition, inequality increases immediate post-innovation rents while reducing later revenues as innovators are displaced by newer entrants. Due to discounting, [6] found that inequality increases innovation incentives. Our model assumes substitute goods; thus, each consumer purchases from only one firm based on the equilibrium prices. We characterize heterogeneous consumer taste[2] and price competition; for instance, a rich consumer will prefer the lower quality product if the price premium of the higher quality product does not justify this consumer's taste for the quality difference. Firms' market shares of each income segment are then determined endogenously by consumer income and taste heterogeneity. Therefore, when income becomes more concentrated, a low-quality firm reduces its price to sustain its low-income demand,

[1] [16] assumes that a successful innovator enters the market, receives an entrant's profit in the first period, and then becomes the monopolist if another innovation enters the market.

[2] Taste heterogeneity is inherent in consumers' preferences for varying qualities of products. Taking clean energy as an example, not all rich consumers have a higher valuation for the innovative solar panel; their idiosyncrasies, in this case environmentalism, are reflected in the taste shocks given in our model. Other examples are ubiquitous in technological industries.

which may lead to a price reduction on the high-quality goods as well because of price competition. In other words, the taste heterogeneity intensifies the price competition and thus lead to new implications about income inequality and innovation.

The settings in Foellmi and Zweimuller and in our work characterize industries where innovative products apply different competitive pressures on the incumbent products because of their substitutability. By noting the opposite effect in the substitute goods case, our findings compliment Foellmi and Zweimuller's work, as a mixture of both cases often applies in practice.

Regarding R&D subsidies, the empirical literature has shown inconsistent findings on how subsidies stimulate R&D activities [7]. Our results suggest market structure to be a potential factor influencing such variations. Our findings on the positive effects of tax incentives on innovation are supported by past empirical evidence [5] [9] [2].

3 Price Competition and Market Structure

In our dynamic problem, each discrete period has the discount factor $\beta \in (0, 1)$. In each period, there exist two groups of firms differing in their objectives and actions. The incumbent firms compete on price in the product market, into which the innovations are introduced as the latest generation or the highest quality good; the potential entrants are the firms making innovation decisions in the R&D race. This section presents the model setup for the price competition in each period and analyze firms' pricing strategies and market segmentation based on consumers' preferences. In Section 4, we will analyze the firm's innovation decisions in the infinite horizon: The innovators, prior to successfully innovating and entering the product market, choose whether to enter the R&D race and, if so, determine the equilibrium level of innovation effort.

In Section 5, we solve for the stationary Markov perfect equilibria of the dynamic programming problem using computational methods. Assuming firms do not collude, the pricing strategies in the analysis here are part of the stationary Markov perfect equilibrium of the dynamic game.

3.1 Consumers

The setup here extends Shaked and Sutton [17] by generalizing the consumer income distribution. Consumers are heterogeneous in their income levels and tastes for the product. Denote a consumer's income by $I \in \{I_H, I_L\}$, such that $I_L < I_H$, and $\triangle = I_H - I_L$; let

$\pi_L \in [0,1]$ and $\pi_H \in [0,1]$ be the proportion of low- and high-income segments respectively. $\pi_H + \pi_L = 1$. Define income per capita $\overline{I} = I_H\pi_H + I_L\pi_L$, and the relative high-income ratio $q_h = \frac{I_H}{\overline{I}}$. Thus, the triple $(\overline{I}, q_h, \pi_H)$ characterizes the income distribution of the economy. Furthermore, each consumer experiences a taste shock denoted by the random variable z, which follows the uniform distribution: $z \sim U[\underline{z}, \overline{z}]$. For simplicity, a consumer's taste is fixed across her life.

In each period, consumers observe firms that produce vertically differentiated, substitute goods as a result of the innovation race, described in Section 4. Denote $k = 1, ..., n$ as the index for product quality, where a higher k represents a higher quality.

The consumers are utility maximizing:

$$\max \;\; U(I, z, k) = u_k * (I + z)$$

where $u_k = e^{ak}$ following [4] and $u_0 < u_1 < ... < u_n$. Each consumer's utility is defined by the utility for consuming a certain quality good weighted by the consumer's disposable income and taste. Let C_k be the relative utility difference between products k and $k-1$, and $C_k > 1$:

$$C_k = \frac{u_k}{u_k - u_{k-1}} = \frac{e^a}{e^a - 1} = C.$$

Define z_k^j as the indifference taste level in the income segment j, so that the consumer with taste z_k^j is indifferent between products k and $k-1$ at their respective prices. So for $j \in \{L, H\}$,

$$U(I_j - p_k, z_k^j, k) = U(I_j - p_{k-1}, z_k^j, k-1).$$

From here, we derive:

$$z_1^j = p_1 C_1 - I_j, \tag{1}$$

$$z_k^j = p_{k-1}(1 - C_k) + p_k C_k - I_j. \tag{2}$$

Then, consumers within each income segment with taste $z > z_k^j$ have the preference order $(k, p_k) \succ (k-1, p_{k-1})$.

Proposition 1. *The indifference taste levels z_k^j have the following properties:*

1. $\forall\ k$, $z_k^j > z_{k-1}^j$, *for* $j \in \{L, H\}$;

2. $\forall\ k$, $z_k^H < z_k^L$;

3. $\forall\ k,\ z_k^H + I_H = z_k^L + I_L,$ *so* $z_k^H + \triangle = z_k^L.$

3.2 Market Structure Analysis

Both the high- and low-income groups will be partitioned at the indifference taste levels for market shares of the successive firms in the order of quality. Given two income groups, the market structure is more elaborate than that in Shaked and Sutton (1982). For example, there exist possible scenarios in which lower quality firms only cover the low-income segment while higher quality firms might cover both income segments.

The revenue functions of the competing firms are as follows:

$$R_1(p_1, p_2, ..., p_n) = \begin{cases} p_1(z_2^L - \underline{z})\pi_L, & (!HL)\ z_2^H \leq \underline{z} \text{ and } z_2^L \geq \underline{z}; \\ p_1(z_2^H - \underline{z})\pi_H + p_1(z_2^L - \underline{z})\pi_L, & (HL)\ z_1^L \leq \underline{z} \text{ and } z_2^H \geq \underline{z}; \\ p_1(z_2^H - \underline{z})\pi_H + p_1(z_2^L - z_1^L)\pi_L, & (HL^*)\ z_1^H \leq \underline{z} \text{ and } z_1^L \geq \underline{z}; \\ p_1(z_2^H - z_1^H)\pi_H + p_1(z_2^L - z_1^L)\pi_L, & (H^*L^*)\ z_1^H \geq \underline{z}. \end{cases} \tag{3}$$

In the first two cases, the lowest taste consumers in the low-income segment strictly prefer purchasing the low-quality product over not buying – the low-income market is covered. In case 1, the lowest quality firm serves only part of the low-income group, whereas in case 2, it also serves some high-income consumers. In the last two cases, some low-taste consumers in the low-income segment would not purchase – the low-income market is not covered. In case 3, the high-income segment is covered, whereas in case 4, the high-income market is not covered.

When the high-income consumers do not purchase any low-quality goods, those with the lowest taste for quality would be captured by an intermediate quality level, T, such that $1 < T < n$, with revenue,

$$R_T(p_1, .., p_T, .., p_n) = p_T(z_{T+1}^H - \underline{z})\pi_H + p_T(z_{T+1}^L - z_T^L)\pi_L. \tag{4}$$

For $1 < k < T$, firm k competes only for the low-income group; $R_k(p_1, p_2, ..., p_n)$, the revenue of firm k given the price of its product p_k, is,

$$R_k(p_1, .., p_k, .., p_n) = p_k(z_{k+1}^L - z_k^L)\pi_L. \tag{5}$$

For $T < k < n$, firm k may have demand from both income groups:

$$R_k(p_1, .., p_k, .., p_n) = p_k(z_{k+1}^H - z_k^H)\pi_H + p_k(z_{k+1}^L - z_k^L)\pi_L. \tag{6}$$

And for $k = n$,

$$R_n(p_1, .., p_k, .., p_n) = p_n(\overline{z} - z_n^H)\pi_H + p_n(\overline{z} - z_n^L)\pi_L. \tag{7}$$

Lemma 1. *Assuming $\Delta < \underline{z} + I_L$, the firm producing quality n products serves at least some of the low-income consumers.*

Proof. Suppose firm of quality n does not serve any consumers in the low-income group; then $z_n^L > \overline{z}$ and $z_n^H \geq \underline{z}$. Its revenue function is:

$$R_n(p_1, ..., p_n) = p_n(\overline{z} - z_n^H)\pi_H. \tag{8}$$

The other firms' revenue functions are as the revenue functions (3), (4), (5), and (6). Firm n's revenue function yields the first-order condition (FOC)

$$\overline{z} - 2z_n^L + \Delta - p_{n-1}(C_n - 1) - I_L = 0, \tag{9}$$

which implies $\overline{z} > 2z_n^L - \Delta + I_L$. $z_n^L > \overline{z}$ then leads to $\overline{z} < \Delta - I_L$, which is false given $\Delta < \underline{z} + I_L$. Contradiction.

Note that we do not need to consider the case where $z_n^H < \underline{z}$ because, although firm n does not get any low-income consumers, it will necessarily be better off by lifting z_n^H. Thus, the above contradiction shows that the firm producing quality n products gets at least some low-income consumers. $\square$

The first-order conditions (FOCs) for revenue functions (5) and (6) are equivalent:

- For $1 < k < n$, and $k \neq T$,

$$z_{k+1}^L - z_k^L - p_k[(C_{k+1} - 1) + C_k] = 0; \tag{10}$$

- For $k = T$,

$$z_{T+1}^L - \pi_L z_T^L - \pi_H \underline{z} - \pi_H \Delta - p_T[(C_{T+1} - 1) + \pi_L C_T] = 0; \tag{11}$$

- For $k = n$,

$$\overline{z} - z_n^L + \Delta\pi_H - p_n C_n = 0. \tag{12}$$

Lemma 2. *Let $\overline{z} < min\{(2+2\pi_L)\underline{z} + (2\pi_L+1)I_L + \pi_H\Delta, 4\underline{z} + 3I_L - \pi_H\Delta\}$, for any Nash equilibrium in this vertically differentiated market, at most two firms (producing products of qualities n and $n-1$) obtain positive market shares. Furthermore, let $\overline{z} > 2\underline{z} + 2\Delta - \pi_H\Delta + I_L$, so the firm producing quality n captures some low-income consumers and may share the high-income segment with the firm producing quality $n-1$.*

Proof. By applying equation (2), the FOCs (10), (11), and (12) can be rewritten as:

$$\begin{aligned} z_{k+1}^L - 2z_k^L - p_k(C_{k+1}-1) - p_{k-1}(C_k - 1) - I_L &= 0, & (13)\\ z_{T+1}^L - 2\pi_L z_T^L - \pi_H\underline{z} - \pi_H\Delta - p_T(C_{T+1}-1) - \pi_L p_{T-1}(C_T-1) - \pi_L I_L &= 0, & (14)\\ \overline{z} - 2z_n^L + \Delta\pi_H - p_{n-1}(C_n-1) - I_L &= 0. & (15)\end{aligned}$$

Since $C_k > 1$ for all k, we get the following conditions:

$$\begin{aligned} z_{k+1}^L &> 2z_k^L + I_L, & (16)\\ z_{T+1}^L &> 2\pi_L z_T^L + \pi_H\underline{z} + \pi_H\Delta + \pi_L I_L, & (17)\\ \overline{z} &> 2z_n^L - \Delta\pi_H + I_L. & (18)\end{aligned}$$

Conditions (16) and (17) combined with condition (18) yield:

$$\begin{aligned} \overline{z} &> 4z_{n-1}^L + 3I_L - \pi_H\Delta, & (19)\\ \overline{z} &> 4\pi_L z_{n-1}^L + \pi_H\Delta + 2\pi_H\underline{z} + 2\pi_L I_L + I_L. & (20)\end{aligned}$$

Given the assumption that $\overline{z} < min\{(2+2\pi_L)\underline{z} + (2\pi_L+1)I_L + \pi_H\Delta, 4\underline{z} + 3I_L - \pi_H\Delta\}$, we obtain $z_{n-1}^L < \underline{z}$. This implies that for any given equilibrium, at most two firms obtain positive market shares.

Given the assumption that $\overline{z} > 2\underline{z} + 2\Delta - \pi_H\Delta + I_L$ (which also trivially leads to $\overline{z} > \pi_H\Delta - I_L$), inequality (18) implies that $z_n^L < \overline{z}$ and is necessary for $z_n^H > \underline{z}$; thus, the firm producing quality n will get some of the low-income segment and may share the high-income segment with the successive firm.

Note that $\Delta < \underline{z} + I_L$ ensures that the range $2\underline{z} + 2\Delta - \pi_H\Delta + I_L < \overline{z} < min\{(2+2\pi_L)\underline{z} + (2\pi_L+1)I_L + \pi_H\Delta, 4\underline{z} + 3I_L - \pi_H\Delta\}$ is non-empty. □

3.3 Two-Firm Equilibrium

Based on the conditions given by Lemma 2, we analyze the equilibrium prices and profits of the two vertically differentiated firms in the market. Let firm 1 be the low-quality firm and firm 2 be the high-quality firm.

Define $V \equiv \frac{u_2 - u_0}{u_2 - u_1} = \frac{C_2 - 1}{C_1} + 1$. We have:

$$
\begin{aligned}
p_1 &= \frac{z_1^j + I_j}{C_1}; && (21)\\
p_2 &= \frac{z_2^j + I_j + (z_1^j + I_j)(V-1)}{C_2}. && (22)
\end{aligned}
$$

Firm 1's revenue functions take the forms of those in Eq. (3), except the case $(!HL)$, where high-income consumers are not part of firm 1's demand. When two firms occupy the market, because firm 2 does not capture the entire high-income segment, both high- and low-income groups will be shared by the two firms. The remaining three cases yield the following first-order conditions:

$$
z_2^L = \begin{cases} \pi_H \Delta + \underline{z} + (z_1^L + I_L)(V-1), & (HL) \\ \pi_H(\Delta + \underline{z}) + z_1^L \pi_L + (z_1^L + I_L)(V - 1 + \pi_L), & (HL^*) \\ z_1^L + (z_1^L + I_L)V. & (H^*L^*) \end{cases} \quad (23)
$$

From the highest quality firm's revenue function, (7), firm 2's FOC is:

$$
z_2^L = \frac{1}{2}\left[\overline{z} + \pi_H \Delta - I_L - (z_1^L + I_L)(V-1)\right]. \quad (24)
$$

Figure 1 plots firm 1's FOCs for different ranges of z_1^L. Regions I, III, and V in the figure correspond to the cases of (HL), (HL^*), and (H^*L^*) in firm 1's revenue functions; and Regions II and IV are the regions between the adjacent cases. In these regions, in equilibrium one firm varies its price while the other holds its price constant. Note that from Eq. (23), firm 1's FOCs are expressed as functions $z_2^L(z_1^L)$, which is increasing, whereas from Eq. (24) firm 2's FOCs are decreasing functions. The point of intersection is the equilibrium taste levels z_1^{L*} and z_2^{L*}, from which equilibrium prices are calculated.

Two firms' FOC intersect in Region I, if at $z_1^L = \underline{z}$, firm 2's z_2^L lies below that of firm 1. This implies the condition $V \geq \frac{\overline{z} - I_L - \pi_H \Delta - 2\underline{z}}{3(\underline{z} + I_L)} + 1$. Similarly, we can derive the boundary conditions for Regions II through V (see Table 1).

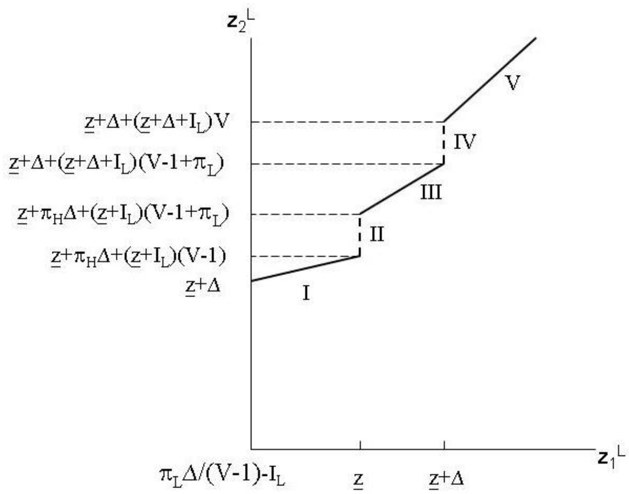

Figure 1: Firm 1's First-Order Conditions

Table 1: Boundary Conditions for Regions I, II, III, IV, and V

Region I	$V \geq \frac{\overline{z}-I_L-\pi_H\Delta-2\underline{z}}{3(\underline{z}+I_L)}+1$
Region II	$\frac{\overline{z}-I_L-\pi_H\Delta-2\underline{z}}{3(\underline{z}+I_L)}+1 \geq V \geq \frac{\overline{z}-I_L-\pi_H\Delta-2\underline{z}}{3(\underline{z}+I_L)}+1-\frac{2\pi_L}{3}$
Region III	$\frac{\overline{z}-I_L-\pi_H\Delta-2\underline{z}}{3(\underline{z}+I_L)}+1-\frac{2\pi_L}{3} \geq V \geq \frac{\overline{z}+\pi_H\Delta-\Delta-\underline{z}}{3(\underline{z}+\Delta+I_L)}+\frac{2\pi_H}{3}$
Region IV	$\frac{\overline{z}+\pi_H\Delta-\Delta-\underline{z}}{3(\underline{z}+\Delta+I_L)}+\frac{2\pi_H}{3} \geq V \geq \frac{\overline{z}+\pi_H\Delta-\Delta-\underline{z}}{3(\underline{z}+\Delta+I_L)}$
Region V	$V \leq \frac{\overline{z}+\pi_H\Delta-\Delta-\underline{z}}{3(\underline{z}+\Delta+I_L)}$

Lemma 3. *Assume* $1.5\Delta < \underline{z}+I_L$*, and let* $2\underline{z}+2\Delta+I_L+\pi_L\Delta-\pi_H\Delta < \overline{z} < min\{(2+2\pi_L)\underline{z}+(2\pi_L+1)I_L+\pi_H\Delta, 4\underline{z}+3I_L-\pi_H\Delta\}$*; there exists a unique equilibrium where exactly two firms have positive market share. The possible regions where the equilibrium lies include Regions I and II. Moreover, both low- and high-income markets are covered (i.e., the equilibrium does not lie in Region III, IV or V).*

Proof. Since both firms occupy both income markets, $z_2^L \geq \underline{z} + \Delta$. From the conditions of the revenue functions in (3), we see that z_1^L is the lowest in case (HL). And Eq. (23) is increasing in z_1^L, while Eq. (24) is decreasing in z_2^L. Thus, if firm 2's z_2^L lies above that of firm 1 on the left end of case (HL), then a unique equilibrium exists.

By firm 1's FOCs (23) in case (HL), $z_1^L = \frac{\pi_L\Delta}{V-1} - I_L$, at $z_2^L = \underline{z} + \Delta$. That $\overline{z} \geq 2\underline{z} + 2\Delta + I_L + \pi_L\Delta - \pi_H\Delta$ implies $z_2^L \geq \underline{z} + \Delta$ in firm 2's FOC (24) at $z_1^L = \frac{\pi_L\Delta}{V-1} - I_L$. Therefore, a unique equilibrium exists with the conditions $2\underline{z} + 2\Delta + I_L + \pi_L\Delta - \pi_H\Delta < \overline{z} < min\{(2 + 2\pi_L)\underline{z} + (2\pi_L + 1)I_L + \pi_H\Delta, 4\underline{z} + 3I_L - \pi_H\Delta\}$.

Suppose $\overline{z} = (2+2\pi_L)\underline{z}+(2\pi_L+1)I_L+\pi_H\Delta$; Region III conditions in Table 1 imply that $V \leq 1$. Given $\overline{z} < min\{(2+2\pi_L)\underline{z}+(2\pi_L+1)I_L+\pi_H\Delta, 4\underline{z}+3I_L-\pi_H\Delta\}$, if the equilibrium were to lie in Region III, then $V < 1$, which cannot hold because V must be greater than 1. Therefore, the equilibrium only occurs in Region I or II. And in these regions, both high- and low-income markets are covered. □

We now derive the equilibrium prices and revenues for Regions I and II. Only the case (HL) from firm 1's revenue functions (3) is relevant at this point. Thus, we have the following FOCs of the two competing firms:

$$z_2^L = \pi_H\Delta + \underline{z} + (z_1^L + I_L)(V-1); \tag{25}$$
$$z_2^L = \frac{1}{2}\left[\overline{z} + \pi_H\Delta - I_L - (z_1^L + I_L)(V-1)\right]. \tag{26}$$

Then we get the equilibrium taste indifference levels:

$$z_1^{L*} = \frac{\overline{z} - 2\underline{z} - \pi_H\Delta - I_L}{3(V-1)} - I_L; \tag{27}$$
$$z_2^{L*} = \frac{1}{3}\left[\overline{z} + \underline{z} + 2\pi_H\Delta - I_L\right]. \tag{28}$$

The equilibrium prices and revenues then follow. They are summarized in Table 2.

Table 2: Equilibrium Prices and Revenues in Regions I and II

	Price	Revenue
Region I	$p_1^* = \frac{\overline{z}-2\underline{z}-\pi_H\Delta-I_L}{3(C-1)}$ $p_2^* = \frac{2\overline{z}-\underline{z}+\pi_H\Delta+I_L}{3C}$	$R_1^* = \frac{(\overline{z}-2\underline{z}-\pi_H\Delta-I_L)^2}{9(C-1)}$ $R_2^* = \frac{(2\overline{z}-\underline{z}+\pi_H\Delta+I_L)^2}{9C}$
Region II	$p_1^* = \frac{\underline{z}+I_L}{C}$ $p_2^* = \frac{\overline{z}+\pi_H\Delta+I_L+(\underline{z}+I_L)(V-1)}{2C}$	$R_1^* = \frac{\underline{z}+I_L}{2C}[\overline{z} - \pi_H\Delta - I_L - 2\underline{z} - (\underline{z} + I_L)(V-1)]$ $R_2^* = \frac{[\overline{z}+\pi_H\Delta+I_L+(\underline{z}+I_L)(V-1)]^2}{4C}$

4 Innovating Firms

This section describes the innovation race and firms' innovation decisions. Potential entrants make decisions in three stages: 1) Entry to the innovation race – firms choose whether to innovate; 2) Innovation effort – firms choose the level of R&D, which affects their probability of successful innovation and hence the probability of market entry; 3) In case of market entry, firms choose their prices, which are described in the equilibrium results in the previous section (see Table 2). Our setup follows the framework developed by Segal and Whinston [16] with the extension of heterogeneity of innovation costs across firms.

There exist M firms that are potential entrants. Every period, they pick up a draw ϵ from a distribution $F(\cdot)$. This draw affects the cost of innovation, which is $\epsilon c(\phi_i(\epsilon))$. Assume the cost function $c(\cdot)$ is convex. $\phi_i(\epsilon) \in (0, 1)$ is the innovation rate of firm i with the draw ϵ, and also firm i's probability of creating a new product.

Assuming $\epsilon \in \{\epsilon_l, \epsilon_h\}$ follows the Bernoulli distribution,[3] the probability of obtaining the draw ϵ_h is η, $\epsilon_l < \epsilon_h$. For simplicity, let the number of firms obtaining the draw ϵ_l in each period be M^l (by the Law of Large Numbers $M^l \approx (1 - \eta)M$).

Multiple innovators may succeed in developing new products. However, only one of these innovations is granted a patent. The firm with a patent then enters the product market and becomes an incumbent producing the highest quality product. We use the simultaneous

[3]The firms with draw ϵ_l are essentially the high-type firms with low variable R&D cost; and firms with draw ϵ_h are the low-type firms. To avoid confusion, instead of using terms of high and low types, we refer to them as low-cost and high-cost firms, respectively.

entry and exit setup; thus, the lowest quality incumbent is pushed out of the market when a new firm enters. The innovation model connects to the market structure analysis at this point, as the post-innovation rents are characterized by the equilibrium market structure (see Table 2).

Let $\pi(\phi^I_-)$ denote the probability of at least one firm successfully creating a new product, where $\phi^I_- \in [0,1]^N$ describes the innovation efforts of all potential entrants. Because in each period only one of these firms is granted a patent and enters the market, the probability of actually obtaining the patent is denoted by $\lambda(\phi, \phi_-)$, where $\phi_- \in [0,1]^{N-1}$ is the innovation efforts of the rest of the innovators. In a symmetric equilibrium, firms with the same draw will make the same decision. Thus, we only consider whether both low- and high-cost firms choose to innovate. Both $\pi(\phi^I_-)$ and $\lambda(\phi, \phi_-)$ have different formulations when either all the firms innovate or only one type of firms innovate. Thus, we analyze these formulations case by case.

If *all firms innovate*, the probability of at least one firm successfully creating a new product among M potential entrants with M^l low-cost innovating firms is denoted by $\pi_{M,M^l}(\phi^I_-)$, where:

$$\pi_{M,M^l}(\phi^I_-) = [1 - (1-\phi(\epsilon_h))^{M-M^l}(1-\phi(\epsilon_l))^{M_l}]. \tag{29}$$

Among M potential entrants with M^l low-cost innovating firms, conditional on successful innovation, the probability of obtaining a patent for any one firm is denoted by $r^i_{M,M^l}(\phi_-)$, where $i \in \{h, l\}$:

$$\begin{aligned} & r^h_{M,M^l}(\phi_-) \\ = & \sum_{x=0}^{M-M^l-1} \sum_{y=0}^{M^l} \left[\binom{M-M^l-1}{x} \binom{M^l}{y} \frac{\phi(\epsilon_h)^x (1-\phi_h)^{M-M^l-1-x} \phi(\epsilon_l)^y (1-\phi(\epsilon_l))^{M^l-y}}{x+y+1} \right], \\ & r^l_{M,M^l}(\phi_-) \\ = & \sum_{x=0}^{M-M^l} \sum_{y=0}^{M^l-1} \left[\binom{M-M^l}{x} \binom{M^l-1}{y} \frac{\phi(\epsilon_h)^x (1-\phi_h)^{M-M^l-x} \phi(\epsilon_l)^y (1-\phi(\epsilon_l))^{M^l-1-y}}{x+y+1} \right]. \end{aligned}$$

The probability of obtaining a patent for this firm with high or low cost among M potential entrants with M^l low-cost innovating firms is, respectively, then $\lambda^i_{M,M^l}(\phi(\epsilon_i), \phi_-)$, where

$i \in \{h, l\}$:

$$\begin{aligned} \lambda^h_{M,M^l}(\phi(\epsilon_h), \phi_-) &= \phi(\epsilon_h) r^h_{M,M^l}(\phi_-), \\ \lambda^l_{M,M^l}(\phi(\epsilon_l), \phi_-) &= \phi(\epsilon_l) r^l_{M,M^l}(\phi_-). \end{aligned}$$

If *only low-cost firms innovate*, the probability of at least one firm successfully creating a new product is:

$$\pi_{M^l,M^l}(\phi^I_-) = [1 - (1 - \phi(\epsilon_l))^{M^l}]. \tag{30}$$

The conditional probability for a given firm is:

$$r^l_{M^l,M^l}(\phi_-) = \sum_{k=0}^{M^l-1} \left[\frac{1}{k+1} \binom{M^l-1}{k} \phi(\epsilon_l)^k (1 - \phi(\epsilon_l))^{M^l-1-k} \right].$$

And based on the above equations, the probability of a (low-cost) firm's obtaining a patent is:

$$\lambda^l_{M^l,M^l}(\phi(\epsilon_l), \phi_-) = \phi(\epsilon_l) r^l_{M^l,M^l}(\phi_-). \tag{31}$$

Following [16] we use the dynamic programming approach to formulate this problem and look for the stationary Markov perfect equilibria. The value functions of the innovating firms are listed below:[4]

$$\begin{aligned} V^0(\epsilon, \phi_-) &= max\{0, -f + V^E(\epsilon, \phi_-)\}; & (32) \\ V^E(\epsilon, \phi_-) &= max_\phi\{\lambda(\phi, \phi_-)V^I_J + (1 - \lambda(\phi, \phi_-))\beta E V^0(\epsilon', \phi'_-) - \epsilon c(\phi)\}; & (33) \\ V^I_i(\epsilon, \phi_-) &= R_i + \beta\pi(\phi^I_-)V^I_{i-1}(\epsilon, \phi_-) + \beta(1 - \pi(\phi^I_-))V^I_i(\epsilon, \phi_-), & (34) \\ & \quad i = 2, ..., J; & \\ V^I_1(\epsilon, \phi_-) &= R_1 + \beta\pi(\phi^I_-)EV^0(\epsilon', \phi'_-) + \beta(1 - \pi(\phi^I_-))V^I_1(\epsilon, \phi_-). & (35) \end{aligned}$$

$V^0(\epsilon, \phi_-)$ is the value function of potential entrants at the start of each stage game; $V^E(\epsilon, \phi_-)$ is the value function of entrants in the R&D race; and $V^I_i(\epsilon, \phi_-)$ and $V^I_1(\epsilon, \phi_-)$ are the value functions for incumbents producing product quality i and the lowest quality product before exiting, respectively. We show that the dynamic programming problem described by Eq. (32) through (35) satisfies the Blackwell sufficient conditions; thus, it has a unique fixed point in a bounded space.

[4]Since draws of high and low costs are taken in each period, the draw of the next period is denoted with an apostrophe (ϵ').

Lemma 4. *The dynamic programming problem characterized by Eq. (32) through (35) has a unique fixed point.*

Proof. We need to show that the problem defined by Eq. (32) through (35) satisfies Blackwell sufficient conditions. Define the operator T as follows:

$$Tv^0(\epsilon, \phi_-) = max\{0, -f + V^E(\epsilon, \phi_-)\}, and$$

$$V^E(\epsilon, \phi_-) = max_\phi g(\phi, \epsilon, \phi_-) + \tilde{\beta}(\phi) E v^0(\epsilon', \phi'_-),$$

where $g(\phi, \epsilon, \phi_-) = \frac{\lambda}{1-\beta(1-\pi)} R_2 + \frac{\beta\lambda\pi}{(1-\beta(1-\pi))^2} R_1 - \epsilon\phi^2 - f$. $\tilde{\beta}(\phi) = \left(\frac{\lambda(\beta\pi)^2}{(1-\beta(1-\pi))^2} + 1 - \lambda\right)$. Here λ stands for $\lambda(\phi, \phi_-)$. π represents $\pi(\phi_-)$.

1) Monotonicity. Let $x_1(\epsilon, \phi_-)$ and $x_2(\epsilon, \phi_-)$ be two bounded functions. $x_1(\epsilon, \phi_-) \leq x_2(\epsilon, \phi_-)$ for all (ϵ, ϕ_-). Let ϕ^* be the optimal solution for the second term in equation (32) given x_1. $V^E(\epsilon^*, \phi_- : x_1) \leq V^E(\epsilon^*, \phi_- : x_2)$. Let ϕ^{**} be the optimal value for the optimization problem of $V^E(\epsilon, \phi_-)$ given x_2. Then $V^E(\epsilon^*, \phi_- : x_2) \leq V^E(\epsilon^{**}, \phi_- : x_2)$. Thus, $Tx_1(\epsilon, \phi_-) \leq Tx_2(\epsilon, \phi_-)$, and the monotonicity condition is satisfied.

2) Discounting. $T(v+a)(\epsilon, \phi_-) = max\{0, -f + max_\phi \ (g(\phi, \epsilon, \phi_-) + \tilde{\beta}(\phi)(Ev(\epsilon', \phi'_-) + a))\}$. Obviously $\tilde{\beta}(\phi) < 1$. Then $T(v+a)(\epsilon, \phi_-) \leq max\{\bar{\beta}a, -f + max_\phi \ (g(\phi, \epsilon, \phi_-) + \tilde{\beta}(\phi)a + \bar{\beta}Ev(\epsilon', \phi'_-))\} = Tv(\epsilon, \phi_-) + \tilde{\beta}(\phi)a$. □

In a symmetric equilibrium of interest, the firms with the same shocks have the same innovation rate. Obviously, the firms do not innovate if they are not in the market. A potential entrant observes its competitors' action and its type, then decides whether to enter the R&D race, and identifies its optimal R&D efforts. In equilibrium, its decision should be the same as that of other firms with the same shocks.

Because of the complexity of the dynamic problem, we use computation methods to find the numerical solutions to the problem described by Eq. (32) through (35). In particular, given $\phi_-(\epsilon)$, we solve this problem using the value function iteration method and derive the policy function $\phi(\epsilon, \phi_-(\epsilon))$. We then evaluate the distance between the derived innovation rate $\phi(\epsilon, \phi_-(\epsilon))$ and the original guess and update the $\phi_-(\epsilon)$ to find the solutions of these equations.[5] We also try a large set of initial guesses to check whether there may exist multiple equilibria. Our computation results are robust under different initial guesses.

[5] We use the "$fsolve''$ function in Matlab to solve this system of equations.

5 Equilibrium Results and Comparative Statics

In this section, we turn to the discussion of our key results regarding the effect of income per capita and income inequality on firms' equilibrium innovation rate. We analyze the change in innovation rates of firms with different shocks, as well as the aggregate innovation level. We then illustrate the implications of public policies, such as R&D tax credits and subsidies, using numerical examples.

5.1 Parameterization

The aim of our analysis is to provide insight into the qualitative properties of the equilibrium innovation rate under the effect of income shocks and different types of innovation policies. Although some parameters are chosen from standard values and previous literature, they are not based on data from specific industries.

The discount rate $\beta = 0.95$ implies the annual interest rate is approximately 5 percent. a in the utility function is 1.4. The income per capita $\overline{I}$ is 0.75. We divide the whole population into two classes: Rich and Poor, each of which has half of the whole population. The relative high income q_h is set to 1.33. We assume half of consumers have high income. The upper bound of the taste shock $\overline{z}$ is 4.2, while the lower bound $\underline{z}$ is 1.2. The sunk cost of innovation f is set to 0.1. As for the functional form of innovation cost $c(\cdot)$, we follow Aghion et al.'s model and use quadratic form, $c(\epsilon) = \epsilon\phi^2$ [1]. Firms with high variable costs for innovation have $\epsilon_h = 20$. Firms with low variable costs for innovation have $\epsilon_l = 10$. We also assume the number of potential entrants is 10 each period and the number of firms with high innovation costs is 5. We set these numbers relatively low to reduce the computation load.

With the above parameterizations, both types of firms conduct innovation. The innovation rate for the firms with high innovation costs is 9.33 percent. The innovation effort of the rest of firms is higher, 19.48 percent, as their innovation costs are lower. And the equilibrium prices fall in Region 2. If we set $a = 1.1$, then the equilibrium falls into Region 1. The firms with high innovation cost have an innovation effort of 8.6 percent. The firms with low innovation cost have an innovation rate of 17.91 percent.

The parameter a characterizes a consumer's valuation for quality. When a is greater, a consumer's utility towards a higher quality of good is higher. Thus, the reward of being a technology leader is greater,[6] and the potential entrants have higher incentive to innovate.

[6] Our analysis focuses on the "relative" quality, as the gap between technology leader and follower is constant across time and the valuation of consumer is also constant.

The aggregate innovation in Region 2 is higher than that in Region 1. In the following exercises, we discuss firms' innovation behaviors in different regions separately. Most of the parameters follow the baseline parameterizations, and we study only one kind of shock in each exercise.

5.2 Innovation and Income Distribution

In this section, we investigate the effect that varying the distribution of consumer incomes has on firms' innovation decisions. As mentioned before, the consumer's income in this economy is characterized by three quantities: income per capita $\overline{I}$, relative high income level $q_h = \frac{I_H}{\overline{I}}$, and the fraction of rich people π_H. We focus on the effects of varying income per capita $\overline{I}$ and varying income inequality q_h.[7]

Varying income inequality to examine the innovation rate yielded an important insight: The price competition among the incumbents is critical when examining the effect of income inequality on the innovation rate. We have found that increasing inequality does not encourage innovation. When income levels become more polarized, a decreasing low-income level triggers overall price reduction due to price competition. Thus, the post-innovation rents are diminished, which discourages innovation. We also incorporate taste heterogeneity among consumers, which relaxes the assumption in the past literature [17] [6] that high-income consumers always prefer the higher quality good. A consumer's willingness to pay for a higher quality good based on her income is moderated by her taste toward a higher quality good; some wealthy consumers may purchase a lower quality good, while some poor consumers (with strong taste for higher quality) may purchase the higher quality good. This formulation allows for market segmentation within a group of consumers of the same income level. As a result, price competition propagates through all firms in the market as income inequality sharpens.

Another important finding is that the effect of income inequality on innovation is sensitive to market structure, which highlights the feature of endogenous market structure in our framework. We found that the equilibrium innovation rate reacts differently to varying inequality under two equilibrium regions obtained in our microfoundation. In Region 2, income inequality has an adverse effect on innovation, as discussed, whereas in Region 1, the innovation rate stays constant. The parameter value a is crucial in determining the equilibrium regions: When quality gaps of the incumbents are small, and/or the income

[7] Generally, Gini coefficient is used to measure the degree of equality in an economy. In our setup, the Gini coefficient is $\frac{1}{2}(1-(1-\pi_H)f_l-(f_l+1)\pi_H)$, where $f_l = \overline{I} - q_h\pi_H$. In our analysis, we fix π_H and vary q_h to study the effect of varying income inequality.

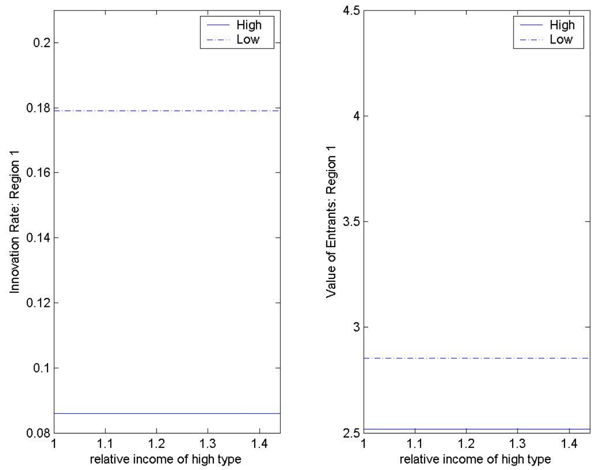

Figure 2: Innovation and Income Inequality – Region 1

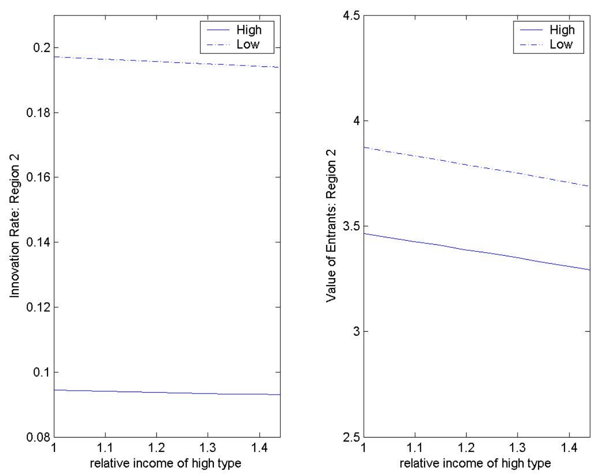

Figure 3: Innovation and Income Inequality – Region 2

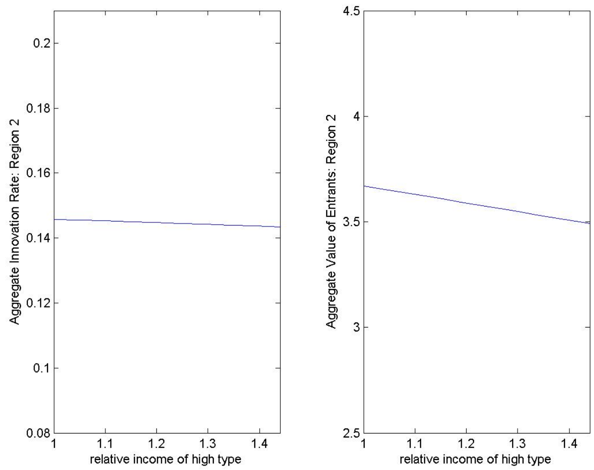

Figure 4: Aggregate Innovation and Income Inequality – Region 2

inequality is low, the results fall under Region 1; when the quality gaps widen, and/or income inequality becomes high, Region 2 takes over. In the former case, increasing inequality causes equal shifting of market demand from the low-income (high-income) segment to the high-income (low-income) segment for the higher-quality (lower-quality) firm, without any price change; therefore, all firms' profits stay the same,[8] which does not disturb the innovation rate (see Figure 2). In the latter case, wide quality gaps allow the low-quality firm to set the price only low enough to cover the low-income market. Increased inequality further brings down the low-income level and, in turn, pushes down the low-quality firm's equilibrium price. Because of the price competition, all firms' equilibrium prices are lowered. The expected value of a potential innovator is then reduced because of price undercutting; thus, innovation is discouraged (see Figure 3).

Our results shed light on evaluating the effect of rising income inequality on aggregate innovation. It is well-known that income inequality rose rapidly after World War II. The Gini coefficient, the common measure of income inequality, increased about 16 percent from 1947 to 2008. The rising income inequality changes consumers' demand and thus the firms' incentives to innovate, as the analysis shows. In particular, our analysis shows that the impact of rising inequality may vary in different industries, as the consumers may have different valuations for qualities of goods.

For income per capita, the equilibrium innovation rates are increasing in both regions, and the increase is more pronounced in Region 2 (see Figures 5 and 6). Intuitively, higher

[8] Recall that income per capita is held constant here.

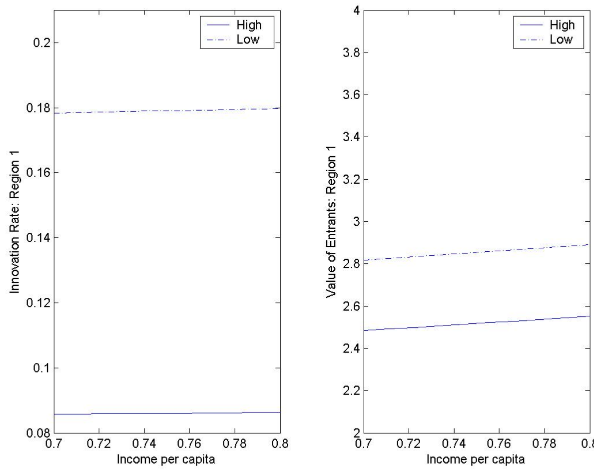

Figure 5: Innovation and Income per Capita – Region 1

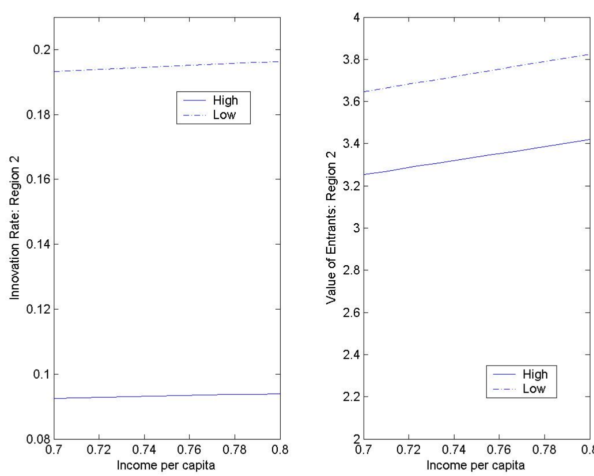

Figure 6: Innovation and Income per Capita – Region 2

income per capita elevates consumers' purchasing power, which generates higher profits for firms and increases post-innovation rents of the innovators. This result is consistent with the procyclicality of R&D in the empirical studies. Again, our results indicate that market structure plays a role in the magnitude of the effect.

5.3 Innovation and Policy

To understand innovation policies, we examined those that regulate different R&D costs. In our model, the innovators incur both variable and fixed costs for conducting R&D. They are heterogeneous in their variable costs determined by a shock in each period. The fixed costs are associated with the upfront overhead expenditures, such as setting up or upgrading research facilities, whereas the variable costs depend on the intensity of the R&D efforts. The number of projects under way, size of the R&D group, degrees of internal and external collaboration, and so on all contribute to the variable innovation costs. The high-type innovators have a lower variable R&D cost and incur lower expenses for the same innovation level as that of the low-type innovators, who have a higher variable cost.

To illustrate the utilization of subsidies, we lower innovators' fixed R&D cost, as subsidies provide assistance for overcoming the barriers of conducting R&D and shift up the total firm value [10] [13]. We found that subsidies that directly lower the fixed R&D cost may have a negative effect under certain market structures (Region 2, see Figure 9); under a different market structure, subsidies may have mixed effects, yet still do not continuously stimulate innovation (Region 1, see Figure 7). By alleviating the R&D barrier, subsidies also undermine innovating firms' incentives to exert greater innovation efforts because expected revenues shift upward; thus, firms become "lazier." However, as subsidies mitigate the intensity of innovation competition in such fashion, they also encourage entry to the R&D race, thus improving the aggregate innovation rate. This effect is marked by the jumps in Figure 7. It shows that as the equilibrium innovation rate reduces to a certain level, high-cost innovators perceive a reasonable chance of success and enter the race. At this point the aggregate innovation rate has an upward shift because of a higher number of active innovators and increased R&D competition (see Figure 8). Therefore, subsidies have the effect of lowering the barrier to the R&D race but do not act as a short-term stimulus.

Our results also yield insights on the relationship between innovation and competitive pressure. As R&D subsidies lower the fixed cost, the increase in competition leads to a surge in the aggregate innovation because both the extensive margin and the intensive margin occur simultaneously as shown in Figure 7 and 8. The extensive margin is reflected in the entry

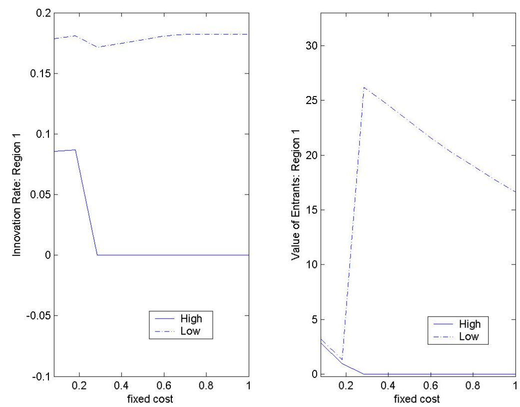

Figure 7: Innovation and Fixed Costs – Region 1

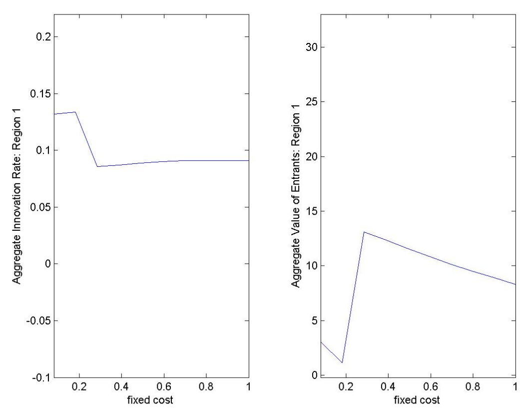

Figure 8: Aggregate Innovation and Fixed Costs – Region 1

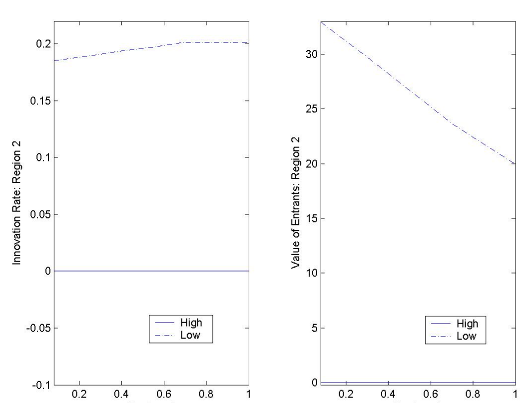

Figure 9: Innovation and Fixed Costs – Region 2

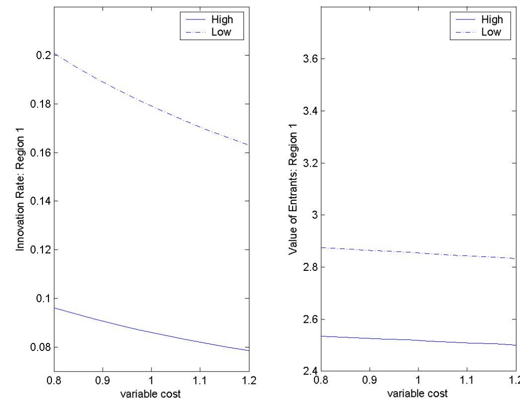

Figure 10: Innovation and Variable Costs – Region 1

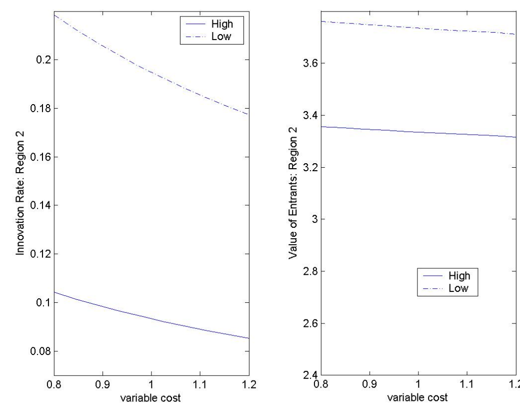

Figure 11: Innovation for Variable Costs – Region 2

of high-cost innovators into the R&D race, whereas the intensive margin is characterized by an upward jump in the innovation rate of both types of innovators. However, in the absence of the extensive margin, the innovation rate decreases (see Figure 9). The extensive margin illustrated is consistent with Vives's work [18], while the intensive margin that takes place simultaneously results from the "escape-competition effect" explained by Aghion et al. in the context of the inverted-U relationship [1].

In the analysis of tax incentives, we apply tax credits as a reduction of the variable R&D costs–across various countries similar fiscal incentives exist to stimulate dollars spent on innovation.[9] We found that reducing variable R&D costs has a generally favorable effect and encourages all types of innovators to exert higher effort.

As Figure 10 shows, as the variable cost decreases, both the value and innovation rate

[9]Hall and Reenen (2000) provides an extensive overview of the tax treatment of R&D in different nations [9].

increase for both types of firms. Similar to the previous observations with income per capita, the effect is pronounced in Region 2 (see Figure 11). And we see that reducing variable R&D costs improves the aggregate innovation.[10] These policies also increase firms' values in equilibrium.

6 Concluding Remarks

We have studied the effect of income on competing firms' innovation rate using a framework that combines endogenous market structure and the dynamic model with heterogeneous innovators. This model adds significant richness to the past literature by incorporating the competition of market incumbents, as well as the infinite horizon of the dynamic R&D race.

We found that while increasing income per capita affects innovation positively, high income inequality may reduce the innovation rate, which contradicts past findings [6]. Furthermore, by endogenizing market structure, we discovered that the change in the innovation rate resulting from income depends on the equilibrium market structure. Similarly, the way an R&D policy shapes innovation may also be conditional on the market structure, according to our results on R&D subsidies and tax credits. Therefore, our work offers an important contribution by identifying this important link between the endogeneity of market structure and the analysis of firms' innovation incentives and R&D policies. This work emphasizes the sensitivity of policy impact during turbulent business cycles and calls for extensive future work on R&D policies that take into account related factors.

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[10] [18] considers reducing variable costs as process innovation. Because our paper focuses on product innovation, we assume all the firms have the same level of process innovation; varying the variable costs then is the common shock to the level of process innovation in the economy.

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