# Love of Novelty: A Source of Innovation-Based Growth... or Underdevelopment Traps?

Furukawa, Yuichi and Lai, Tat-kei and Sato, Kenji

Chukyo University, IÉSEG School of Management and LEM-CNRS 9221, Osaka Prefecture University

July 2019

# Love of Novelty: A Source of Innovation-Based Growth... or Underdevelopment Traps?*

Yuichi Furukawa,† Chukyo University and RIETI

Tat-kei Lai, IÉSEG School of Management and LEM-CNRS 9221

Kenji Sato, Osaka Prefecture University

July 2019

**Abstract**

This study develops a new dynamic general equilibrium model to explore the role of people's love of novelty in innovation and innovation-based growth. The model considers (a) an infinitely lived representative consumer who has standard love-of-variety preferences for differentiated products and additional love-of-novelty preferences for new products, and (b) technological progress driven by two costly and time-consuming innovation activities, new product development and existing product development. We demonstrate that consumer love of novelty is a source of innovation-based growth, in the sense that economies with a moderate love of novelty can achieve innovation and long-run growth through cycles between periods in which new product development is active and those in which existing product development is active. However, if the preference for novelty is too strong—or too weak—the economy is caught in an underdevelopment trap with less innovation and no long-run growth. Our results suggest that the love of novelty is a source of innovation-based growth, but it can lead to an underdevelopment trap if it is too strong, according to recent empirical evidence.

*JEL Classification Codes*: E32; O40; Z10

*Keywords*: Love/fear of novelty; innovation; innovation-based economic growth

*This study is conducted as part of a research project, Evidence-based Policy Study on the Law and Economics of Market Quality, undertaken by the Research Institute of Economy, Trade and Industry (RIETI). An earlier version of this paper was part of *RIETI Discussion Paper Series* 18-E-073 under the title "Novelty-Seeking Traits and Innovation." The authors would like to thank Taro Akiyama, Tomohiro Ara, Martine Carré-Tallon, Nicola Coniglio, Mario Curucini, Erkan Gören, Gene Grossman, Makoto Hanazono, Tomoya Hanibuchi, Keisaku Higashida, Takeo Hori, Mitsuhide Hoshino, Kenta Ikeuchi, Jun-ichi Itaya, Arata Ito, Takashi Kamihigashi, Yoshimasa Komoriya, Keisuke Kondo, Sung-Ho Lee, Ryo Makioka, Junya Masuda, Kiyoshi Matsubara, Koyo Miyoshi, Akira Momota, Masayuki Morikawa, Hiroshi Mukunoki, Takumi Naito, Kenta Nakamura, Masao Oda, Ryoji Ohdoi, Yuka Ohno, Masayuki Okawa, Rui Ota, Pascalis Raimondos, Yoko Sakamoto, Yoichi Sugita, Takaji Suzuki, Yasuhiro Takarada, Yasuo Takatsuki, Yoshihiro Tomaru, Yoshiaki Usui, Annalisa Vinella, Akihiko Yanase, Makoto Yano, and the conference/seminar/meeting participants at Economic Theory and Policy Workshop, Fukushima Economics Workshop 2018, Chonnam National University, Copenhagen Business School, Dosisha University (Goshokita Seminar), 2015/2017 IEFS Japan Annual Meeting, IÉSEG School of Management, Japan Patent Office, Paris-Dauphine University, RIETI (Discussion Paper Seminar), Sophia University, University of Bari, University of Porto, and Yokohama National University for their helpful comments and support. Yuichi Furukawa acknowledges the partial financial support from a Research Grant Program of the Toyota Foundation, JSPS Grant-in-Aids for Scientific Research (C) #18K01522 and for Scientific Research (B) #16H03612, and RIETI. Kenji Sato acknowledges the partial financial support of a Grant-in-Aid for JSPS Research Fellow and a JSPS Grant-in-Aid for Scientific Research (C) #16K03552.

†Corresponding author. Email address: you.furukawa@gmail.com

# 1 Introduction

It is a commonplace assertion in economics that culture, like institutions and geography, is a fundamental cause of cross-country differences in macroeconomic performance (Acemoglu et al. 2005). However, as Mokyr (2005) argues, it is still unclear, from both theoretical and empirical perspectives, how and to what extent culture affects such differences. Ample literature has explored this question, in consideration of the various dimensions of culture, such as preferences, entrepreneurial traits, religion, family ties, and so on.[1] In this study, we provide a new approach to this growing research agenda by shedding light on the love of novelty as an individual cultural preference.

The desire for new ideas, or love of novelty, is widely considered important for innovation. For example, Fagerberg (2005, 2013) argues that "'openness' to new ideas, solutions, etc. is essential for innovation" because innovation requires people and firms to "search widely for new ideas, inputs and sources of inspiration." Given that innovation is recognized as a major driver of long-run growth in macroeconomics (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992), it is safe to say that there is a (rough) consensus that love of novelty, at the macro level, is a source of economic growth and especially innovation-based growth. Somewhat oddly, however, little formal research has aimed to formally identify the role of people's love of novelty as a cultural human trait in terms of macroeconomic performance such as innovation and growth.

We propose a new dynamic general equilibrium framework that helps us understand how consumer love of novelty affects innovation and innovation-based growth by extending the canonical growth model with expanding product varieties (Romer 1990, Grossman and Helpman 1991). In doing so, we incorporate two new features into a class of variety-expansion growth models, in which innovators of products enjoy a temporary monopoly (Matsuyama 1999, 2001). An advantage to using this class of models is that new and old products are clearly distinguished and have separate roles in the equilibrium, which facilitates the process of modeling love of novelty.[2] The first feature is that we assume that an infinitely lived representative consumer has not only preferences for differentiated products ("love-of-variety") but also an additional preference for new products ("love-of-novelty"). The second feature considers the transformation process by which new goods become old. We incorporate the well-accepted view that each single innovation involves a combination of different types of innovation activities, namely, new product development and existing product development (OECD 2018). Both types involve time and resource consuming investment activities.[3] In our model, as a result, new ideas are first developed as new products, and they can survive as "old" products when investments in existing product development succeed.[4]

[1] See below for a literature review.

[2] See also below for more information on this class of growth models.

[3] This categorization essentially follows the latest Oslo Manual (OECD 2018), which proposes two general categories of innovation "by comparing both new and improved innovations to the firm's existing products."

[4] Assuming that the success is uncertain, whether a new product ultimately survives and takes root in the economy is also uncertain. This is consistent with the nature of technological progress in history, which often referred to as "technological inertia" (Mokyr 1992). In the history of technological innovation, as Mokyr argues, most societies have exhibited a strong resistance to new ideas, experiencing technological stasis. As a result, newly developed products and technologies often fail to survive, despite their ostensible economic superiority. The survival of a new product or technology is a highly uncertain event, and innovation therefore has ever occurred only cyclically (Mokyr 2000, 2004). Examples include various products and technologies such as steam engines and the internet; see, for instance, Diamond

These two new features help us identify a basic role of consumer love of novelty in aggregate innovation and innovation-based growth. In the model, firms involved in innovation always swing between investing in new product development and existing product development. Through the marketplace, then, the relative profitability of these two investment activities inherently depends on the extent to which the consumer prefers new products to old products. Specifically, a stronger love of novelty by the consumer directly encourages firms to invent new products, yet it discourages firms from improving existing old products to survive in the market equilibrium. Because new and existing product developments are indispensable for the entire process of innovation, the aggregate level of innovation depends on a good balance between these two effects. Our analysis demonstrates the mechanism that creates the ambiguous role of the love of novelty.

We show that the consumer's love of novelty has a non-monotonic effect on aggregate innovation and growth. If love of novelty is especially weak, firms invent fewer new products, even though they are the source of existing product development. Because each innovation requires new and existing product development to be completed, the aggregate level of innovation is too small for the economy to achieve long-run growth. Such an economy is caught in an underdevelopment trap. If, then, the love of novelty is not small but moderate, both types of innovation perpetually occur along an equilibrium path, though cyclically. In this case, periods in which new product development occurs and periods in which existing product development occurs alternate along an equilibrium path,[5] whereby the economy achieves long-run growth through innovation cycles. These results show that the love of novelty is an essential source of innovation-based growth in the long run, consistent with conventional wisdom.

In the case of excessive love of novelty, firms eventually invest exclusively in inventing new products; thus, no improvements to old products occur in the long-run equilibrium. In this case, the economy is trapped in a situation in which new goods are invented every period because of new product development, but new goods rarely survive in the absence of existing product development. As in the case of a weak love of novelty, the economy loses the balance between the two types of innovation; the aggregate level of innovation is too low to achieve long-run growth. Thus, the love of novelty also leads to an underdevelopment trap when it is too strong. Indeed, the overall effect of consumer love of novelty is ambiguous: moderate love of novelty is a fundamental source of innovation-based growth (in line with what is generally believed), but excessive love of novelty can cause an underdevelopment trap.

The theoretical findings above lend support to the widely accepted view that culture is a fundamental cause of cross-country differences in macroeconomic performance, by focusing on an important aspect of national culture—the public's love of novelty. Since different people or regions typically have different attitudes toward novel things on average (e.g., Rogers 1962, Tellis et al. 2009), love of novelty as a national characteristic may be a core determinant of economic growth and development. In line with this prediction, a recent empirical study by Gören (2017) reports cross-country evidence for a significant inverted-U relationship between individual traits of seeking novelty and economic development. His empirical results suggest that novelty-seeking traits as a cultural trait is a source of growth and development provided that it is moderate, but it can have a negative

(1997) for more details.

[5] In the baseline model, an innovative economy is always perpetually cyclical; in Section 5, however, we show that it can also stably converge to a unique balanced growth path, by considering a natural extension of the baseline model.

effect if it is too strong or too weak. This is consistent with our theoretical findings.

We also consider some extensions to the baseline model. Specifically, if we relax the assumption of a single-period monopoly and instead assume protracted monopoly, as in the original Romer model,[6] we can show that new and existing product development coexist in equilibrium. In this case, the equilibrium rate of innovation for any period is an inverted U-shaped function of the consumer's love of novelty, which confirms our main finding.

Our study contributes to theoretical literature on innovation cycles by identifying the love of novelty as a novel factor for cyclical innovation (Judd 1985, Shleifer 1986, Deneckere and Judd 1992, Gale 1996, Francois and Shi 1999, Matsuyama 1999, 2001, and Furukawa 2015). In the main analysis, following this theoretical literature, we assume that the innovator can enjoy only a single-period monopoly, and we demonstrate that when the love of novelty is moderate, innovation is cyclical on an equilibrium path. On this cyclical path, the two types of innovations, new and existing product development, perpetually alternate on an equilibrium path Although this assumption is relaxed in Section 5, as explained above, it is reasonably justifiable because the duration of patent protection, or, more generally, monopoly power, can persist for only a finite period of time *in reality*. Allowing for a multiperiod monopoly, from a more general perspective, Iwaisako and Futagami (2007) identify an essential role of the temporary nature of monopoly in growth cycles in an innovation-based growth model with a *finite* patent length.[7] Our study extends these by developing a new model of innovation and growth cycles and characterizing the role of consumer love of novelty as a source of innovation cycles.

Our study also contributes to a growing body of theoretical literature on culture and growth. Galor and Moav (2002) show that individual preferences for offspring quality play a role in population growth and human capital formation.[8] Subsequent studies by Ashraf and Galor (2007, 2013a, 2013b, 2017) explore cultural/genetic diversity and regional development at different stages and in different places.[9] Several papers have identified the ambiguous role of some cultural factors. For example, Ashraf and Galor (2013a) show an inverted U-shaped relationship between genetic diversity within a country and regional economic development. Cozzi (1998) considers a cultural asset that is unproductive at the individual level, traded between different generations, yet has positive external effects on productivity growth. Then, he shows that culture can be a bubble that causes dynamic indeterminacy and self-fulfilling stagnation. Thus, the role of culture in his model is ambiguous in that it can encourage or discourage economic growth.

The studies by Galor and Michalopoulos (2012) and Doepke and Zilibotti (2014) are

---

[6]See Segerstrom et al. (1990), Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992).

[7]See, for instance, Iwaisako and Tanaka (2017) for endogenous growth cycles in an overlapping generations model.

[8]A large body of empirical literature is available. Tabellini (2010) shows that cultural propensities such as trust have a significant effect on regional per-capita income in Europe. Alesina and Giuliano (2010) examine the effects of family ties on economic performance. See also Bénabou et al. (2015, 2016), who show that innovation can be negatively associated with people's religiosity.

[9]See also Chu (2007), who provides the notable argument that entrepreneurial overconfidence can cause different rates of economic growth across countries. Moreover, Chu and Cozzi (2011) focus on cultural preferences for fertility. In a broader context, as Yano (2009) asserts, the coordination of such cultural factors with laws and rules is indispensable to deriving high quality markets and thereby healthy economic growth. This study extends this literature by investigating a composition effect of the public's love of novelty and patent on innovation and long-run growth. See also Dastidar and Yano (2017) and Yano and Furukawa (2019) for recent studies on market quality theory.

also related to our study. Both studies identify the critical role of entrepreneurial traits in innovation and economic growth by considering the endogenous evolution of a fraction of people who exhibit entrepreneurial spirit (in terms of risk tolerance). Given that entrepreneurial traits should be partially attributable to openness to novelty, we can say that their studies focus on one important aspect of the love of novelty by entrepreneurs. Our paper contributes to this literature by examining the role of a representative consumer's love of novelty as a cultural factor in an innovation-based growth model and identifying the ambiguous role of the love of novelty.[10]

Literature on two-stage innovation models is also related to our study, and most models have distinguished basic and applied research (see, e.g., Aghion and Howitt 1996, Michelacci 2003, Akiyama 2009, Cozzi and Galli 2009, 2013, 2014, Acs and Sanders 2012, Chu et al. 2012, Chu and Furukawa 2013, Konishi 2015). Because we consider two separate activities of *applied* innovation, firms earn profits in both stages of innovation. This differs from existing models, in which there is no profit in the early, basic research stages of innovation. Our study thus complements the literature by first considering two commercial stages of innovation, and then by characterizing the role of consumer love of novelty on aggregate innovation and growth.

The remainder of this paper is organized as follows. Section 2 presents the basic model, and Section 3 characterizes the equilibrium dynamics of the model. Section 4 identifies the critical role of the love of novelty in innovation and growth in the long run. Section 5 provides extensions to the baseline model. Finally, Section 6 offers concluding remarks.

# 2 Innovation-Based Growth Model with Love of Novelty

This section presents our basic innovation-based growth model, in which innovation occurs endogenously as a product of the firms' profit-seeking R&D investment and thereby the variety of products increases over time, following Romer (1990). In this section, we first proceed with the assumption that firms can only enjoy temporary (one period) monopoly power, as in Matsuyama (1999, 2001) and Acemoglu et al. (2012). This is assumed because in this class of models, new products and old products play separate but essential roles in equilibrium, facilitating the modeling of people's love of novelty—as will be apparent later. In Section 5, this assumption of a one-period monopoly is relaxed.

To investigate the role of love of novelty of optimizing agents, our model has two new assumptions. (i) First, we assume that the representative agent is endowed with the standard love-of-product variety and love of novelty; thus, he/she would have some extra weight on new products compared with old products.[11] Second, (ii) we think of two types of innovation: one type is to invent new products, and the other type is to ensure invented products have a long life in the market. We refer to these two types of innovation as new product development and existing product development, which both require R&D investment by profit-seeking firms.

[10] Doi and Mino (2008) also explore the role of consumption-side factors in innovation and innovation-based growth by focusing on habit formation and consumption externalities.

[11] In this literature, some models have physical capital accumulation (e.g., Matsuyama 2001). To make our analysis tractable, we abstract from this aspect because our focus is on preferences for new products, innovation, and innovation-driven growth.

## 2.1 Consumption and Love of Novelty

An infinitely lived representative agent inelastically supplies $L$ units of labor in each period. The representative agent solves the standard dynamic optimization of consumption and saving over an infinite horizon:

$$\max U = \sum_{t=0}^{\infty} \beta^t \ln u(t), \tag{1}$$

where $\beta \in (0,1)$ is the time preference rate, and $u(t)$ is an index of consumption in period $t$. We assume that periodic utility $u$ is defined over differentiated consumption goods, and each is indexed by $j$.[12] Namely, the agent is endowed with so-called love-of-variety preferences. As is standard, we consider a constant elasticity of substitution utility function:

$$u(t) = \left( \int_{j \in A(t) \cup N(t)} \left( \varepsilon(j,t)\ x(j,t) \right)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where $x(j,t)$ is the consumption of good $j$ in period $t$, $\sigma \geq 1$ is the elasticity of substitution between any two consumption goods, and $\varepsilon(j,t)$ is a variable determining the consumer's preference for each good, $j$. Here, the consumption goods are categorized into two types: new goods and old goods. Let $N(t)$ be the set of new goods invented in period $t$ and $A(t)$ be the set of old goods invented prior to period $t$. To simplify the description, let $A(t)$ and $N(t)$ also denote the number (measure) of goods.

When considering the innate love of novelty, we assume that the representative agent is endowed with "love-of-novelty" preferences, in addition to the standard love-of-variety preferences.

First, we attempt to observe a benchmark in which the consumer prefers new goods and old goods equally; there is no particular love of novelty. In this case, all goods should have identical $\varepsilon(j,t)$ for all $j \in A(t) \cup N(t)$. Normalizing this parameter to 1, the consumer's utility function can be written as

$$u(t) = \left( \int_{j \in A(t)} x(j,t)^{\frac{\sigma-1}{\sigma}} dj + \int_{j \in N(t)} x(j,t)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}} \tag{3}$$

Now, suppose that the consumer has some *extra* preference, $\varepsilon$, for *novelty* that he/she considers in terms of a good being new or a condition in which a good is new:

$$\varepsilon(j,t) = \begin{cases} 1 & \text{if } j \in A(t) \text{ (old goods)} \\ \varepsilon & \text{if } j \in N(t) \text{ (new goods)} \end{cases}. \tag{4}$$

Applying (4) to (2), (3) becomes

$$u(t) = \left( \int_{j \in A(t)} x(j,t)^{\frac{\sigma-1}{\sigma}} dj + \varepsilon \int_{j \in N(t)} x(j,t)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}. \tag{5}$$

[12] This follows Grossman and Helpman (1991, ch. 3). In our model, thus, the variety of consumption goods endogenously increases over time, unlike in the original Romer model (in which the variety of intermediate goods increases). Therefore, in our model, patents are granted for consumption goods, but they are often for intermediate goods in reality. Nevertheless, we adopt the present setting because we are interested in modeling consumers' love of novelty. Notably, however, we can obtain similar results even if we consider an expanding variety of *intermediate* goods.

When $\varepsilon = 1$, first, the consumer has no preference for novelty and prefers all goods equally, as in (3). This provides the benchmark, which has been intensively investigated in the literature. When $\varepsilon > 1$, the consumer has a love of novelty and prefers new goods to old goods. The higher $\varepsilon$, the stronger the love of novelty. To retain generality, we also allow for $\varepsilon < 1$. When $\varepsilon < 1$, the consumer's love of novelty is very weak, or we can say that the consumer has a so-called "fear of novelty" (Barber 1961), preferring old goods to new goods. This sort of negative preference for novelty can also be observed in reality and develops from people's innate "mental resistance to new ideas" (Beveridge 1959). For simplicity, we refer to $\varepsilon$ as the consumer's love of novelty for all $\varepsilon > 0$.[13]

The infinitely lived consumer solves the static optimization in (1); as is well known, we have the demand functions:

$$x(j,t) = \varepsilon(j,t)^{\sigma-1} \frac{E(t)p(j,t)^{-\sigma}}{P(t)^{1-\sigma}}, \tag{6}$$

where the consumer's spending on differentiated goods is:

$$E(t) \equiv \int_{j \in A(t) \cup N(t)} p(j,t)x(j,t)dj, \tag{7}$$

$P(t)$ is the usual price index, defined as

$$P(t) \equiv \left( \int_{j \in A(t) \cup N(t)} (p(j,t)/\varepsilon(j,t))^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}}, \tag{8}$$

and $p(j,t)$ is the price of good $j$ in period $t$. By solving the dynamic optimization, we also obtain the Euler equation:[14]

$$\frac{E(t+1)}{E(t)} = \beta(1 + r(t)), \tag{9}$$

where $r(t)$ denotes the interest rate.

## 2.2 Production

A continuum of firms produces consumption goods $j \in A(t) \cup N(t)$. Each good $j$, a new or old good, is dominated by a monopolistic producer. We consider a one-for-one technology in goods production. Namely, any producer, $j \in A(t)$ or $N(t)$, hires $x(j,t)$ units of labor to produce $x(j,t)$ units of good $j$, and monopolistically sells them to the consumer. The marginal cost is, thus, equal to the wage rate, $w(t)$.

As shown in (6), the consumption good producers, $j \in A(t) \cup N(t)$, face a constant price elasticity of market demand, equal to $\sigma \geq 1$. The unconstrained mark-up for a monopolistic producer is $\sigma/(\sigma - 1) > 1$. Thus, the mark-up goes to infinity in a Cobb-Douglas case of $\sigma = 1$. Nevertheless, to observe the role of substitutability between goods,

[13] In this study, we exclude any possibility of $\varepsilon < 0$ because this is a trivial case, in which case the consumer obtains disutility from buying new products and thus simply chooses $x(j,t) = 0$ for all $j \in N(t)$.

[14] Here we consider the standard lifetime budget constraint as follows: $E(t+1) + Q(t+1) = (1 + r(t))Q(t) + W(t)L$, where $Q(t)$ denotes the value of financial assets (i.e., equity of monopolistic firms) owned by the representative consumer.

captured by $\sigma$, in detail, we allow for the case of $\sigma = 1$,[15] by introducing an upper bound of the mark-up, say, $\mu > 1$. This upper bound $\mu$ has often been called a so-called patent breadth (see, e.g., Li 2001, Goh and Olivier 2002, Iwaisako and Futagami 2013, Chu et al. 2016).[16] Following the literature, we assume $\mu \leq \sigma/(\sigma - 1)$.[17] Notably, this introduction of a mark-up upper bound, $\mu$, is only for clarifying what occurs in the Cobb-Douglas case ($\sigma = 1$). Thus, the main results do not alter qualitatively at all without the upper bound $\mu$.

Accordingly, each firm sets a monopolistic price at:

$$p(j,t) = \mu w(t) \tag{10}$$

for all $j$. Using (4), (6), and (10), the output and monopolistic profit for a new good are given by:

$$x(j,t) = \frac{\varepsilon^{\sigma-1} E(t)}{P(t)^{1-\sigma}} \left(\mu w(t)\right)^{-\sigma} \equiv x^n(t) \text{ for } j \in N(t) \tag{11}$$

and

$$\pi(j,t) = \varepsilon^{\sigma-1} \frac{\mu - 1}{\mu^\sigma} E(t) \left(\frac{w(t)}{P(t)}\right)^{1-\sigma} \equiv \pi^n(t) \text{ for } j \in N(t). \tag{12}$$

Equation (12) shows that when $\sigma > 1$, the profit for a new good, $\pi^n(t)$, increases with the love of novelty $\varepsilon$ and the total expenditure, $E(t)$, and decreases with the real wage, $w(t)/P(t)$. When $\sigma = 1$ (the Cobb-Douglas case with no substitutability between goods), additionally, it becomes independent of the love of novelty $\varepsilon$, and the real wage, $w(t)/P(t)$.

We can also derive the output and monopolistic profit for an old good, from (4), (6), and (10):

$$x(j,t) = \frac{E(t)}{P(t)^{1-\sigma}} \left(\mu w(t)\right)^{-\sigma} \equiv x^a(t) \text{ for } j \in A(t) \tag{13}$$

and

$$\pi(j,t) = \frac{\mu - 1}{\mu^\sigma} E(t) \left(\frac{w(t)}{P(t)}\right)^{1-\sigma} \equiv \pi^a(t) \text{ for } j \in A(t). \tag{14}$$

The profit $\pi^a(t)$ associated with an old good is always free from the love of novelty $\varepsilon$.

## 2.3 Innovation

In this section, we present two types of innovation. One type of innovation is to invent new goods, and the other type is to ensure that invented goods have a long life in the market; we label these two types of innovation new product development and existing product development, respectively. First, R&D firms invent new consumption goods. We suppose new goods will become obsolete without further investments. Then, firms would

[15]When $\sigma = 1$, consumption goods are not substitutes but independent goods. Thus, if one needs to examine the role of goods substitutability, it is useful to think of the case without substitutability (i.e., the case of $\sigma = 1$).

[16]The breadth of a patent here is identified with "the flow rate of profit available to the patentee" and often interpreted as "the ability of the patentee to raise price" (Gilbert and Shapiro 1990). We can easily justify the existence of a price upper bound, or patent breadth, by considering potential imitators whose production cost increases with patent breadth, $\mu$. In a different context, $\mu$ can also be considered a result of price regulation (Evans et al. 2003).

[17]Notably, as shown later, our result can hold when $\mu = \sigma/(\sigma - 1)$, that is, when there is no upper bound of a mark-up.

invest in existing product development for survival. If investments succeed, new goods would survive to become "old" goods.[18]

### 2.3.1 New Product Development

There is a potentially infinite number of R&D firms. A firm can invent a new good in period $t$ by making an investment of $1/A(t-1)$ units of labor in period $t-1$. We follow Romer (1990) to consider "external effects arising from knowledge spillovers" of the stock of existing technologies, represented by $A(t-1)$. For simplicity, there is no spillover from newly invented goods, because we suppose that they are so new that their information would not be diffused well. Nevertheless, even if we allow for new goods in the stock of existing technologies, the main results will not qualitatively change. Firms that invent new goods earn a monopolistic profit in period $t$, $\pi^n(t)$.

As aforementioned, in the baseline model, we assume that the monopolistic firm can enjoy only a temporary (one-period) monopoly, following some endogenous growth models such as Francois and Shi (1999), Matsuyama (1999, 2001), and Acemoglu et al. (2012). The free entry condition for new product development can be written as:

$$W^n(t-1) \equiv \frac{\pi^n(t)}{1+r(t-1)} - \frac{w(t-1)}{A(t-1)} \leq 0 \text{ for } t \geq 1 \tag{15}$$

where $W^n(t-1)$ denotes the discounted present value of inventing a new good. $R^N(t-1)$ denotes the units of labor devoted to new product development in period $t-1$. Then, we have

$$N(t) = A(t-1)R^N(t-1). \tag{16}$$

### 2.3.2 Existing Product Development

Due to the one-period nature of monopoly power, the new goods, $N(t)$, invented in period $t$ can potentially be manufactured by any firm in the subsequent period, $t+1$. The goods are, at this point, no longer new but "old." We assume that each new good can be obsolete before becoming an old good unless investments for survival are made and succeed. We call this type of innovation for survival existing product development.

Specifically, an R&D firm engaging in existing product development invests one unit of labor in period $t$ and searches through the set of the new goods, $N(t)$. From among $N(t)$, the firm then successfully makes $\chi(t)$ units of new goods survive to become old goods, and enjoys a one-period monopoly for those $\chi(t)$ goods to earn the profits of $\chi(t)\pi^a(t+1)$. The free entry condition for existing product development can be given as:

$$W^a(t) \equiv \frac{\chi(t)\pi^a(t+1)}{1+r(t)} - w(t) \leq 0 \text{ for } t \geq 0, \tag{17}$$

in which $W^a(t)$ denotes the discounted present value for existing product development. Concerning $\chi(t)$, we consider a simple technology, $\chi(t) \equiv \kappa N(t)$, in which $\kappa \in (0,1)$ is a

[18]Our two types of innovations basically correspond to the standard categories of innovations, namely, product innovation and business process innovation (OECD 2018).

productivity parameter.[19] With this function, we assume that firms can find more new goods when there are more new goods $N(t)$ in the marketplace.

Through this process, the new goods of $N(t)$ are partially converted into the old goods, whose number is expressed as $A(t+1)-A(t)$. Denote as $R^A(t)$ the units of labor devoted to existing product development in period $t$. Then we have

$$A(t+1)-A(t)=\chi(t)R^A(t)\le N(t). \tag{18}$$

For simplicity, we assume that none of the old goods becomes obsolete, although it is easy to allow for some depreciation for $A(t)$ without rendering any essential change to the result. For descriptive purposes, we define $\rho(t)$ as a macroeconomic rate at which new goods survive to be transformed into old goods:

$$\rho(t+1)\equiv \chi(t)R^A(t)/N(t). \tag{19}$$

In the subsequent period, $t+2$, due to the temporary monopoly again, the "new" old goods, $A(t+1)-A(t)$, could potentially be produced by any firm. We follow Acemoglu et al. (2012) by assuming that monopoly rights will be, then, allocated randomly to a firm from the pool of potential firms whose ownership belongs to the representative agent. Thus, the monopoly profits for these "new" old goods will be transferred to new monopolistic firms owned by the representative agent.[20] Consequently, in our model, all goods are monopolistically competitively produced in equilibrium, and their profits are allocated to the representative agent as dividends.[21]

## 2.4 Labor Market

As shown in (12) and (14), the real wage $w(t)/P(t)$ is a critical component of the profits. Thus, having the following is beneficial:

$$\frac{w(t)}{P(t)}=\frac{1}{\mu}\left[A(t)+\varepsilon^{\sigma-1}N(t)\right]^{\frac{1}{\sigma-1}}, \tag{20}$$

which uses $p(j,t)=\mu w(t)$ for any $j\in A(t)\cup N(t)$ with (8). The labor market clearing condition is:

$$L=\int_{j\in A(t)\cup N(t)} x(j,t)dj+R^N(t)+R^A(t). \tag{21}$$

The left side in (21) denotes the labor supply, and the right side denotes the labor demand for production, new product development $R^N(t)$, and existing product development $R^A(t)$ in each period $t$. It is useful to derive the labor demand from the production sector as

$$\int_{j\in A(t)\cup N(t)} x(j,t)dj=\frac{1}{\mu}\frac{E(t)}{w(t)}, \tag{22}$$

[19] From a broader perspective, this $\kappa$ can relate to firms' absorptive capacity (Cohen and Levinthal 1989). See also Aghion and Jaravel (2015) for a recent contribution, in consideration of the role of absorptive capacity in innovation and growth.

[20] The financial asset $Q(t)$ owned by the consumer (in the form of equity of monopolistic firms) earns the return rate, $r(t)$, in each period, $t$; see footnote 14. As is standard in the canonical innovation-based growth model, this earning is from the profits of all monopolistic firms (in the form of dividends).

[21] Alternatively, we could also proceed in such a manner that goods are sold at a perfectly competitive price (e.g., Matsuyama 2001). However, we understand that this option would complicate the analysis without garnering new insights. In addition, the interaction between monopolistic and competitive sectors is notable but beyond our scope. Thus, in this paper, we ensure the analysis as simple as possible to highlight the main topic discussed in the introduction.

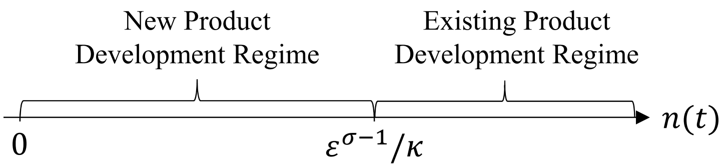



Figure 1: Illustration of Lemma 1

which uses (11), (13), (20), and (21).

# 3 Equilibrium Dynamics

We are now ready to derive the dynamical system that characterizes the law of motion for the equilibrium trajectory of the economy. In doing this, it is beneficial to define $n(t) \equiv N(t)/A(t)$, which is the ratio of new to old goods. By using the free entry conditions in (15) and (17), along with (12) and (14), we derive the following lemma.

**Lemma 1** *Only new product development occurs in equilibrium when* $n(t) < \varepsilon^{\sigma-1}/\kappa$. *Only existing product development occurs when* $n(t) > \varepsilon^{\sigma-1}/\kappa$.

**Proof.** Suppose that firms invest in new product development in equilibrium. Then, the free entry condition (15) must hold with equality (giving firms a zero net payoff). With (12), (14), (17), and (20), this equality implies $n(t) \leq \varepsilon^{\sigma-1}/\kappa$. Where $n(t) < \varepsilon^{\sigma-1}/\kappa$, that is, (17) holds with inequality, there is no investment in existing product development in equilibrium. Using this information, we can easily prove the first half of the lemma. An analogous proof can be applied to the second half. ■

The result of Lemma 1 is presented in Figure 1. The cut-off level of $n(t)$, $\varepsilon^{\sigma-1}/\kappa$, generates two regimes in the economy. The first regime corresponds to $n(t) \in (0, \varepsilon^{\sigma-1}/\kappa)$, which we call a new product development regime. The second regime corresponds to $n(t) \in (\varepsilon^{\sigma-1}/\kappa, \infty)$, which we call an existing product development regime. At the cut-off point, the economy includes both activities; however, we can ignore it, because the point has zero measure.

As shown in Lemma 1, a type of specialization occurs in this model. In reality, any economy appears to be engaged in both new and existing product development, more or less, at any point in time. We can easily remove this unrealistic aspect concerning specialization from the model by, as we do in Section 5, allowing the innovator a long-lived monopoly or simply introducing an exogenous growth factor. As will be apparent later, either change to the baseline model could provide another interesting analysis but result in the analysis being less tractable. Thus we adopt the present setting for simplicity.

In each period, $t$, the value of $n(t)$ should be supposed to be given, because it is a pre-determined (stock) variable. In a hypothetical situation in which $n(t)$ is taken as given, Lemma 1 implies that, for a given $n(t)$, an economy is more likely to engage in new product development if (and only if) the love of novelty, $\varepsilon$, is stronger and/or the productivity for existing product development, $\kappa$, is lower. This is because there is a higher relative profit for the invention of a new good, compared with the investment in existing goods' survival, when the consumer prefers new goods to old goods more

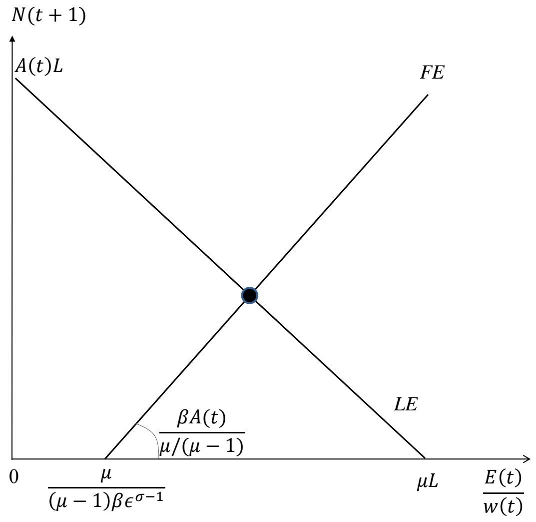



Figure 2: New Product Development Regime

strongly (due to larger $\varepsilon$) and/or the cost for survival investments is higher (due to lower $\kappa$). The development of technologies that earn a higher profit is encouraged in market equilibrium. For the analogous reason, an economy is more likely to engage in existing product development when $\varepsilon^{\sigma-1}/\kappa$ is smaller, in which case there is a higher relative profit for survival investments.

## 3.1 New Product Development Regime

With $n(t) < \varepsilon^{\sigma-1}/\kappa$, by Lemma 1, the economy falls into the new product development regime. With (9), (15), (12), and (20), the free entry condition for invention, $W^n(t) = 0$, becomes:

$$N(t+1) = \frac{A(t)}{\varepsilon^{\sigma-1}} \left[ \frac{\beta\varepsilon^{\sigma-1}}{\mu/(\mu-1)} \frac{E(t)}{w(t)} - 1 \right], \tag{23}$$

which uses $A(t+1) = A(t)$ (or $\rho(t+1) = 0$). Given $A(t)$, this describes a profit-motive aspect of the inventive activity: the larger the discounted profit from selling new goods $((\beta\varepsilon^{\sigma-1}(\mu-1)/\mu)E(t)/w(t))$, the greater the incentives for firms to invent a new good. The profit for a new good increases as the wage-adjusted expenditure $E(t)/w(t)$ increases and as the consumer's love of novelty $\varepsilon$ increases. Additionally, when $n(t) < \varepsilon^{\sigma-1}/\kappa$, no firm has an incentive to invest in existing product development; in such a case, $R^A(t) = 0$. The labor market condition (21), thus, becomes:

$$N(t+1) = A(t) \left[ L - \frac{1}{\mu} \frac{E(t)}{w(t)} \right], \tag{24}$$

which uses (16) and (22). Given $A(t)$, the greater the wage-adjusted expenditure $E(t)/w(t)$, the more resources will be devoted to production, leaving fewer resources for innovation, resulting in a smaller $N(t+1)$.

Figure 2 depicts (23) and (24) and is labeled with $FE$ and $LE$, respectively, which determine the equilibrium number of new goods, $N(t+1)$, and the wage-adjusted expenditure, $E(t)/w(t)$, as a unique intersection. Given the predetermined variable, $A(t)$, new goods, $N(t+1)$, is increasing in the time preference rate $\beta$, the labor force $L$, and the patent breadth $\mu$, all of which are natural effects.

The effect of the elasticity of substitution between goods, $\sigma \geq 1$, is more complex and is positive if the consumer has a love of novelty, that is, if $\varepsilon > 1$. Because $\sigma$ determines the level of goods substitutability, a higher $\sigma$ generally leads to a larger demand for a preferable good (relative to a less preferred good). Thus, with the consumer's love of novelty ($\varepsilon > 1$), the elasticity of substitution $\sigma$ positively affects $N(t+1)$ through an upward shift of the $FE$ curve in Figure 2, by increasing the expenditure share for a new good and thereby its profit. However, in the benchmark case of $\varepsilon = 1$, comprising neither a love or fear of novelty, the elasticity of substitution $\sigma$ has no role because all goods, both new and old, are equally desirable for the consumer and thus their demands/profits are also equal. When the consumer has a fear of novelty, that is, $\varepsilon < 1$, the effect of $\sigma$ on $N(t+1)$ is negative because old goods are now preferable. Again, a higher substitutability $\sigma$ leads to a larger demand for a preferable good, in general. Thus, in this fear-of-novelty case, higher $\sigma$ generates a downward shift of the $FE$ curve, by decreasing the profits for new goods (and increasing the profits for old goods).

As for the love of novelty $\varepsilon$, a higher $\varepsilon$ causes an upward shift in the $FE$ curve in the standard case of $\sigma > 1$, where goods are substitutes. This result is simply because the demand for a new good becomes larger if the consumer prefers new goods to old goods more strongly (higher $\varepsilon$). Then, the equilibrium profit for new goods, $(\beta\varepsilon^{\sigma-1}(\mu-1)/\mu)E(t)/w(t)$, is also larger.[22] The upward shift of the $FE$ curve leads to an increase in $N(t+1)$ in equilibrium. In the special case of $\sigma = 1$ (where goods are independent goods), $\varepsilon$ has no role because the expenditure share for any independent good, new or old, is constant, and free from $\varepsilon$.

We can formally confirm this effect of $\varepsilon$ by solving (23) and (24):

$$N(t+1) = \Theta A(t), \tag{25}$$

where

$$\Theta \equiv \frac{\varepsilon^{\sigma-1}(\mu-1)L - 1/\beta}{\varepsilon^{\sigma-1}\left((\mu-1)+1/\beta\right)}. \tag{26}$$

Equation (25) determines the equilibrium amount of new goods in the new product development regime. The coefficient $\Theta$ is increasing in the love of novelty $\varepsilon$ and the standard parameters $\beta$, $L$, and $\mu$. We can interpret the parameter composite $\Theta$ as the potential demand for new goods. Assuming $\Theta > 0$, we exclude a trivial case where there is no invention of new goods in any situation, by imposing $\varepsilon^{\sigma-1}\beta(\mu-1)L > 1$, which provides a lower bound of $\varepsilon$ as $[1/(\beta(\mu-1)L)]^{1/(\sigma-1)} \equiv \varepsilon_0$. Additionally, because $R^A(t) = 0$ and thus $\rho(t+1) = 0$ in the present regime, from (18), the old goods do not increase; $A(t+1) = A(t)$. Therefore, we easily verify that if $\Theta > \varepsilon^{\sigma-1}/\kappa$ holds, $N(t+1)/A(t+1) \equiv n(t+1) > \varepsilon^{\sigma-1}/\kappa$ holds, whereby the economy moves to the existing product development regime in period $t+1$. Conversely, if $\Theta < \varepsilon^{\sigma-1}/\kappa$, $n(t+1) < \varepsilon^{\sigma-1}/\kappa$. Then, the economy is trapped in the new product development regime. In this situation, $N(t)$ and $A(t)$ are constant over time, resulting in less innovation in the sense that there is only one type of innovation, that is, new product development, $N(t)$. Consequently, there is no long-run growth because the variety of goods, $N(t) + A(t)$, is constant over time.

[22] See also (12).

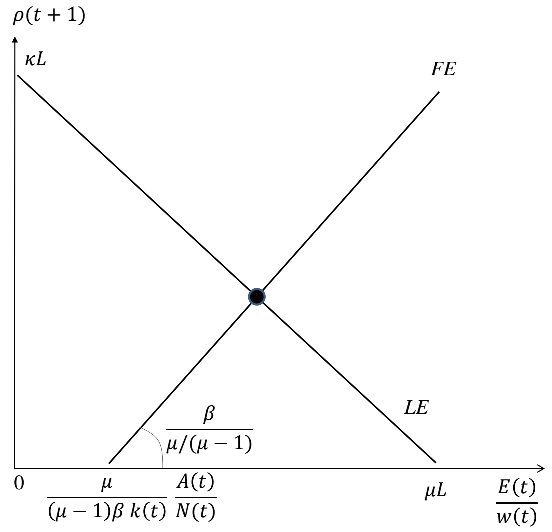



Figure 3: Existing Product Development Regime

**Lemma 2** *The economy is trapped in the new product development regime if and only if* $\Theta < \varepsilon^{\sigma-1}/\kappa$.

## 3.2 Existing Product Development Regime

With $n(t) > \varepsilon^{\sigma-1}/\kappa$, by Lemma 1, the economy is in the existing product development regime in period $t$; $R^A(t) \geq 0$, and $R^N(t) = 0$. Rearranging the labor market condition (21), with (22), yields the survival rate for new goods as:

$$\rho(t+1) = \kappa R^A(t) = \kappa \left( L - \frac{1}{\mu} \frac{E(t)}{w(t)} \right). \tag{27}$$

Analogous to (24), (27) captures the trade-off on resources between the production of goods and the investment in existing product development. With (9), (14), and (17), the free entry condition $W^a(t) = 0$ becomes

$$\rho(t+1) = \frac{\kappa\beta}{\mu/(\mu-1)} \frac{E(t)}{w(t)} - \frac{A(t)}{N(t)}, \tag{28}$$

which uses $N(t+1) = R^N(t) = 0$ from (16) and $A(t+1) = A(t) + \chi(t)R^A(t) = A(t) + \chi(t)\rho(t+1)/\kappa$ from (18). Naturally, the transformation rate $\rho(t+1)$ increases with the discounted profit from producing the old good $(\beta(\mu-1)/\mu)E(t)/w(t)$ and also increases with the number of new goods $N(t)$, because R&D firms can find more inventions (i.e., opportunities for improvement). Figure 3 illustrates how $\rho(t+1)$ is determined by (27) and (28). Solving (27) and (28), we obtain:[23]

$$\rho(t+1) = \min\left\{\frac{1}{1+\beta(\mu-1)}\left(\kappa\beta(\mu-1)L - \frac{A(t)}{N(t)}\right), 1\right\}. \tag{29}$$

Using (29), with (18), the growth of old goods is as follows:

$$A(t+1) = A(t)\min\left\{\frac{\beta(\mu-1)}{1+\beta(\mu-1)}\left(1+\kappa L\frac{N(t)}{A(t)}\right), 1+\frac{N(t)}{A(t)}\right\} \tag{30}$$

In the present regime, the new goods do not increase; $N(t+1) = 0$ from (16). This result implies $n(t+1) = 0$, which is clearly lower than $\varepsilon^{\sigma-1}/\kappa$. We therefore have Lemma 3.

**Lemma 3** *The existing product development regime is always unstable; thus, the economy necessarily shifts to the new product development regime.*

# 4 The Role of Love of Novelty in Innovation and Long-run Growth

In this section, we examine the effects of consumers' love of novelty on innovation and growth in the long run. We follow the standard literature to assume $\sigma > 1$.[24] Lemma 2 shows that in the case with $\Theta < \varepsilon^{\sigma-1}/\kappa$, the economy is fatally caught in the trap without existing product development, in which no long-run growth is possible because new goods $N(t)$ and old goods $A(t)$ are constant. In such a trapped economy, the inventive potential $\Theta$ is relatively low, and the consumer's love of novelty, $\varepsilon$, is relatively strong. On the one hand, the new product development regime is larger due to a high $\varepsilon$; on the other hand, the invention flow $N(t)$ within the regime tends to be low, due to a low $\Theta$. These two effects are negative on innovation; thus, the economy with $\Theta < \varepsilon^{\sigma-1}/\kappa$ is trapped. To avoid traps, $\Theta > \varepsilon^{\sigma-1}/\kappa$ must hold as shown in Lemma 3. As is common in the standard R&D-based growth model, traps can be avoided only if labor is sufficiently abundant.[25] Specifically, we assume the following condition:

[23]Notably, $\rho(t+1) > 0$ always holds, due to $\varepsilon^{\sigma-1}\beta(\mu-1)L > 1$. When $\rho(t+1) = 1$ holds in (29), all new goods survive in period $t+1$. In this case, the free entry condition (28) does not hold anymore; the labor market condition (27), with $\rho(t+1) = 1$, would determine the equilibrium value of the wage-adjusted expenditure, $E(t)/w(t)$. Whether $\rho(t+1) < 1$ or $\rho(t+1) = 1$ occurs in equilibrium, our results do not alter qualitatively. Only for reference, it is notable that $\rho(t+1) < 1$ occurs if and only if $\kappa L < 1 + 1/(\beta(\mu-1))$.

[24]If $\sigma = 1$, the consumption goods are independent goods; thus, the expenditure share between new and old goods is constant, and free from love of novelty $\varepsilon$. Notably, under $\sigma = 1$, the condition in Lemma 2 becomes independent of $\varepsilon$.

[25]This is due to the well-known scale effect within the model. Although the existence of the scale effect has been empirically rejected from a long-run perspective, by using 100 years of data (Jones 1995), it might play a role in world development in the *very* long run: As Boserup (1965) argues, population growth often triggers the adoption of new technology, because people are forced to adopt new technology when their population becomes too large to be supported by existing technology. The empirical finding of Kremer (1993) also suggests that total research output increases with population. Consistent with these views, Lemma 4 shows that population size affects technological progress in the long run. The threshold level of $L$ in (31), $L_0$, comprises several parameters. Because, for instance, $L_0$ decreases with $\kappa$, the productivity of firms has a role in avoiding traps, which is natural and intuitive.

$$L > 2\sqrt{\frac{1}{\kappa}\left(1+\frac{1}{\beta\left(\mu-1\right)}\right)\frac{1}{\beta\left(\mu-1\right)}} \equiv L_0. \tag{31}$$

**Lemma 4** *Under (31), there exist threshold values $\varepsilon_+ > \varepsilon_- > \varepsilon_0$ for which*

$$\Theta > \varepsilon^{\sigma-1}/\kappa \iff \varepsilon \in (\varepsilon_-, \varepsilon_+).$$

**Proof.** From (26), we can show that $\Theta > \varepsilon^{\sigma-1}/\kappa$ if and only if

$$F(\varepsilon^{\sigma-1}) \equiv \frac{1}{\kappa}\left(1+\frac{1}{\beta\left(\mu-1\right)}\right)\left(\varepsilon^{\sigma-1}\right)^2 - L\varepsilon^{\sigma-1} + \frac{1}{\beta\left(\mu-1\right)} < 0. \tag{32}$$

Because $F$ is quadratic and convex in $\varepsilon^{\sigma-1}$, (32) is possible only when $F(x) = 0$ has two distinct real roots. The positiveness of the discriminant ensures this, that is,

$$D \equiv L^2 - \frac{4}{\kappa}\left(1+\frac{1}{\beta\left(\mu-1\right)}\right)\frac{1}{\beta\left(\mu-1\right)} > 0, \tag{33}$$

which is equivalent to (31). Suppose that (31) holds and let the solutions to $F(x) = 0$ be $\varepsilon_-^{\sigma-1} < \varepsilon_+^{\sigma-1}$.[26] As is easily verified, $\varepsilon_+^{\sigma-1} > 0$ holds. Because $F(0) > 0$, $\varepsilon_-^{\sigma-1} > 0$ also holds. To prove that $\varepsilon_0^{\sigma-1} = 1/(\beta(\mu-1)L) < \varepsilon_-^{\sigma-1}$, it suffices to show that $F(\varepsilon_0^{\sigma-1}) > 0$ and $F'(\varepsilon_0^{\sigma-1}) < 0$. In fact,

$$\begin{aligned}
F(\varepsilon_0^{\sigma-1}) &= \frac{1}{\kappa}\left(1+\frac{1}{\beta(\mu-1)}\right)\left(\varepsilon_0^{\sigma-1}\right)^2 > 0,\\
F'(\varepsilon_0^{\sigma-1}) &= \frac{2}{\kappa}\left(1+\frac{1}{\beta\left(\mu-1\right)}\right)\frac{1}{\beta L\left(\mu-1\right)} - L = \frac{1}{2L}(L_0^2 - L^2) < 0.
\end{aligned}$$

Because the solution set to $F(x) < 0$ is $(\varepsilon_-^{\sigma-1}, \varepsilon_+^{\sigma-1})$, with $\varepsilon_0 < \varepsilon_-$, any $\varepsilon \in (\varepsilon_-, \varepsilon_+)$ satisfies both $\varepsilon > \varepsilon_0$ and the no-trap condition. Conversely, any $\varepsilon > \varepsilon_0$ outside of this interval violates the no-trap condition. ■

Condition (31) is indispensable for our analysis. Notably, there exists an $\varepsilon > \varepsilon_0$ that satisfies the no-trap condition, $\Theta > \varepsilon^{\sigma-1}/\kappa$, if and only if (31) holds.[27] Thus, in the following analysis, we assume (31) to avoid the trivial case of any economies getting trapped in the no-innovation situation.

Lemma 4 characterizes the parameter range in which the economy has the potential to innovate and grow in the long run. Lemma 4 also states that the role of love of novelty $\varepsilon$ in achieving $\Theta > \varepsilon^{\sigma-1}/\kappa$ is ambiguous because $\Theta$ is increasing in $\varepsilon$, which generates two opposite effects of $\varepsilon$. On the one hand, (a) a higher $\varepsilon$ makes the invention of new goods profitable relative to the investment in existing product development. As a result of this relative profitability effect, the new product development regime $(0, \varepsilon^{\sigma-1}/\kappa)$ will become large, whereby the economy is more likely to become trapped in the new product development regime. However, (b) a higher $\varepsilon$ also leads to a larger potential demand $\Theta$, and there are more new goods $N(t)$ to be created in the new product development

[26] $\varepsilon_-^{\sigma-1} = \frac{L-\sqrt{D}}{(2/\kappa)(1+1/(\beta(\mu-1)))}$, $\varepsilon_+^{\sigma-1} = \frac{L+\sqrt{D}}{(2/\kappa)(1+1/(\beta(\mu-1)))}$.

[27] The sufficiency of (31) is proven in Lemma 4. Notably, $D \leq 0 \Leftrightarrow L \leq L_0$. (31) is also necessary because quadratic inequality (32) has no solution if $L \leq L_0$.

regime. This leaves more incentives for firms to engage in existing product development, noting that new goods are the essential source of existing product development. With this positive indirect effect of $\varepsilon$, the economy is more likely to jump out of the new product development region. These two opposite effects interact to create an equilibrium role for $\varepsilon$. The following two propositions show that the role of the love of novelty $\varepsilon$ in innovation is also ambiguous.

**Proposition 1** *When the infinitely lived consumer's love of novelty $\varepsilon$ is moderate, such that $\varepsilon \in (\varepsilon_-, \varepsilon_+)$, the economy achieves long-run growth, through perpetual cycles between periods of new product development and existing product development.*

**Proof.** For $\varepsilon \in (\varepsilon_-, \varepsilon_+)$, because of Lemmas 2 and 4, $\Theta > \varepsilon^{\sigma-1}/\kappa$ holds and the new product development regime is always explosive. Thus, any path starting from initial values lower than $\varepsilon^{\sigma-1}/\kappa$ eventually moves toward the existing product development regime. Then, because of Lemma 3, the economy will necessarily go back to some point within the new product development regime. Therefore, if $\varepsilon$ is moderate, the economy perpetually fluctuates, moving back and forth between the two regimes. In this case, innovation occurs perpetually and cyclically because both $N_t$ and $A_t$ permanently grow over time, but alternately. ■

Proposition 1 suggests that the love of novelty $\varepsilon$ can be a source of innovation-driven growth in the long run, because there are permanently expanding goods spaces, $N(t)$ and $A(t)$. Innovation-driven growth occurs here because the aforementioned two opposite effects of $\varepsilon$ can be balanced well in a moderate range of $\varepsilon$. However, if the level is extreme, the love of novelty $\varepsilon$ can be a cause of underdevelopment traps rather than the source of growth, by depressing innovation.

**Proposition 2** *When the infinitely lived consumer's love of novelty $\varepsilon$ is sufficiently weak or strong, such that $\varepsilon \notin (\varepsilon_-, \varepsilon_+)$, a globally stable equilibrium trap occurs in which new products are invented but none can survive in the market, due to the absence of existing product development. The economy fails to achieve long-run growth.*

**Proof.** For $\varepsilon \notin (\varepsilon_-, \varepsilon_+)$, because of Lemmas 2 and 4, $\Theta \leq \varepsilon^{\sigma-1}/\kappa$ holds and the new product development regime is a trap. Because of Lemma 3, the existing product development regime is always explosive, and any path starting from any point in either regime is eventually trapped in the new product development regime. ■

Proposition 2 implies that the "fear of novelty" (Beveridge 1959, Barber 1961) and love of novelty may both cause an economy to fall into an underdevelopment trap. It is straightforward to understand that the consumer's fear of novelty negatively affects innovation. Intuitively, with a smaller $\varepsilon$, the consumer has a smaller demand for new products $N(t)$, implying smaller $N(t)$. Because new goods are the input for existing product development, a smaller $N(t)$ discourages existing product development by lowering its net benefit, which comes from the aforementioned effect (b). As a result, with a strong fear of novelty, or a very low $\varepsilon$, the economy is more likely to be caught in the trap, in which investments in new product development occur and investments in existing product development do not occur. Because both types of innovative investments are essential, the numbers of new goods and old goods, $N(t)$ and $A(t)$, are constant over time. Thus, a very weak of love of novelty, or a strong fear of novelty, can cause the underdevelopment trap of no long-run growth. This result is consistent with the historical view in Mokyr (2000), who considers that the lack of "receptivity of a society to new technological ideas" is "an integral part of underdevelopment." The innate fear of novelty for consumers should be an important source of the absence of receptivity.

Equally important, Proposition 2 also identifies the negative role of a too *strong* love of novelty. This role may seem counter-intuitive but the mechanism is natural. Due to effect (b), a high $\varepsilon$ encourages new product development, providing more new goods $N(t)$. Then, it further encourages existing product development, because existing product development uses new goods as input. However, due to effect (a), $\varepsilon$ increases the relative profitability of new product development to existing product development. When $\varepsilon$ is very high, this relative profitability effect dominates the positive one to take away from firms any incentives for existing product development. In this case, only new product development occurs in equilibrium. The economy is trapped again, in which $N(t)$ and $A(t)$ are constant over time. Thus, no long-run growth is observed in an economy with a too strong love of novelty.

Those two propositions identify the ambiguous role of the consumer's love of novelty in innovation and innovation-based growth. The following theorem provides a summary.

**Theorem 1** *When the love of novelty is moderate, it is the fundamental source of innovation-based economic growth in the long run. However, a too strong love of novelty and a too weak love of novelty causes an underdevelopment trap, in which new goods are invented (due to the presence of new product development) but do not survive (due to the absence of existing product development). In the trapped situation, the total number of goods,* $N(t) + A(t)$, *is constant over time; there is no long-run growth.*

**Proof.** Proven in the text by using Propositions 1 and 2. ■

In Theorem 1, we identify an ambiguous role of the public's love of novelty in innovation and innovation-based economic growth. Intuitively, the love of novelty encourages the invention of new goods, but each innovation also involves investments for the survival of those invented (existing) goods. Thus, innovation at the aggregate level can be maximized with a good balance between new and existing product development. This is why the role of love of novelty is ambiguous; a too weak and a too strong love of novelty depresses innovation, whereby the economy can be caught in underdevelopment traps with no long-run growth. In summary, we conclude that the love of novelty is a source of innovation-based growth but can become a cause of underdevelopment traps when too strong. The threshold values of the love of novelty $\varepsilon$ determine which case occurs and are formally derived in Lemma 4.

As we already mentioned in the introduction, our theoretical predictions are in line with recent empirical evidence, showing a significant inverted-U relationship between individual traits of seeking novelty and economic development (Gören 2017).[28] The evidence suggests that novelty-seeking traits as a cultural trait concerning the love of novelty is a source of growth and development given that it is moderate, but it has a negative effect if it is too strong or too weak. This is consistent with our theoretical findings.

As shown in Appendix A, we also observe suggestive evidence that supports our result. First, using cross-country data, we observe inverted U-shaped relationships between the

[28]See also Furukawa et al. (2018, 2019) for other supporting evidence.

love of novelty and innovation. This result is consistent with our theoretical finding of the ambiguous role of love of novelty in innovation. Second, we also observe a positive relationship between the love of novelty and the level of *originality* of innovations at the country level. Assuming new product development generates more *original* innovations than existing product development, the evidence suggests a positive effect of the love of novelty on new product development. As explained, the positive effect on new product development is the key mechanism for our theoretical result. All in all, the cross-country patterns may support the relevance of our theory.

# 5 Extensions

In this section, we explore two extensions to our baseline model. First, our economy features only trap and cycle in dynamic equilibrium. By introducing an exogenous growth factor into the baseline model, we show that the model can have a balanced growth equilibrium similar to the standard growth model. Second, for analytical tractability, we assume the one-period nature of monopoly power. We relax this assumption and allow for a long lived monopoly, whereby the model is more similar to the canonical R&D-based growth models (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992). In these extensions, our main message continues to hold: a too strong love or fear of novelty can depress innovation and economic growth in the long run. Notably, these extensions also resolve another limitation of the baseline model, by generating a new equilibrium in which new and existing development coexist.

## 5.1 Balanced Growth and Path Dependence

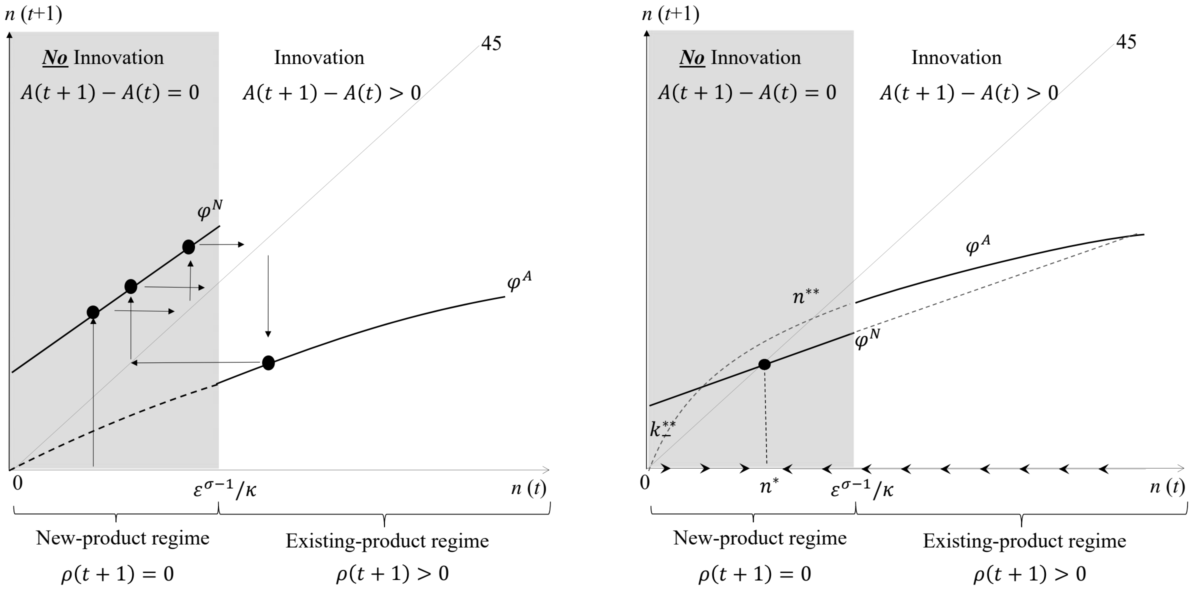
To allow for a balanced growth equilibrium, we add minimal elements to the process of innovation. Following Anderlini et al. (2013), we introduce an exogenous growth factor, $\eta(t) \geq 0$, into new product development;[29] the number of endogenously invented goods, $A(t)R^N(t)$, together with the number of exogenously given ones, $\eta(t)$, determine the dynamics of new goods by $N(t+1) = A(t)R^N(t) + \eta(t)$. This captures so-called "invention by accident," which sometimes occurs in reality.[30] Without any intended investments or efforts, researchers can simply create new ideas by accident or mistake as a by-product of regular, intentional research activity. For the sake of simplicity, we assume $\eta(t) = \eta N(t)$, with $\eta \in [0, 1)$.[31] When $W^n(t) = 0$, the new good $N(t)$ thus evolves in the new product development regime due to

$$N(t+1) = \Theta A(t) + \eta N(t), \tag{34}$$

[29]Exogenous growth factors are often assumed in research for a deeper understanding of the role of technological progress in various phenomena; see, for instance, Lucas and Moll (2014) and Benhabib et al. (2017). Given that our goal in this paper is to investigate the cause of innovation, our extended model still has the endogenous component, $R^N(t)$, which is more in accordance with Anderlini et al. (2013), who consider endogenous and exogenous growth factors in the process of technological progress.

[30]See, for example, Middendorf (1981) for more details on this type of innovation.

[31]If $\eta > 1$, the new good, $N(t)$, autonomously expands without the help of endogenous new product development. Given the focus of our paper, we should restrict the exogenous growth factor to be lower than 1; $\eta < 1$.




(a) Innovation Cycles with $\varepsilon \in (\varepsilon'_-, \varepsilon'_+)$ (b) Global Trap with $\varepsilon \notin (\varepsilon'_-, \varepsilon'_+)$

Figure 4: Cycles and Global Traps

which corresponds to (25). When $W^a(t) = 0$, the free entry condition similar to (28) is now

$$\rho(t+1) = \frac{\kappa\beta}{\mu/(\mu-1)}\frac{E(t)}{w(t)} - \frac{A(t)}{N(t)} - \eta\varepsilon^{\sigma-1}, \tag{35}$$

which uses $N(t+1) = \eta N(t)$ because $R^N(t) = 0$. From (27) and (35), in the existing product development regime, the old good $A(t)$ evolves due to

$$\rho(t+1) = \frac{1}{1+\beta(\mu-1)}\left(\beta(\mu-1)\kappa L - \frac{A(t)}{N(t)} - \eta\varepsilon^{\sigma-1}\right).\text{[32]} \tag{36}$$

Combining (34) and (36), we can derive the equilibrium dynamic system as:

$$n(t+1) = \begin{cases} \eta n(t) + \Theta \equiv \varphi^N(n(t)) & \text{for } n(t) < \varepsilon^{\sigma-1}/\kappa \\ \frac{\eta(1+\beta(\mu-1))n(t)}{\beta(\mu-1)+(\beta(\mu-1)\kappa L-\eta\varepsilon^{\sigma-1})n(t)} \equiv \varphi^A(n(t)) & \text{for } n(t) > \varepsilon^{\sigma-1}/\kappa \end{cases}, \tag{37}$$

which uses (18).[33] Function $\varphi^N$ is linear, $\varphi^A$ is concave, and both are increasing in $n(t)$, each of which has a unique fixed point for $n(t) > 0$, labeled $n^*$ and $n^{**}$, respectively.

With a slight modification to the conditions, Proposition 1 continues to hold at least locally. (A proof requires a tedious sequence of similar calculations, which is omitted here.)[34] Suppose

$$L > \frac{1-\eta}{\kappa}\left(1 + \frac{1}{\beta(\mu-1)}\right) + \frac{1}{\beta(\mu-1)} \equiv L'_0,$$

[32] To ensure feasibility, such that $\rho(t+1) \in (0,1)$ for any $n(t)$, it would suffice to assume $\beta(\mu-1)\kappa L - \left((\beta(\mu-1) + \kappa/\varepsilon^{\sigma-1} + 1\right) < \eta\varepsilon^{\sigma-1} < \beta(\mu-1)\kappa L$.

[33] We also use $A(t+1) = A(t)$ for $n(t) < \varepsilon^{\sigma-1}/\kappa$ and $N(t+1) = \eta N(t)$ for $n(t) > \varepsilon^{\sigma-1}/\kappa$. To ensure $n(t+1) > 0$ for any $n(t) > \varepsilon^{\sigma-1}/\kappa$, we impose an upper bound of $\varepsilon$, such that $\varepsilon < [(\kappa/\eta)\beta(\mu-1)L]^{1/(\sigma-1)}$.

[34] A formal proof is available upon request from the authors.

to avoid the trivial case likewise. Then, we can revise Lemma 4 as follows: Under the coexistence of endogenous and exogenous innovation, there exists a threshold value of $\varepsilon$, $\varepsilon'_+$, such that $\Theta/(1-\eta) > \varepsilon^{\sigma-1}/\kappa$ holds for $1 < \varepsilon < \varepsilon'_+$, and $\Theta/(1-\eta) \leq \varepsilon^{\sigma-1}/\kappa$ for $\varepsilon \geq \varepsilon'_+$.[35] This shows that if (and only if) the consumer's love of novelty $\varepsilon$ is sufficiently strong, there is a *locally* stable trap, $n^*$. Once the economy falls into the new product development regime, the economy is trapped and converging to the situation, $n^*$, in which there is no innovation.

Concerning the existing product development regime, there are two possibilities. First, if $n^{**}$ exists outside this regime, the equilibrium behavior of the economy is quite similar to that in the original model. That is, when $n^* > \varepsilon^{\sigma-1}/\kappa$, the economy achieves innovation and growth perpetually through irregular cycles of new and existing product development (Figure 4a). Otherwise, that is, if $n^* < \varepsilon^{\sigma-1}/\kappa$, the economy is fatally caught in a globally stable trap, $n^*$, called a global trap (Figure 4b).

Second, if $n^{**}$ is included in the existing product development regime, it may work as a globally stable steady state (Figure 5a). This case is for $n^* > \varepsilon^{\sigma-1}/\kappa$. At point $n^{**}$, the number of new goods, $N(t)$, and that of old goods, $A(t)$, grow at the same rate. Therefore, in this case, any path starting from any initial state converges to point $n^{**}$ that provides the economy balanced growth, similar to the standard growth model. Figure 5b depicts another interesting case where $n^* < \varepsilon^{\sigma-1}/\kappa$. There are two locally stable steady states, and whether the economy converges to a balanced growth path, $n^{**}$, or a locally stable trap, $n^*$, depends on the initial condition. So-called path dependence implies that the economy may suffer from a lock-in by virtue of historical events (e.g., Arthur 1989). We call this sort of trap a local trap.

In summary, we demonstrate that the minor change leads to drastically different equilibrium behaviors of the economy such as balanced growth and path dependence; however, the message in our main results does not alter: A too strong love of novelty, and a too weak love of novelty, negatively affect innovation and growth in the long run.

## 5.2 Departing from a One-period Monopoly

The purpose of the second extension is to relax the assumption of a one-period monopoly. To achieve this goal, we consider a stochastic process through which firms can obtain long-lived monopoly power. Specifically, we assume that if an R&D firm that invents a new good in period $t$ invests $z(t)/A(t)$ units of labor in existing product development,[36] it will survive with long-lived monopoly power from period $t+1$ onward at a probability of $s(t+1) = s(z(t)) \in [0,1]$. At the probability of $1 - s(t+1)$, the firm fails to obtain long-lived monopoly power and exits. We consider a simple linear survival function such as $s(z) = \psi z$ with $z \geq 0$; see Dinopoulos and Syropoulos (2007) and Eicher and García-Peñalosa (2008) for R&D-based growth models with this type of endogenous survival of innovations.[37] Here, $\psi > 0$ is a productivity parameter. Because $s(z)$ is a probability, $s(z) \leq 1$ must hold, and thus $z \leq 1/\psi$. The law of motion governing the evolution of the

[35]Notably, $\varepsilon'_-$ and $\varepsilon'_+$ are solutions to the quadratic equation in $\varepsilon$, given by $\Theta/(1-\eta) = \varepsilon^{\sigma-1}/\kappa$, noting $n^* = \Theta/(1-\eta)$. They are almost the same as $\varepsilon_-$ and $\varepsilon_+$ in Lemma 4.

[36]Alternatively, if we consider that an arbitrarily chosen outside firm makes this investment, the equilibrium conditions would not alter.

[37]See also Furukawa (2013) and Niwa (2018) for more recent papers. In this section, we use the modelling specification of firms' endogenous survival developed by these two papers.

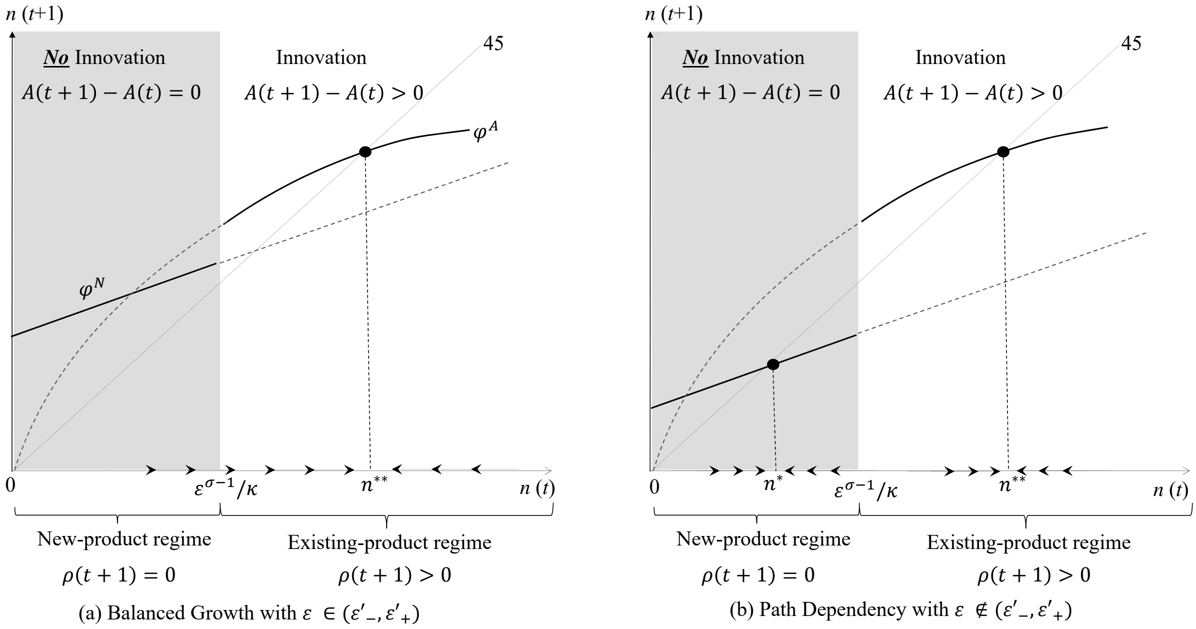



Figure 5: Balanced Growth and Path Dependency

old goods $A(t)$ is, thus, given by

$$A(t+1) = A(t) + s(t+1)N(t). \tag{38}$$

The discounted present value of a new good (or a firm inventing a new good) can be described as the following Bellman equation:

$$V^n(t) = \max_{z(t)} \left[ \pi^n(t) - \frac{w(t)z(t)}{A(t)} + s(t+1)\frac{V^a(t+1)}{1+r(t)} \right] \tag{39}$$

subject to $s(t+1) = \psi z(t) \in (0,1)$. The discounted present value of a successfully survived firm follows the following Bellman equation:

$$V^a(t) = \pi^a(t) + \frac{V^a(t+1)}{1+r(t)}. \tag{40}$$

Solving optimization in (39), there are three kinds of equilibrium: (i) the value of an old good satisfies

$$\tilde{W}^a(t) \equiv \psi \frac{V^a(t+1)}{1+r(t)} - \frac{w(t)}{A(t)} = 0 \tag{41}$$

for $0 < z(t) < 1/\psi$; (ii) $z(t) = 1/\psi$ holds with $\tilde{W}^a(t) \geq 0$; and (iii) $z(t) = 0$ holds with $\tilde{W}^a(t) \leq 0$. Free entry for new product development ensures

$$W^n(t) \equiv \frac{V^n(t+1)}{1+r(t)} - \frac{w(t)}{A(t)} = 0 \tag{42}$$

for $N(t+1) > 0$.

Here we restrict our analysis to the more interesting interior-solution case, (i), in which new and existing product development coexist; $N(t+1) > 0$ and $1 < z(t) < 1/\psi$.

Conditions (41) and (42) imply that the balanced values of new and old goods, $\psi V^a(t) = V^n(t)$, hold as long as $0 < z(t) < 1/\psi$. The following labor market clearing condition closes this extended model:

$$L = \frac{1}{\mu}\frac{E(t)}{w(t)} + \frac{z(t)N(t)}{A(t)} + \frac{N(t+1)}{A(t)}, \tag{43}$$

which is basically analogous to (21) except that the aggregate use of labor for existing product development now depends on each firm's endogenous decision, $z(t)$. Using (38)–(43), we can show that the equilibrium dynamical system in terms of the rate of innovation, $g(t) \equiv (A(t+1) - A(t))/A(t)$, is as follows.[38]

$$1 + g(t+1) = \frac{\varepsilon^{\sigma-1}}{\varepsilon^{\sigma-1} - \psi}\left[(1 + \psi L + \beta\psi) - \frac{\varepsilon^{\sigma-1}}{\varepsilon^{\sigma-1} - \psi}\frac{\beta\psi\,(1 + \psi L)}{1 + g(t)}\right]. \tag{44}$$

Using (44), we can straightforwardly prove the following: In the interior case of $0 < z(t) < 1/\psi$, for any given $g(t)$ on an equilibrium path, the equilibrium rate of innovation $g(t+1)$ can be an inverted U-shaped function in the love of novelty $\varepsilon$. To verify this, we define $\tilde{\varepsilon} \equiv \varepsilon^{\sigma-1}/\left(\varepsilon^{\sigma-1} - \psi\right)$ and $\varepsilon^* \equiv (1 + \beta + \psi L)\,(1 + g(t))\,/(2\beta\,(1 + \psi L))$ for descriptive convenience. Then, (44) becomes

$$1 + g(t+1) = \tilde{\varepsilon}\left[(1 + \beta + \psi L) - \frac{\beta\,(1 + \psi L)}{1 + g(t)}\tilde{\varepsilon}\right]. \tag{45}$$

Differentiating (45), $g(t+1)$ increases (decreases) with $\tilde{\varepsilon}$ for $\tilde{\varepsilon} \in (0, \varepsilon^*)$ (for $\tilde{\varepsilon} \in (\varepsilon^*, 2\varepsilon^*)$). Therefore, an inverted U-shaped relationship is observed between $\tilde{\varepsilon}$ and $g(t+1)$, and the maximum point is $\varepsilon^*$. Because $\tilde{\varepsilon}$ is decreasing in $\varepsilon$ and the feasible domain of $\tilde{\varepsilon}$ is $(1, \infty)$ (resulting from $\varepsilon \in (\psi, \infty)$), we can straightforwardly show that the relationship between $\varepsilon$ and $g(t+1)$ is also an inverted U-shape for the feasible range of $\varepsilon$ if $\varepsilon^* > 1$. This inequality holds for any $g(t) > 0$ if $1 + \beta + \psi L > 2\beta\,(1 + \psi L)$, which holds when, for instance, $\psi$ is sufficiently small. To conclude, in the general case in which a monopoly can last longer than one period, the love of novelty can have an inverted-U effect on innovation and growth. This result confirms our main message that the role of the public's love of novelty in innovation and growth is ambiguous.

# 6 Concluding Remarks

In this study, we explore the role of people's love of novelty in innovation and innovation-based growth by developing an innovation-based growth model in which the role of consumers' love of novelty in aggregate innovation can be addressed. In the model, innovation is the combination of two types of innovations, new product development and existing product development; additionally, the infinitely-lived representative consumer has a particular preference for new products (compared with old products), in addition to the standard love-of-variety preferences. Using this model, we show that the consumer's love of novelty can be a source of innovation and long-run growth when moderate. Then, we demonstrate a mechanism through which the love of novelty can cause underdevelopment traps that result in less innovations when its level is too weak or too strong. Thus, we conclude that people's love of novelty might have an ambiguous effect: too weak and too strong love for novelty can depress innovation and innovation-driven growth.

[38] See Appendix B for a proof on the derivations of (44).

## References


[1] Acemoglu, Daron, Simon Johnson, and James A. Robinson. "Institutions as a fundamental cause of long-term growth," *Handbook of Economic Growth*, 1A: 386–464 (2005).

[2] Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. "The environment and directed technical change," *American Economic Review*, 102: 131–166 (2012).

[3] Acs, Z., and M. Sanders. "Patents, knowledge spillovers, and entrepreneurship," *Small Business Economics*, 39: 801–17 (2012).

[4] Aghion, Philippe and Peter Howitt. "A model of growth through creative destruction," *Econometrica*, 60: 323–351 (1992).

[5] Aghion, Philippe, and Peter Howitt. "Research and development in the growth process," *Journal of Economic Growth*, 1: 49–73 (1996).

[6] Aghion, Philippe, and Xavier Jarave. "Knowledge spillovers, innovation and growth," *Economic Journal*, 125: 533—573 (2015).

[7] Akiyama, Taro. R&D, entrepreneurship, and growth." manuscript (2009).

[8] Alesina, Alberto, and Paola Giuliano. "The power of the family," *Journal of Economic Growth*, 15: 93–125 (2010).

[9] Anderlini, Luca , Leonardo Felli, Giovanni Immordino, and Alessandro Riboni. "Legal institutions, innovation and growth," *International Economic Review*, 54: 937–956 (2013).

[10] Arthur, W. Brian. "Competing technologies, increasing returns, and lock-in by historical events," *Economic Journal* 99: 116–131 (1989).

[11] Ashraf, Quamrul, and Oded Galor. "Cultural assimilation, cultural diffusion and the origin of the wealth of nations." *CEPR Discussion Papers* No. 6444 (2007).

[12] Ashraf, Quamrul, and Oded Galor. "The 'Out of Africa' hypothesis, human genetic diversity, and comparative economic development," *American Economic Review*, 103: 1–46 (2013a).

[13] Ashraf, Quamrul, and Oded Galor. "Genetic diversity and the origins of cultural fragmentation," *American Economic Review Papers and Proceedings*, 103: 528–533 (2013b).

[14] Ashraf, Quamrul, and Oded Galor. "The macrogenoeconomics of comparative development," *Journal of Economic Literature*, forthcoming (2017).

[15] Barber, Bernard. "Resistance by scientists to scientific discovery," *Science*, 134: 596–602 (1961).

[16] Barro, Robert, and Jong-Wha Lee. "A new data set of educational attainment in the world, 1950-2010," *Journal of Development Economics*, 104: 184-198 (2013).

[17] Bénabou, Roland, Davide Ticchi, and Andrea Vindigni. "Religion and innovation," *American Economic Review: Papers & Proceedings*, 105: 346–351 (2015).

[18] Bénabou, Roland, Davide Ticchi, Andrea Vindigni. "Forbidden fruits: The political economy of science, religion, and growth," *NBER Working Paper Series*, 21105 (2016). Available at: https://www.princeton.edu/˜rbenabou/papers/Religion%20July%202016%20new.pdf (accessed on August 29, 2017).

[19] Benhabib, Jess, Jesse Perla, and Christopher Tonetti. "Reconciling models of diffusion and innovation: A theory of the productivity distribution and technology frontier, *NBER Working Paper* No. 23095 (2017).

[20] Bento, Pedro. "Quantifying the effects of patent protection on innovation, imitation, growth, and aggregate productivity, "mimeo (2018).

[21] Beveridge, William Ian Beardmore. *The Art of Scientific Investigation*, Random House, New York (1959).

[22] Boserup, Ester. *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*, Chicago: Aldine (1965).

[23] Chu, Angus C. "Confidence-enhanced economic growth," *The B.E. Journal of Macroeconomics (Topics)*, 7: Article 13 (2007).

[24] Chu, Angus C, and Guido Cozzi. "Cultural preference on fertility and the growth and welfare effects of intellectual property rights," *MPRA Paper* No. 31283 (2011).

[25] Chu, Angus C., and Yuichi Furukawa. "Patentability and knowledge spillovers of basic R&D," *Southern Economic Journal*, 79: 928–945 (2013).

[26] Chu, Angus C., Guido Cozzi, and Silvia Galli. "Does intellectual monopoly stimulate or stifle innovation?" *European Economic Review*, 56: 727–746 (2012).

[27] Chu, Angus C., Guido Cozzi, Shiyuan Pan, and Mengbo Zhang. "Do stronger patents stimulate or stifle innovation? The crucial role of financial development," *MPRA Paper* No. 73630 (2016).

[28] Cloninger, Claude R. "A unified biosocial theory of personality and its role in the development of anxiety states," *Psychiatric Developments* 4: 167–226 (1986).

[29] Cohen, Wesley M. and Daniel A. Levinthal. "Innovation and learning: The two faces of R&D," *Economic Journal*, 99: 569–596 (1989).

[30] Cozzi, Guido. "Culture as a bubble," *Journal of Political Economy*, 106: 376–394 (1998).

[31] Cozzi, Guido, and Silvia Galli. "Science-based R&D in Schumpeterian growth," *Scottish Journal of Political Economy*, 56, 474–491 (2009).

[32] Cozzi, Guido, and Silvia Galli. "Privatization of knowledge: Did the U.S. get it right?" *Economics Working Paper Series* 1307, University of St. Gallen, School of Economics and Political Science (2013).

[33] Cozzi, Guido, and Silvia Galli. "Sequential R&D and blocking patents in the dynamics of growth," *Journal of Economic Growth*, 19: 183–219 (2014).

[34] Dastidar, Krishnendu G., and Makoto Yano. "Corruption, market quality and entry deterrence in emerging economies," *RIETI Discussion Paper Series* 17-E-010 (2017).

[35] Deneckere, Raymond and Kenneth Judd. "Cyclical and chaotic behavior in a dynamic equilibrium model," in *Cycles and Chaos in Economic Equilibrium*, ed. by Jess Benhabib. Princeton: Princeton University Press (1992).

[36] Diamond, Jared. *Guns, Germs, and Steel*, New York: W. W. Norton (1997).

[37] Dinopoulos, Elias, and Syropoulos, Constantinos. "Rent protection as a barrier to innovation and growth," *Economic Theory*, 32: 309–332 (2007).

[38] Doepke, Matthias, and Fabrizio Zilibotti. "Culture, entrepreneurship, and growth," *Handbook of Economic Growth*, 2A: 1-48 (2014).

[39] Doi, Junko, and Kazuo Mino. "A variety-expansion model of growth with external habit formation," *Journal of Economic Dynamics and Control*, 32: 3055–3083 (2008).

[40] Eicher, Theo, and García-Peñalosa, Cecilia. "Endogenous strength of intellectual property rights: Implications for economic development and growth," *European Economic Review*, 52: 237–258 (2008).

[41] Evans, Lewis, Neil Quigley, and Jie Zhang. "Optimal price regulation in a growth model with monopolistic suppliers of intermediate goods," *Canadian Journal of Economics*, 36: 463–474 (2003).

[42] Fagerberg, Jan. "Innovation: A guide to the literature," in *Oxford Handbook of Innovation*, ed. by J. Fagerberg, D. Mowery, and R. Nelson: Oxford University Press (2006).

[43] Fagerberg, Jan. "Innovation: A new guide," Working Paper, University of Oslo, Aalborg University, and Lund University (2013). Available at:
http:// www.sv.uio.no/tik/InnoWP/tik_working_paper_19112013.pdf (accessed on August 29, 2017).

[44] Francois, Patrick, and Shouyong Shi. "Innovation, growth, and welfare-improving cycles," *Journal of Economic Theory*, 85: 226–57 (1999).

[45] Furukawa, Yuichi. "The struggle to survive in the R&D sector: Implications for innovation and growth," *Economics Letters*, 121: 26–29 (2013).

[46] Furukawa, Yuichi. "Leapfrogging cycles in international competition," *Economic Theory*, 59: 401–433 (2015).

[47] Furukawa, Yuichi, Tat-kei Lai, and Kenji Sato. "Novelty-seeking traits and innovation," *RIETI Discussion Paper Series* 18-E-073 (2018).

[48] Furukawa, Yuichi, Tat-kei Lai, and Kenji Sato. "Novelty-seeking traits and applied research activities," *Applied Economics Letters*, forthcoming (2019).

[49] Gale, Douglas. “Delay and cycles,” *Review of Economic Studies*, 63: 169–98 (1996).

[50] Galor, Oded, and Stelios Michalopoulos. “Evolution and the growth process: Natural selection of entrepreneurial traits.” *Journal of Economic Theory*, 147: 759–780 (2012).

[51] Galor, Oded, and Omer Moav. “Natural selection and the origin of economic growth.” *Quarterly Journal of Economics*, 117: 1133–1192 (2002).

[52] Gilbert, Richard, and Carl Shapiro. “Optimal patent length and breadth,” *RAND Journal of Economics*, 21: 106–112 (1990).

[53] Goh, A.-T., and J. Olivier. “Optimal patent protection in a two-sector economy,” *International Economic Review*, 43: 1191–1214 (2002).

[54] Gören, Erkan. “The persistent effects of novelty-seeking traits on comparative economic development,” *Journal of Development Economics*, 126: 112–126 (2017).

[55] Grossman, Gene M., and Elhanan Helpman. *Innovation and Growth in the Global Economy*, Cambridge, MA: MIT Press (1991).

[56] Hall, Bronwyn H., Adam Jaffe, and Manuel Trajtenberg. “The NBER patent citations data file: Lessons, insights and methodological tools,”*NBER Working Papers* No. 8498 (2001).

[57] Iwaisako, Tatsuro, and Koichi Futagami. “Dynamic analysis of patent policy in an endogenous growth model,”*Journal of Economic Theory*, 132: 306–334 (2007).

[58] Iwaisako, Tatsuro, and Koichi Futagami. “Patent protection, capital accumulation, and economic growth,” *Economic Theory*, 52: 631–668 (2013).

[59] Iwaisako, Tatsuro, and Hitoshi Tanaka. “Product cycles and growth cycles,”*Journal of International Economics*, 105: 22–40 (2017).

[60] Jones, Charles I. “Time series tests of endogenous growth models,” *Quarterly Journal of Economics*, 110: 495–525 (1995).

[61] Judd, Kenneth L. “On the performance of patents,” *Econometrica*, 53: 567–586 (1985).

[62] Konishi, Kunihiko. “Basic and applied research: A welfare analysis.” *Japanese Economic Review*, 69: 414–437 (2018).

[63] Kremer, Michael. “Population growth and technological change: One million B.C. to 1990,” *Quarterly Journal of Economics*, 108: 681–716 (1993).

[64] Li, Chol.-Won. “On the policy implications of endogenous technological progress,” *Economic Journal*, 111: C164–C179 (2001).

[65] Lucas, Robert. E., and Benjamin Moll “Knowledge growth and the allocation of time.” *Journal of Political Economy*, 122: 1–51 (2014).

[66] Matsuyama, Kiminori. “Growing through cycles,” *Econometrica*, 67: 335–47 (1999).

[67] Matsuyama, Kiminori. “Growing through cycles in an infinitely lived agent economy,” *Journal of Economic Theory*, 100: 220–34 (2001).

[68] Michelacci, Claudio. “Low returns in R&D due to the lack of entrepreneurial skills,” *Economic Journal*, 113: 207–25 (2003).

[69] Middendorf, William H. *What every engineer should know about inventing*, New York: Marcel Dekker (1981).

[70] Mokyr, Joel. “Technological inertia in economic history,” *Journal of Economic History*, 52: 325–338 (1992).

[71] Mokyr, Joel. “Innovation and its enemies: The economic and political roots of technological inertia,” in *A Not-so-dismal Science: A Broader View of Economies and Societies*, ed. by Mancur Olson and Satu Kahkohnen. Oxford: Oxford University Press (2000 (1996, DP)).

[72] Mokyr, Joel. *The gifts of Athena: Historical origins of the knowledge economy.* Princeton, NJ: Princeton University Press (2004).

[73] Mokyr, Joel. “Long-term economic growth and the history of technology,” *Handbook of Economic Growth*, 1B: 1114–1174 (2005).

[74] Niwa, Sumiko. “Effects of a blocking patent on R&D with endogenous survival activities,” *Journal of Economics*, forthcoming (2018).

[75] OECD/Eurostat. *Oslo Manual 2018: Guidelines for Collecting, Reporting and Using Data on Innovation, 4th Edition*, The Measurement of Scientific, Technological and Innovation Activities, OECD Publishing, Paris/Eurostat, Luxembourg (2018).

[76] Park, Walter G. “International patent protection: 1960-2005,” *Research Policy*, 37: 761–766 (2008).

[77] Romer, Paul. M. “Endogenous technological change,” *Journal of Political Economy*, 98: S71–S102 (1990).

[78] Segerstrom, Paul, T. C. A. Anant, and Elias Dinopoulos. “A Schumpeterian Model of the Product Life Cycle, ” *American Economic Review*, 80: 1077-91 (1990).

[79] Shleifer, Andrei. “Implementation cycles,” *Journal of Political Economy*, 94: 1163–1190 (1986).

[80] Tabellini, Guido. “Culture and institutions: Economic development in the regions of Europe,” *Journal of the European Economic Association*, 8: 677–716 (2010).

[81] Yano, Makoto. “The foundation of market quality economics,” *Japanese Economic Review*, 60: 1–32 (2009).

[82] Yano, Makoto, and Yuichi Furukawa. “Two-dimensional constrained chaos and time in innovation: An analysis of industrial revolution cycles,” *RIETI Discussion Paper Series* 19-E-008 (2019).

# Appendix A: Cross-country Relationships Between Love of Novelty, Innovation, and Originality

In this Appendix, we document some suggestive evidence regarding the country-level relationships between Love of novelty, Innovation, and Originality.

**Data and variables** To measure the "Love of novelty" of the people of a country, we use data from Question E046 of the World Values Survey (WVS). This survey question asks respondents to score this statement, "Ideas stood test of time better vs New ideas better." The score ranges from 1 ("Ideas that stood test of time are generally best") to 10 ("New ideas are generally better than old ones"). To construct the country-level measure, we collapse the WVS sample with valid responses to E046 into country-level means. This variable is also used by Bénabou et al. (2015) to measure people's general openness to novelty.

We use patent data from the World Intellectual Property Organization (WIPO) and population data from the World Bank to construct several measures of innovation, including Patent applications per million capita in log, Trademark applications per million capita in log, Industrial design applications per million capita in log, and Scientific and technical journal articles per million capita in log.[39] As an alternative measure of innovation, we also use the Global Innovation Index.[40]

Our "Originality" variable measures a country's "original" patents relative to the "benchmark" U.S. patent within the same patent class and granting year. Specifically, we use the NBER patent data from Hall et al. (2001) to construct this variable. The NBER patent database contains a measure of originality for each patent granted between 1973 and 1999, defined as:[41]

$$1 - \sum_{j=1}^{J} \left( \frac{\text{Citations made which belong to patent class } j}{\text{Total citations made}} \right)^2 . \tag{A1}$$

This measure takes a high value when a patent cites other patents that belong to a wide range of patent classes but a low value when only citing other patents that belong to a narrow range of patent classes. For each patent class and granting year, we identify the "benchmark" as the median value of the above measure in (A1) for U.S. patents. For each patent, we compute the difference between the patent's originality measure in (A1) and the U.S. benchmark. Then our Originality index for a country is the average of this difference; when a country has a higher Originality index, then this country's patents tend to be more original than the U.S. benchmarks.

In the next subsection, we report the unconditional relationships between Love of novelty, Innovation, and Originality. We also estimate several simple ordinary least squares (OLS) regressions with additional country-level controls, including log GDP per capita,

[39] More specifically, Patent applications per million capita for a country is computed as the sum of the country's patent applications over 2010–2015 divided by the country's average population over 2010–2015. The other measures are computed in a similar way.

[40] For each country, we take the average of non-missing values over 2011-2015 as its Global Innovation Index.

[41] See Bento (2018) for a recent study that also uses Hall et al.'s (2001) originality measure. Notably, his focus is quite different from ours, and particularly on the effects of patent protection on patent originality.

log Population, intellectual property protection, years of tertiary schooling, net inflow of foreign direct investment as a percentage of GDP, and religiosity (share of religious people and share of people believing in God).[42] Data for GDP per capita are from the World Bank; data for the net inflow of foreign direct investment (FDI) as a percentage of GDP are from the World Development Index (WDI); the index of patent rights comes from Park (2008); data for years of tertiary schooling are from Barro and Lee (2013). To construct the two measures of religiosity, we use the survey questions F034 and F050 of WVS. More specifically, F034 asks whether the respondent is a religious person (the survey question is: "Independently of whether you go to church or not, would you say you are ..." with possible answers 1 ("A religious person"), 2 ("Not a religious person"), and 3 ("A convinced atheist").) F050 asks whether the respondent believes in god (the survey question is: "Which, if any, of the following do you believe in? ... God" with possible answers 0 ("No") and 1 ("Yes").) Notably, the control variables are country-level means between 1990 and 2010 except that the two religiosity measures are means between 1981 and 2002. Table 1 reports the summary statistics of the various variables used.[43]

**Results and discussions** We first examine the relationship between Love of novelty and Innovation. Figure 6(a) to Figure 6(e) show the scatter plots of the country-level means of E046 of WVS against the five different aforementioned innovation measures. In each scatter plot, the line is a fitted quadratic curve. In these various scatter plots, we observe an inverted-U relationship between Love of novelty and Innovation: Innovation is lower when Love of novelty is either very weak or very strong. These relationships are all statistically significant. The aforementioned relationships are purely unconditional. We also estimate a set of OLS regressions by including various country-level control variables. These results are reported in Tables 2 to 6, respectively. We find that the inverted-U relationship is significant (except when the Global Innovation Index is the outcome variable).

Next, we examine the relationship between Love of novelty and Originality. Figure 6(f) shows a scatter plot of the country-level means of E046 of WVS against our Originality measure. The linear fitted line has a positive slope (but is statistically insignificant). In Table 7, we also estimate a set of OLS regressions. We find that, when other control variables are included (in Columns (2) to (4)), Love of novelty is positively and significantly related to Originality.

Overall, there seems to be an inverted-U relationship between Love of novelty and Innovation and a positive relationship between Love of novelty and Originality. Nevertheless, we are aware of various limitations of the empirical analysis. For instance, one major concern is regarding the measurement of "love of novelty." In the empirical analysis, we use data from the WVS to construct the country-level love of novelty index. We can argue that answers to such types of survey questions do not necessarily provide an accurate measure of the extent to which consumers love new products. One further question is whether these answers can be compared across countries; this comparison is especially relevant in our case because we cannot control for country-level differences through country fixed-effects in our country-level regressions. An even more challenging concern is whether the relationships we observe are causal. Without a credible instrument that is correlated with people's love of novelty but is not correlated with other factors that

[42] These control variables are also used in Bénabou et al. (2016).

[43] Notably, this variable has an outlier (for Colombia); its value is 8.210, whereas the maximum value of the remaining countries is approximately 6.185. In the results reported, this outlier is excluded.

can potentially affect innovation activities, we cannot show that love of novelty *causally* affects innovation activities.

Although these empirical concerns are important, it is beyond the scope of this study to address them. Therefore, we emphasize that the empirical results reported in this Appendix should be interpreted as *suggestive* evidence in line with the predictions of the theoretical predictions of our model.

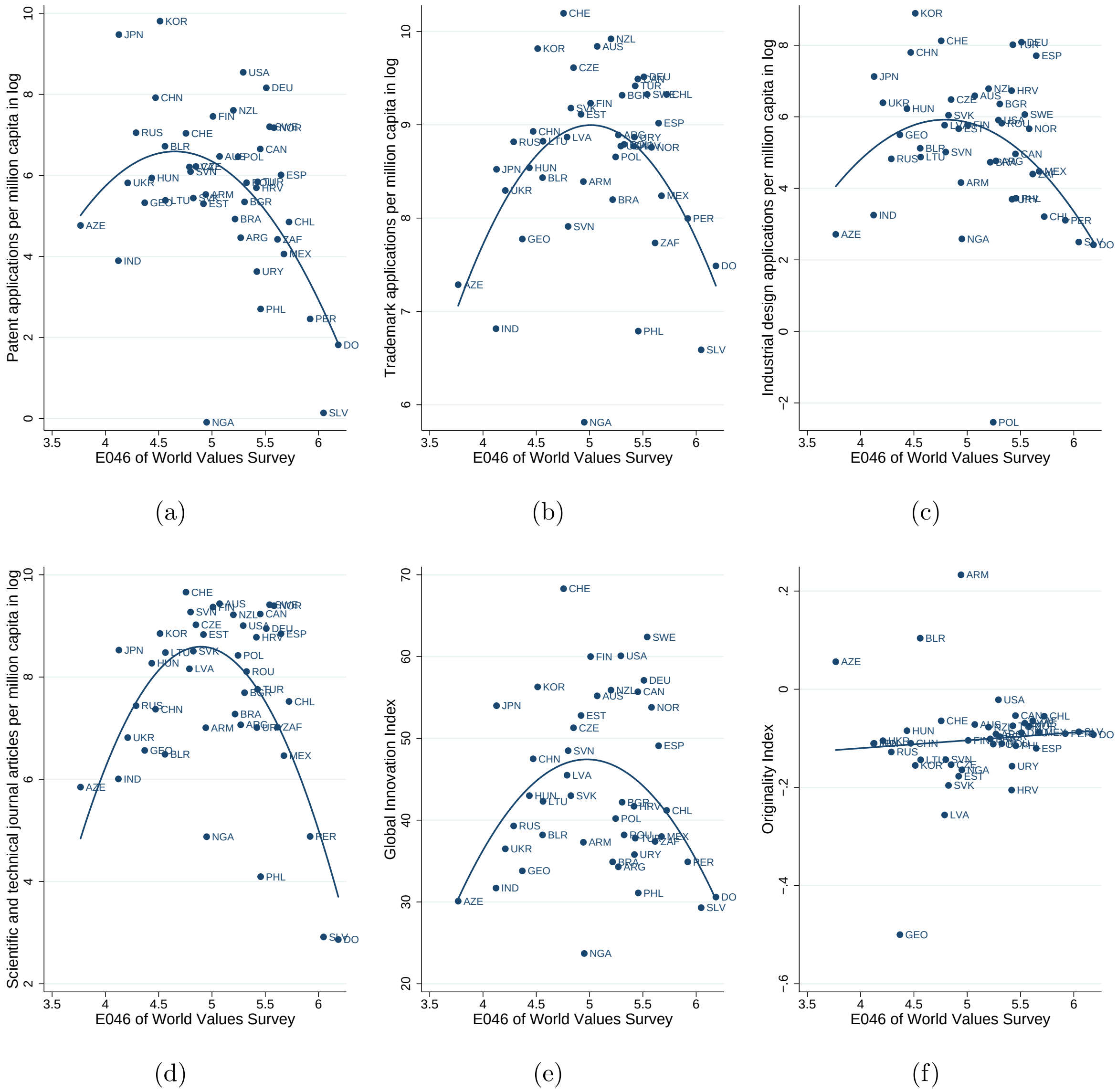



Figure 6: Scatter plots

Table 1: Summary statistics

| Variable | $N$ | Mean | S.D. | Min. | 1st Q. | Median | 3rd Q. | Max. |
|---|---|---|---|---|---|---|---|---|
| Patent applications per million capita in log | 43 | 5.622 | 2.092 | −0.090 | 4.766 | 5.820 | 7.039 | 9.807 |
| Trademark applications per million capita in log | 43 | 8.606 | 0.950 | 5.812 | 8.198 | 8.790 | 9.316 | 10.194 |
| Industrial design applications per million capita in log | 43 | 5.245 | 2.061 | −2.540 | 4.163 | 5.667 | 6.483 | 8.894 |
| Sci. and tech. journal articles per million capita in log | 43 | 7.599 | 1.719 | 2.865 | 6.816 | 8.108 | 8.950 | 9.661 |
| Global Innovation Index | 43 | 43.721 | 10.521 | 23.700 | 35.800 | 41.700 | 53.800 | 68.300 |
| Originality | 43 | −0.103 | 0.100 | −0.500 | −0.144 | −0.101 | −0.075 | 0.233 |
| E046 of WVS | 43 | 5.065 | 0.563 | 3.767 | 4.563 | 5.201 | 5.457 | 6.185 |
| GDP per capita in log | 43 | 9.140 | 1.150 | 6.713 | 8.163 | 9.098 | 10.222 | 11.275 |
| Population in log | 43 | 2.997 | 1.644 | 0.343 | 1.644 | 2.717 | 4.146 | 7.133 |
| Index of patent rights | 35 | 3.458 | 0.673 | 2.382 | 2.936 | 3.250 | 4.074 | 4.840 |
| Years of tertiary schooling | 31 | 43.868 | 20.138 | 10.280 | 28.860 | 40.300 | 59.700 | 79.640 |
| FDI (as % of GDP) | 43 | 3.768 | 3.473 | 0.142 | 1.860 | 2.921 | 4.293 | 21.356 |
| % religious people | 43 | 0.659 | 0.195 | 0.160 | 0.556 | 0.708 | 0.804 | 0.949 |
| % people believing in God | 41 | 0.811 | 0.166 | 0.424 | 0.672 | 0.856 | 0.960 | 0.996 |

Table 2: The relationship between Love of novelty and Innovation (1)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Love of novelty | 18.756*** | 7.912 | 12.661** | 9.268* |
| | (6.579) | (5.023) | (5.018) | (4.792) |
| (Love of novelty)$^2$ | −2.016*** | −0.942* | −1.362*** | −1.024** |
| | (0.655) | (0.496) | (0.502) | (0.477) |
| GDP per capita (log) | | 0.843*** | 0.687** | 0.738*** |
| | | (0.316) | (0.284) | (0.254) |
| Population (log) | | 0.411** | 0.469*** | 0.323** |
| | | (0.166) | (0.123) | (0.128) |
| Index of patent rights | | 0.537 | 0.318 | 0.479 |
| | | (0.401) | (0.392) | (0.345) |
| Years of tertiary schooling | | 0.018 | 0.023** | 0.019** |
| | | (0.012) | (0.009) | (0.009) |
| FDI (as % of GDP) | | 0.042 | 0.001 | −0.072 |
| | | (0.104) | (0.081) | (0.079) |
| % religious people | | | −2.841*** | |
| | | | (0.829) | |
| % people believing in God | | | | −2.958*** |
| | | | | (0.927) |
| Constant | −37.030** | −21.679* | −31.195*** | −22.430** |
| | (16.351) | (12.432) | (11.737) | (11.265) |
| Observations | 43 | 31 | 31 | 29 |
| $R^2$ | 0.265 | 0.842 | 0.881 | 0.900 |

Note: The dependent variable is Patent applications per million capita in log. Robust standard errors are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.

Table 3: The relationship between Love of novelty and Innovation (2)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Love of novelty | 12.526*** | 9.278*** | 11.232*** | 10.330*** |
| | (2.953) | (2.900) | (2.924) | (2.885) |
| (Love of novelty)$^2$ | −1.250*** | −0.948*** | −1.120*** | −1.033*** |
| | (0.298) | (0.283) | (0.286) | (0.282) |
| GDP per capita (log) | | 0.503** | 0.439* | 0.458** |
| | | (0.228) | (0.231) | (0.221) |
| Population (log) | | 0.021 | 0.044 | −0.015 |
| | | (0.089) | (0.071) | (0.077) |
| Index of patent rights | | −0.266 | −0.356 | −0.310 |
| | | (0.286) | (0.283) | (0.276) |
| Years of tertiary schooling | | 0.006 | 0.008 | 0.008 |
| | | (0.006) | (0.006) | (0.006) |
| FDI (as % of GDP) | | 0.098 | 0.081 | 0.056 |
| | | (0.074) | (0.067) | (0.069) |
| % religious people | | | −1.168** | |
| | | | (0.472) | |
| % people believing in God | | | | −0.989 |
| | | | | (0.628) |
| Constant | −22.391*** | −17.986** | −21.900*** | −19.595*** |
| | (7.210) | (6.999) | (6.686) | (6.558) |
| Observations | 43 | 31 | 31 | 29 |
| $R^2$ | 0.230 | 0.698 | 0.735 | 0.748 |

Note: The dependent variable is Trademark applications per million capita in log. Robust standard errors are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.

Table 4: The relationship between Love of novelty and Innovation (3)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Love of novelty | 16.938*** | 6.281 | 16.384** | 18.186*** |
| | (6.250) | (10.277) | (7.566) | (5.579) |
| (Love of novelty)$^2$ | −1.766*** | −0.739 | −1.632** | −1.847*** |
| | (0.607) | (1.007) | (0.759) | (0.552) |
| GDP per capita (log) | | 0.747** | 0.416 | 0.501 |
| | | (0.363) | (0.319) | (0.323) |
| Population (log) | | 0.072 | 0.195 | 0.067 |
| | | (0.211) | (0.164) | (0.163) |
| Index of patent rights | | 0.940* | 0.475 | 0.474 |
| | | (0.540) | (0.396) | (0.384) |
| Years of tertiary schooling | | −0.030 | −0.019 | −0.016 |
| | | (0.019) | (0.016) | (0.014) |
| FDI (as % of GDP) | | 0.001 | −0.086 | −0.103 |
| | | (0.149) | (0.134) | (0.119) |
| % religious people | | | −6.044*** | |
| | | | (2.232) | |
| % people believing in God | | | | −3.351** |
| | | | | (1.404) |
| Constant | −34.685** | −16.371 | −36.613** | −41.421*** |
| | (15.812) | (24.429) | (17.903) | (12.661) |
| Observations | 43 | 31 | 31 | 29 |
| $R^2$ | 0.136 | 0.369 | 0.530 | 0.665 |

Note: The dependent variable is Industrial design applications per million capita in log. Robust standard errors are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.

Table 5: The relationship between Love of novelty and Innovation (4)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Love of novelty | 28.827*** | 19.842*** | 20.307*** | 19.741*** |
| | (4.930) | (4.053) | (4.105) | (4.309) |
| (Love of novelty)$^2$ | −2.944*** | −2.061*** | −2.102*** | −2.041*** |
| | (0.494) | (0.395) | (0.398) | (0.419) |
| GDP per capita (log) | | 1.053*** | 1.038*** | 1.039*** |
| | | (0.309) | (0.309) | (0.296) |
| Population (log) | | 0.171* | 0.177* | 0.164 |
| | | (0.101) | (0.097) | (0.103) |
| Index of patent rights | | 0.054 | 0.032 | 0.058 |
| | | (0.377) | (0.377) | (0.362) |
| Years of tertiary schooling | | 0.001 | 0.001 | −0.000 |
| | | (0.007) | (0.007) | (0.007) |
| FDI (as % of GDP) | | 0.139** | 0.135* | 0.121* |
| | | (0.070) | (0.070) | (0.068) |
| % religious people | | | −0.278 | |
| | | | (0.551) | |
| % people believing in God | | | | −0.595 |
| | | | | (0.551) |
| Constant | −61.975*** | −50.279*** | −51.210*** | −49.606*** |
| | (12.171) | (9.381) | (9.500) | (9.950) |
| Observations | 43 | 31 | 31 | 29 |
| $R^2$ | 0.427 | 0.905 | 0.906 | 0.910 |

Note: The dependent variable is Scientific and technical journal articles per million capita in log. Robust standard errors are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.

Table 6: The relationship between Love of novelty and Innovation (5)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Love of novelty | 116.348*** | 13.917 | 34.502 | 14.254 |
| | (28.577) | (26.129) | (28.068) | (23.452) |
| (Love of novelty)$^2$ | −11.693*** | −1.755 | −3.573 | −1.699 |
| | (2.812) | (2.533) | (2.669) | (2.223) |
| GDP per capita (log) | | 5.201*** | 4.528*** | 4.985*** |
| | | (1.225) | (1.453) | (1.261) |
| Population (log) | | 0.224 | 0.475 | −0.533 |
| | | (0.797) | (0.702) | (0.672) |
| Index of patent rights | | 5.799*** | 4.851*** | 5.735*** |
| | | (1.827) | (1.676) | (1.590) |
| Years of tertiary schooling | | −0.003 | 0.018 | 0.020 |
| | | (0.069) | (0.079) | (0.064) |
| FDI (as % of GDP) | | 0.357 | 0.180 | −0.068 |
| | | (0.631) | (0.485) | (0.480) |
| % religious people | | | −12.315** | |
| | | | (5.419) | |
| % people believing in God | | | | −3.404 |
| | | | | (5.654) |
| Constant | −241.981*** | −49.802 | −91.048 | −45.619 |
| | (71.391) | (64.658) | (67.642) | (57.965) |
| Observations | 43 | 31 | 31 | 29 |
| $R^2$ | 0.164 | 0.846 | 0.875 | 0.889 |

Note: The dependent variable is Global Innovation Index. Robust standard errors are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.

Table 7: The relationship between Love of novelty and Originality

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Love of novelty | 0.016 | 0.032*** | 0.022** | 0.013* |
| | (0.029) | (0.011) | (0.009) | (0.008) |
| GDP per capita (log) | | 0.009 | 0.012* | 0.012** |
| | | (0.006) | (0.006) | (0.006) |
| Population (log) | | 0.009* | 0.007* | 0.007* |
| | | (0.005) | (0.004) | (0.004) |
| Index of patent rights | | 0.012 | 0.017* | 0.016* |
| | | (0.009) | (0.009) | (0.008) |
| Years of tertiary schooling | | −0.000 | −0.000 | −0.000 |
| | | (0.000) | (0.000) | (0.000) |
| FDI (as % of GDP) | | 0.004 | 0.004** | 0.006*** |
| | | (0.002) | (0.002) | (0.002) |
| % religious people | | | 0.058** | |
| | | | (0.023) | |
| % people believing in God | | | | 0.112*** |
| | | | | (0.022) |
| Constant | −0.184 | −0.426*** | −0.438*** | −0.462*** |
| | (0.158) | (0.098) | (0.084) | (0.080) |
| Observations | 43 | 31 | 31 | 29 |
| $R^2$ | 0.008 | 0.397 | 0.488 | 0.611 |

Note: The dependent variable is Originality. Robust standard errors are reported in parentheses. *: significance at 10% level; **: significance at 5% level; ***: significance at 1% level.

# Appendix B: Proof for (44)

Solving the maximization problem in (39), the first order condition gives rise to

$$\psi \frac{V^a(t+1)}{1+r(t)} = \frac{w(t)}{A(t)}, \tag{B1}$$

which must hold in the interior-solution equilibrium where $z(t) \in (0, 1/\psi)$. Incorporating (B1) for (39) and (40) yields

$$V^n(t) = \pi^n(t) \tag{B2a}$$

and

$$V^a(t) = \pi^a(t) + \frac{w(t)}{A(t)}, \tag{B2b}$$

respectively.

Together with these conditions on innovation values, we will derive the equilibrium dynamical system of the extended model (for the interior-solution case). First, substituting (B2a) and (B2b) into the balanced value condition $\psi V^a(t) = V^n(t)$, we obtain

$$\frac{E(t)}{w(t)} = \frac{\psi}{\varepsilon^{\sigma-1} - \psi} \frac{\mu}{\mu - 1} \frac{A(t) + \varepsilon^{\sigma-1} N(t)}{A(t)}, \tag{B3}$$

which uses (12), (14), and (20) for the expressions of profits, $\pi^n(t)$ and $\pi^a(t)$. To proceed, we need to assume $\varepsilon^{\sigma-1} > \psi$ since $E(t)/w(t)$ must be positive. Second, substituting (B2a) into the free entry condition (42), we obtain

$$\frac{E(t)}{w(t)} = \frac{1}{\beta\varepsilon^{\sigma-1}} \frac{\mu}{\mu - 1} \frac{A(t+1) + \varepsilon^{\sigma-1} N(t+1)}{A(t)}, \tag{B4}$$

which uses the Euler equation (9), (12) and (20). Finally, incorporating (38) for the labor market equilibrium condition (43), with $s(t+1) = \psi z(t)$, we obtain

$$\frac{E(t)}{w(t)} = \mu \left[ L - \frac{1}{\psi} \frac{A(t+1) - A(t)}{A(t)} - \frac{N(t+1)}{A(t)} \right]. \tag{B5}$$

These three conditions, (B3)–(B5), govern the equilibrium dynamic behavior of our economy in the interior case of $z(t) \in (0, 1/\psi)$. Specifically, these determine $E(t)/w(t)$, $A(t+1)$, and $N(t+1)$ as a function in $A(t)$ and $N(t)$.

Since our interest is in the dynamics of the growth rate, $g(t) \equiv (A(t+1) - A(t))/A(t)$, we rewrite (B3)–(B5) as follows. First, we use (B4) and (B5) to express $N(t+1)$ as a function of $g(t)$ and $A(t)$:

$$N(t+1) = A(t) \frac{1}{\psi} \left[ \frac{(\psi L + 1)(\beta(\mu - 1))}{\beta(\mu - 1) + 1} - \frac{\beta\varepsilon^{\sigma-1}(\mu - 1) + \psi}{\varepsilon^{\sigma-1}(\beta(\mu - 1) + 1)} (1 + g(t)) \right]. \tag{B6}$$

Using (B3) and (B4), then, we express $1 + g(t)$ as a function in $A(t)$, $N(t+1)$, and $N(t)$:

$$1 + g(t) = \frac{\beta\psi\varepsilon^{\sigma-1}}{\varepsilon^{\sigma-1} - \psi} \left( 1 + \varepsilon^{\sigma-1} \frac{N(t)}{A(t-1)} \frac{1}{1 + g(t-1)} \right) - \varepsilon^{\sigma-1} \frac{N(t+1)}{A(t)}, \tag{B7}$$

which uses $A(t) = A(t-1)(1 + g(t-1))$. To eliminate $N(t+1)$ and $N(t)$ from (B7), we use (B6), yielding (44).