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

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Abstract

This study develops a new dynamic general equilibrium model to explore the role of people's love of novelty as a cultural preference 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 consumers' love of novelty is a source of innovation-based growth, wherein economies with a moderate love of novelty can achieve innovation and long-run growth through endogenous cycles between periods in which new product development is active and those in which existing product development is active. However, if love of novelty preference is too weak or too strong, the economy is caught in an underdevelopment trap with less innovation and no long-run growth. We also provide some suggestive empirical evidence that supports our theoretical predictions.

JEL Classification Codes: E71; O40

Keywords: Cultural preferences, macro-based behavioral economics; innovation and growth cycles; endogenous growth; underdevelopment traps

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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, from both theoretical and empirical perspectives, it is still unclear how and to what extent culture explains such differences. A large body of literature has examined this question, considering such dimensions as preferences, entrepreneurial traits, religion, and family ties.[1] This study provides a new approach to this growing research agenda by clarifying the importance of the desire for new ideas (or "love of novelty") as an individual cultural preference.

Love of novelty is widely considered important for innovation. For example, Fagerberg (2004, 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 considered a major driver of long-run growth in macroeconomics (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992), a relevant research question is to identify the role of people's love of novelty as a cultural preference in terms of macroeconomic performance such as innovation and growth.

To motivate our theoretical analysis, we first show in Figure 1 some country-level relationships between love of novelty (using data from the World Values Survey) and innovation (using data from World Intellectual Property Organization and other databases). This figure shows an inverted-U relationship between love of novelty and innovations and a positive relationship between love of novelty and original innovations, suggesting that the relationship between love of novelty and innovation can be non-trivial.[2]

Our theoretical analysis extends Matsuyama (1999, 2001) by incorporating the following new features.[3] First, we assume that an infinitely lived representative consumer has preferences for both differentiated products ("love of variety") *and* new products ("love of novelty"). Second, we incorporate the well-accepted view that each single innovation involves a combination of new and existing product development (OECD 2018).[4] Specifically, in our model, new ideas are first invented as original products, and they are transformed and developed into "old" products through existing product development.

Our core finding is that, depending on its level, love of novelty can play different roles in innovation and growth: (a) When love of novelty preference is weak, firms invent fewer original products, even though they are the source of existing product development.

[1] See Section 2 for a literature review.

[2] Details about the data sources and variables and additional regression results are in the Appendix. A recent 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 can be a source of growth and development provided that it is moderate, but it can have a negative effect if it is too strong or too weak. This is consistent with our theoretical findings. The key difference between Gören (2017) and our study is that Gören (2017) characterizes people's novelty-seeking traits by genetic information whereas we consider love of novelty as an individual cultural preference. Certainly, the two views are related; see, e.g., Ashraf and Galor (2013) for evidence for the significant relationship between genetic diversity and cultural fragmentation.

[3] An advantage of using this class of innovation-based growth 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; see also below for more information on this class of growth models.

[4] 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."

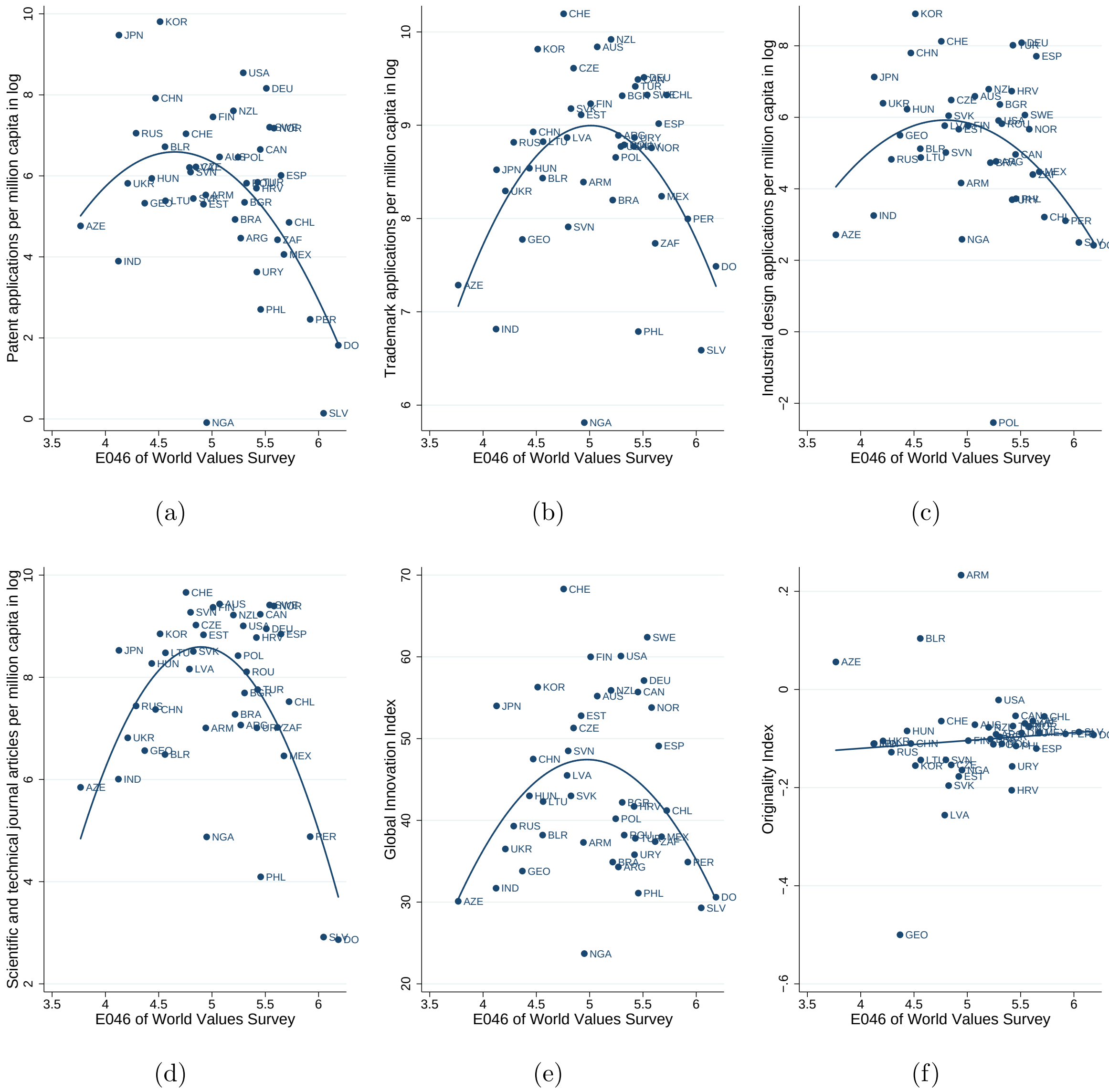


Figure 1: Scatter Plots

Note: This figure shows various scatter plots between love of novelty (measured by Question E046 of the World Values Survey) and measures of innovation. Further details about the data sources and the variables are in the Appendix.

Since each innovation requires new and existing product development, the aggregate level of innovation is too small for the economy to achieve long-run growth, resulting in an underdevelopment trap. (b) When love of novelty is moderate, both types of innovation perpetually occur along an equilibrium path, however cyclically. Along the equilibrium path, periods in which new product development occurs and periods in which existing product development alternate,[5] whereby the economy achieves long-run growth through innovation cycles. (c) In the case of strong love of novelty, firms eventually invest exclusively in inventing new products; thus, no improvements to old products occur in

[5]In our model, an innovative economy is perpetually cyclical; however, we can show that it also stably converges to a unique balanced growth path by considering a natural extension of our model. See Furukawa et al. (2019) for the details.

the long-run equilibrium. In this case, the economy is trapped in a situation where new goods are invented constantly, but they rarely survive in the absence of existing product development. As in the case of 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, further resulting in an underdevelopment trap. Therefore, the overall effect of love of novelty is ambiguous: moderate love of novelty is a fundamental source of innovation-based growth (consistent with what is generally believed), but weak or strong love of novelty can cause an underdevelopment trap. We also calibrate the model to US data to simulate the transition dynamics of the economy switching between the two different innovation processes.

The theoretical findings above support the widely accepted view that culture is a fundamental cause of cross-country differences in macroeconomic performance, by considering an important aspect of national culture—the public's love of novelty. Since different people or regions typically have different attitudes toward novel things overall (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. Specifically, our finding implies that the lack or excess of the public's love of novelty is a fundamental cause of underdevelopment. This supports the view of Mokyr (2000), who asserts that cultural preference for new ideas is "highly relevant to the experience of underdeveloped countries whose failure to adopt best-practice technologies is often regarded as an integral part of underdevelopment."

This paper proceeds as follows. Section 2 discusses our contributions relative to the existing literature. Section 3 presents the basic model, and Section 4 characterizes the equilibrium dynamics of the model. Section 5 identifies the critical role of the love of novelty in innovation and growth in the long run. Section 6 provides a quantitative analysis. Finally, Section 7 offers some concluding remarks.

2 Related Literature

Our study contributes to the literature on innovation-based growth (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992). While, as we first mentioned, the importance of culture as an essential source of growth is widely perceived in economics, few studies explore the role of cultural aspects of people's preferences in innovation-based growth. Chu (2007), for example, notably argues that entrepreneurial overconfidence can cause different economic growth rates across countries, using a standard innovation-based growth model.[6] More recently, Pan et al. (2018), Hof and Prettner (2019), and Chu et al. (2020) have examined status-seeking preferences in the innovation-based growth model. Our study contributes to this literature by examining the role of consumer love of novelty as a cultural source of innovation-based growth.

Broadly interpreting the meaning of culture or cultural preferences, our study also relates to Galor and Michalopoulos (2012) and Doepke and Zilibotti (2014). They 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

[6] 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 Dastidar and Yano (2021) and Yano and Furukawa (2023) for recent studies on market quality theory.

terms of risk tolerance). Given that entrepreneurial traits should be partially attributable to culture, their studies and ours contribute to the literature on culture, innovation, and growth by examining different cultural factors.[7]

More broadly, several studies examine the role of culture in other classes of the endogenous growth model. For example, Cozzi (1998) considers a cultural asset unproductive at the individual level, traded between different generations, yet has positive external effects on productivity growth. He further 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. Galor and Moav (2002) show that individual preferences for offspring quality contribute to population growth and human capital formation. Subsequent studies by Ashraf and Galor (2007, 2013a, 2013b, 2018) explore cultural/genetic diversity and regional development at different stages and places.[8] Several studies in this line of research have identified the *ambiguous* role of some cultural factors, as in our study. For example, Ashraf and Galor (2013a) show an inverted U-shaped relationship between genetic diversity within a country and regional economic development.

We also contribute to the 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, Furukawa 2015, Sunaga 2017, and Yano and Furukawa 2023). 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. 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 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.[9] 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.

Lastly, our study is related to the literature on two-stage innovation models. Most models in this literature 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 2018). We consider two separate activities of *applied* innovation; thus, 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. Therefore, our study complements the literature by first considering two commercial stages of innovation and further characterizing the role of consumer love of novelty on aggregate innovation and growth.

[7] 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.

[8] See also Chu and Cozzi (2011) for cultural preferences for fertility. A large body of empirical literature is also available: Tabellini (2010) shows that cultural propensities such as trust significantly affect regional per-capita income in Europe. Alesina and Giuliano (2010) examine the effects of family ties on economic performance. See also Bénabou et al. (2022), who show that innovation can be negatively associated with people's religiosity.

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

3 Innovation-Based Growth Model with Love of Novelty

This section presents our basic innovation-based growth model, following Matsuyama (1999, 2001). As in his models, innovation occurs endogenously as a product of the firms' profit-seeking R&D investment, and the variety of products increases over time (Romer 1990) with the assumption that firms can only enjoy temporary (one period) monopoly power. This assumption is used because new and old products play separate but essential roles in equilibrium, facilitating the modeling of people's love of novelty—as will be apparent later.

Our model demonstrates two new assumptions to investigate the role of love of novelty of optimizing agents. First, we assume that the representative agent is endowed with the standard love-of-product variety and love of novelty; therefore, they would have some extra weight on new products compared with old products.[10] Second, we think of two types of innovation: one is to invent new products, and the other is to ensure invented products have a long life in the market. We refer to these two types of innovation as new and existing product development, which both require R&D investment by profit-seeking firms.

3.1 Consumption and Love of Novelty

An infinitely lived representative agent inelastically supplies L units of labor during 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.[11] Namely, the agent is endowed with so-called love-of-variety preferences. As is standard, we consider a constant elasticity of substitution utility function:

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

where $x(j,t)$ represents the consumption of good j in period t, $\sigma \geq 1$ represents 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

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

[11] This follows Grossman and Helpman (1991, ch. 3). In our model, 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.

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 wherein 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, ε, 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) yields

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

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 ε, 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 ε as the consumer's love of novelty for all $\varepsilon > 0$.[12]

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

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

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

and $p(j,t)$ is the price of good j in period t. By solving the dynamic optimization, we also obtain the Euler equation:[13]

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

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

3.2 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, therefore, 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, captured by σ, we allow for the case of $\sigma = 1$,[14] by introducing an upper bound of the mark-up, say, $\mu > 1$. This upper bound μ has often been referred to as a patent breadth.[15] Following the literature, we assume $\mu \leq \sigma/(\sigma-1)$.[16] Notably, this introduction of a mark-up upper bound, μ, is only for clarifying what occurs in the Cobb-Douglas case ($\sigma = 1$). Therefore, the main results do not alter qualitatively at all without the upper bound μ.

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

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

[13]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.

[14]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 $\sigma = 1$).

[15]See, for example, Li (2001), Goh and Olivier (2002), Iwaisako and Futagami (2013), and Chu et al. (2020, 2022) for growth-theoretic analyses. 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, μ. In a different context, μ can also be considered a result of price regulation (Evans et al. 2003).

[16]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.

Equation (12) shows that when $\sigma > 1$, the profit for a new good, $\pi^n(t)$, increases with the love of novelty ε 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), it becomes independent of the love of novelty ε, 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):

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

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 ε.

3.3 Innovation

In this section, we present two types of innovation. One is to invent new goods, and the other 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. Firms would further invest in existing product development. If investments succeed, new goods would be transformed and developed into new "old" goods.[17]

3.3.1 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 $A(t-1)$. There is no spillover from newly invented goods as they are so new that their information would not be diffused appropriately. Nevertheless, even if we allow for new goods in the stock of existing technologies, the main results will not change qualitatively. 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 Matsuyama (1999, 2001). 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

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

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

3.3.2 Existing Product Development

Owing 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, $t+1$. At this point, the goods are no longer new but "old." We assume that each new good becomes obsolete before becoming an old good unless additional investments are made and succeed; however, one can utilize new goods *as seeds* and develop them into new "old goods." We refer to this type of activity for developing old goods as existing product development.

As a first step, an R&D firm engaging in existing product development invests one unit of labor in period t and searches through the set of new goods, $N(t)$. From among $N(t)$, the firm meets only a fraction, $\phi \in (0,1)$, of the new goods as seeds for old goods. The new goods each firm meets are randomly chosen from $N(t)$. The firm then makes $\chi(t)$ units of old products from the new goods of $\phi N(t)$ by coming up with *different combinations* of those new goods. It is worth mentioning that the number of differentiated old goods that can potentially emerge from $N(t)$ is not bounded. This is because the number of possible combinations of $\phi N(t)$ new goods is not bounded due to continuity.

After existing product development, the firm enjoys a one-period monopoly for those $\chi(t)$ old 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, $\chi(t) \equiv \lambda(\phi N(t))$, where $\lambda > 0$ is a productivity parameter.[18] For descriptive purposes, we define a composite parameter, $\kappa \equiv \lambda\phi > 0$. Then we have $\chi(t) = \kappa N(t)$.

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 $R^A(t)$ as the units of labor devoted to existing product development in period t. Further we obtain

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

For simplicity, we assume that none of the old goods becomes obsolete. However, 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 of existing product development at which old goods are made from new goods:

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

In the subsequent period, $t+2$, owing 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 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

[18] From a broader perspective, this λ 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.

monopolistic firms owned by the representative agent.[19] Consequently, in our model, all goods are monopolistically competitively produced in equilibrium, and their profits are allocated to the representative agent as dividends.

Alternatively, we could also adopt another standard setting that old goods are sold at a perfectly competitive price (e.g., Matsuyama 1999, 2001). However, we understand that this option would complicate the analysis without changing the results qualitatively. In addition, while the interaction between monopolistic and competitive sectors is known as a source of perpetual cycles in the literature, our analysis shows that without this source, cycles can persist on an equilibrium path owing to a novel mechanism depending on the strength of consumer love of novelty. Therefore, in this study, we ensure that the analysis is as simple as possible to highlight the insight derived from our new framework.

3.4 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

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

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

4 Equilibrium Dynamics

In order to derive the dynamical system that characterizes the law of motion for the equilibrium trajectory of the economy, 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 $n(t) > \varepsilon^{\sigma-1}/\kappa$.*

[19]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 13. 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).

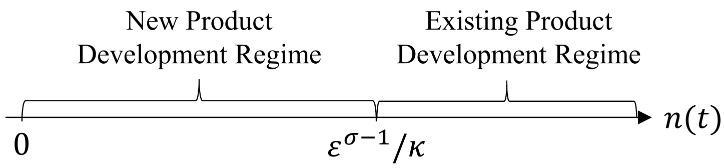


Figure 2: Illustration of Lemma 1

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. ■

Figure 2 presents the result of Lemma 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 refer to as a new product development regime. The second regime corresponds to $n(t) \in (\varepsilon^{\sigma-1}/\kappa, \infty)$, which we refer to as 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 eliminate this unrealistic aspect concerning specialization from the model by allowing the innovator a long-lived monopoly or simply introducing an exogenous growth factor. Either change to the baseline model could provide another interesting analysis, but the tractability of our model would cease to exist.[20] Thus, we adopt the present setting for simplicity.

In each period, t, the value of $n(t)$ should 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, ε, is stronger and/or the productivity for existing product development, κ, is lower. This is because there is a higher relative profit for the invention of a new good, compared to the investment in existing product development, when the consumer prefers new goods to old goods more strongly (owing to larger ε) and/or the cost for investments in existing product development is higher (owing to lower κ). 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 investments in existing product development.

4.1 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, $W^n(t) = 0$,

[20]See Furukawa et al. (2019) for details.

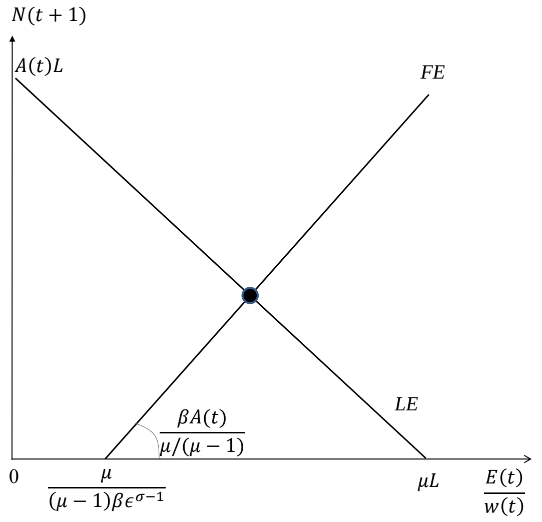


Figure 3: New Product Development Regime

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 ε 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), therefore, 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 3 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, $N(t+1)$, are increasing in the time preference rate β, the labor force L, and the patent breadth μ, all of which are natural effects.

The effect of the elasticity of substitution between goods, $\sigma \geq 1$, is more complex, and it becomes positive if the consumer has a love of novelty, that is, if $\varepsilon > 1$. Because σ determines the level of goods substitutability, a higher σ generally results in 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 σ positively affects $N(t+1)$ through an upward shift of the FE curve in Figure 3, 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 σ has no role because all new and old goods are equally desirable for the consumer; thus, their demands/profits are also equal. When the consumer has a fear of novelty, that is, $\varepsilon < 1$, the effect of σ on $N(t+1)$ is negative because old goods are now preferable. Again, a higher substitutability σ leads to a larger demand for a preferable good, generally. Therefore, in this fear-of-novelty case, higher σ generates a downward shift of the FE curve, by decreasing the profits for new goods (and increasing the profits for old goods).

Regarding the love of novelty ε, a higher ε 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 ε). Further, the equilibrium profit for new goods, $(\beta\varepsilon^{\sigma-1}(\mu - 1)/\mu)E(t)/w(t)$, is also larger.[21] The upward shift of the FE curve results in an increase in $N(t+1)$ in equilibrium. In the special case of $\sigma = 1$ (where goods are independent goods), the love of novelty ε has no role because the expenditure share for any independent good, new or old, is constant, and free from ε.

We can formally confirm this effect of ε 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 Θ is increasing in the love of novelty ε and the standard parameters β, L, and μ. We can interpret the parameter composite Θ 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 ε as $[1/(\beta(\mu-1)L)]^{1/(\sigma-1)} \equiv \varepsilon_0$. Additionally, because $R^A(t) = 0$ and then $\rho(t+1) = 0$ 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, then $N(t+1)/A(t+1) \equiv n(t+1) > \varepsilon^{\sigma-1}/\kappa$ 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—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.

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

4.2 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 rate of existing product development for new goods as:

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

[21] See also (12).

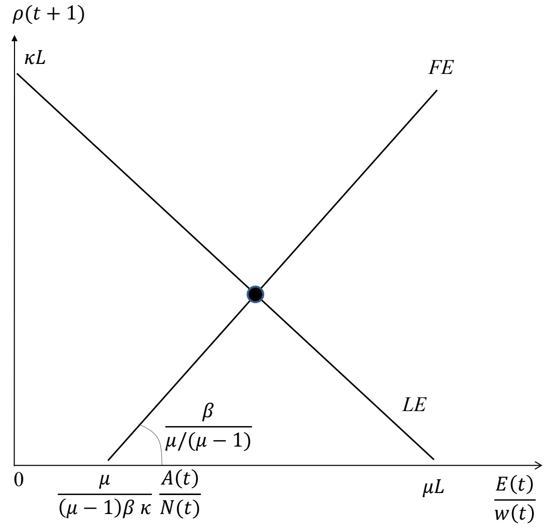


Figure 4: Existing Product Development Regime

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 rate of existing product development $\rho(t+1)$ 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 4 illustrates how $\rho(t+1)$ is determined by (27) and (28). Solving (27) and (28), we obtain:[22]

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

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

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

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

[22]Note that $\rho(t+1) > 0$ always holds, owing to $\varepsilon^{\sigma-1}\beta(\mu-1)L > 1$.

5 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 $\sigma > 1$.[23] 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 Θ is relatively low, and the consumer's love of novelty, ε, is relatively strong. On the one hand, the new product development regime is larger owing to a high ε. On the other hand, the invention flow $N(t)$ within the regime tends to be low, owing to a low Θ. These two effects are negative on innovation; therefore, 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.[24] Specifically, we assume the following condition:

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

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,

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

which is equivalent to (31). Suppose that (31) holds and let the solutions to $F(x) = 0$ be $\varepsilon_-^{\sigma-1} < \varepsilon_+^{\sigma-1}$.[25] As is easily verified, $\varepsilon_+^{\sigma-1} > 0$ holds. Because $F(0) > 0$, $\varepsilon_-^{\sigma-1} > 0$ also

[23] 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 ε. Notably, under $\sigma = 1$, the condition in Lemma 2 becomes independent of ε.

[24] This is owing 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 contribute to 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 κ, the productivity of firms has a role in avoiding traps, which is natural and intuitive.

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

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,

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

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.[26] Thus, in the following analysis, we assume (31) to avoid the trivial case of any economies 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 ε in achieving $\Theta > \varepsilon^{\sigma-1}/\kappa$ is ambiguous because Θ is increasing in ε, which generates two opposite effects of ε. On the one hand, (a) a higher ε 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 ε also results in a larger potential demand Θ, and there are more new goods $N(t)$ to be created in the new product development 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 ε, 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 ε. The following two propositions show that the role of the love of novelty ε in innovation is also ambiguous.

Proposition 1 *When the infinitely lived consumer's love of novelty ε 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. Furthermore, because of Lemma 3, the economy will necessarily go back to some point within the new product development regime. Therefore, if ε 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 ε can be a source of innovation-driven growth in the long run, because there are permanently expanding goods spaces, $N(t)$

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

and $A(t)$. Innovation-driven growth occurs here because the aforementioned two opposite effects of ε can be balanced well in a moderate range of ε. However, if the level is extreme, the love of novelty ε 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 ε 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, owing 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 ε, 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 results from the aforementioned effect (b). Consequently, with a strong fear of novelty, or a very low ε, 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.

Significantly, 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. Owing to effect (b), a high ε encourages new product development, providing more new goods $N(t)$. It further encourages existing product development, because existing product development uses new goods as input. However, owing to effect (a), ε increases the relative profitability of new product development to existing product development. When ε is very high, this relative profitability effect dominates the positive one to take away/remove any incentives from firms 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* *(owing to the presence of new product development) but not developed into old goods (owing 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 existing product development. 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. We conclude that the love of novelty is a source of innovation-based growth but can become a cause of underdevelopment traps when it is too strong.

It is worth repeating that the key assumption generating the ambiguous role of love of novelty is the structure of an innovation market: innovation covers various activities including the creation of new goods but also the development of existing (relatively old) goods. Too strong love for new goods, as well as the same for old goods, can be harmful for innovation-driven growth because long-run innovation essentially depends on a good balance between two separate but sequential innovation activities, new and existing good development.

In summary, the theoretical analysis in this section suggests that, empirically, we should expect an inverted-U relationship between love of novelty and innovations. Besides, assuming new product development generates more *original* innovations than existing product development, we should also expect a positive relationship between love of novelty and original innovations. The scatter plots in Figure 1 are consistent with these predictions. Additional regression results are in the Appendix.

6 Quantitative Analysis

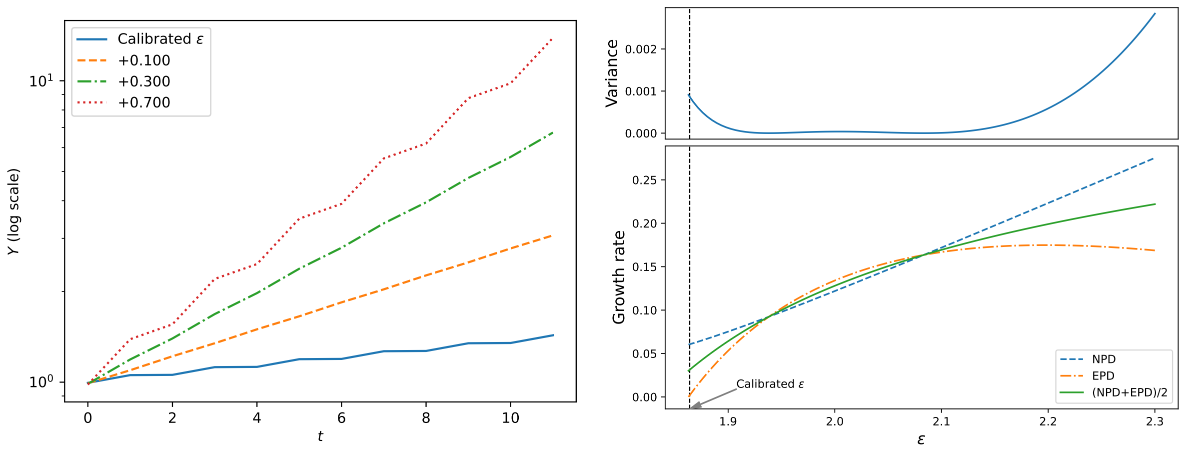
In this section, we calibrate the model to aggregate US data to perform quantitative exercises. We aim to quantify the love of novelty and then simulate the transition dynamics of the economy switching between the two innovation processes, which also gives an idea concerning values of the upper/lower bounds of love of novelty, ε. In calibrating the model, we normalize the labor size L to be unity as is standard in the endogenous growth literature.

Now, the model features the following parameters: $\{\beta, \sigma, \kappa, \mu, \varepsilon\}$. We set the discount rate β to 0.95, which falls in the range of conventional values.[27] Then, we consider a range of values for the markup ratio $\mu \in \{1.1, 1.2, 1.3, \sigma/(\sigma-1)\}$, which roughly cover the empirically plausible range, $1.05 - 1.4$, of markups suggested in Jones and Williams (2000). Note that $\sigma/(\sigma-1)$ gives a theoretical upper bound of μ. Further, we set the elasticity of substitution between differentiated goods σ to 4, which is the mean of estimates of substitution elasticity at the three-digit level in Broda and Weinstein (2006). Accordingly, the upper bound of μ becomes $\sigma/(\sigma-1) = 1.33\cdots$, which is also within the empirically plausible range. Since this value of $\sigma = 4$ is calculated using data during

[27]Note that a time preference rate β of 0.95 in discrete-time models is analogous to a subjective discount rate of 0.05 in continuous-time models (e.g., Acemoglu and Akcigit 2012).

β	σ	μ	κ	ε	$(\varepsilon_-, \varepsilon_+)$	Growth potential
0.950	4.000	1.100	320.053	2.65	undefined	trapped
0.950	4.000	1.200	217.865	1.864	$(1.862, 3.048)$	growing
0.950	4.000	1.300	219.928	1.568	$(1.561, 3.556)$	growing
0.950	4.000	1.333	237.158	1.503	$(1.497, 3.772)$	growing

Table 1: Calibrated Parameters



(a) Transitional paths

(b) Growth rates

Figure 5: The Dynamics of Total Output

the period from 1990 to 2001, for the rest of the parameters $\{\kappa, \varepsilon\}$, we calibrate the model using an average of aggregate data during the same period. For each value of μ, we calibrate the values of R&D productivity κ and love of novelty ε targeting a GDP growth rate of 3.09% and an R&D share in GDP of 2.54%.[28] We report the calibrated parameter values in Table 1.

Under these calibrated parameter values, for all values of markup μ, the calibrated love-of-novelty parameter, ε, is larger than unity, i.e., a *love* of novelty, not a fear of novelty. Note, however, that for the lowest markup $\mu = 1.1$, the growth condition, $\varepsilon \in (\varepsilon_-, \varepsilon_+)$, does not hold because (31) is violated. This indicates that the economy with lower markups tends to be trapped in underdevelopment, consistent with the usual intuition. Thus, depending on the markup, our quantitative exercise may suggest the U.S. economy in the 1990s had a love of novelty.

We also demonstrate the transitional dynamics of the economy switching between the two innovation processes, i.e., new and existing product development. Figure 5 illustrates an equilibrium path of (the logarithm of) the total output (in real terms), i.e., $Y^i(t) \equiv E(t)/P(t) + w(t)R^i(t)/P(t)$ with $i = \{N, A\}$. Without any loss of generality, we may suppose that the initial period, $t = 0$, is a period where new product development occurs, and normalize $A(0)$ to be 1.[29]

[28] These are an average value using World Bank Open Data. Note that we only use data of 1996–2001 for the R&D share owing to data availability. Additionally, note that the derivations for theoretical moments used in our calibration are available upon request.

[29] This requires $n(0) \equiv N(0)/A(0) < \varepsilon^{\sigma-1}/\kappa$ (Lemma 1). Since the economy alternates between those two innovation processes, only existing product development occurs in period $t-1$, ; hence, $N(0) = 0$. Thus, $n(0) < \varepsilon^{\sigma-1}/\kappa$ always holds.

Figure 5 (a) illustrates four equilibrium paths of the total output, $Y^i(t)$, with different levels of the love of novelty ε. As shown in the figure, with either level of ε, the total output fluctuates along an equilibrium path, and the growth rate trend is higher with higher ε. It also suggests that the growth path becomes first less volatile and then more volatile as the love ε of novelty becomes stronger, implying a non-monotonic effect of ε on volatility.

To formally identify the relationship between the love of novelty ε and growth volatility, in the lower half of Figure 5 (b), we illustrate the relationship between ε and the three growth rates: one in the new product development (NPD) regime (the blue line, labeled as "NPD"), another in the existing product development (EPD) regime (the orange line, labeled as "EPD"), and an arithmetic mean of these two (the green line, labeled as (NPD+EPD)/2).[30] As shown, as ε increases, the growth rate with NPD increases; then, the growth rate with EPD first increases and then decreases, showing an inverted U-shaped relationship. Notably, these two growth rates are equated at two points, where the total output grows at a constant rate without any fluctuations (i.e., balanced growth). This further implies that the volatility is minimized at these two points; as shown in the upper half of Figure 5 (b), a very strong love of novelty, ε, causes higher volatility as well as higher trend growth. In summary, our numerical exercise indicates that (a) a stronger love of novelty increases the trend growth rate, but (b) a substantial increase from the benchmark level may tend to increase volatility.

To end up this section, we elaborate on an intuition behind the relationship between the love of novelty ε and the growth rates. Potentially, there are four effects of a stronger love of novelty (i.e., higher ε) on growth. Higher ε, at first, encourages NPD. The increased NPD investment results in two effects. On the one hand, (i) it leaves fewer labor resources for production in the NPD regime, decreasing Y^N. On the other hand, (ii) it also brings about more new products in the EPD regime, which encourages production in the EPD regime and increases the output Y^A. Since more new products also imply more "seeds" for EPD, (iii) it increases the EPD investment, which leaves fewer resources for production in the EPD regime and decreases Y^A. Finally, (iv) the increased EPD investment leads the old goods $A(t)$ to grow faster from the EPD to NPD regime, and the NPD regime has more old goods, which encourages production in the NPD regime and increases Y^N. Given that the growth rate in the NPD (EPD) regime is defined as $g^N \equiv Y^A/Y^N - 1$ ($g^A \equiv Y^N/Y^A - 1$), effects (i) and (ii) affect $g^N(t)$ positively and $g^A(t)$ negatively; effects (iii) and (iv) do the opposite. Therefore, the total effects are potentially ambiguous. With our calibrated parameters, as shown in Figure 5 (b), the positive effect on g^N dominates; the opposite effects on g^A interact with each other to create an inverted-U relationship between ε and g^A.

7 Concluding Remarks

In this study, we explore the role of people's love of novelty in innovation and innovation-based growth by developing a new innovation-based growth model. 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

[30] Our simulation does not replicate the inverted-U relationship we document in Figure 1 in a strict sense. However, in our model, the average growth rate becomes zero if $\varepsilon \notin (\varepsilon_-, \varepsilon_+)$, and it becomes positive with moderate $\varepsilon \in (\varepsilon_-, \varepsilon_+)$. Thus, very high and very low ε can hurt innovation and growth. In this sense, our theory can capture an essential aspect of the non-monotonic relationship in Figure 1.

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. Further, we demonstrate a mechanism through which the love of novelty can cause underdevelopment traps that result in fewer innovations when its level is too weak or too strong. Therefore, 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.

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Appendix: Some Suggestive Country-level Evidence Between Love of Novelty and Innovation

Our theoretical analysis suggests an inverted-U relationship between love of novelty and innovations and a positive relationship between love of novelty and original innovations. Figure 1 already shows some unconditional correlations between love of novelty and innovations. In this Appendix, we provide further details about the data sources and variables as well as some additional regression results.

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 the 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.[31]

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.[32] As an alternative measure of innovation, we also use the Global Innovation Index.[33]

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:[34]

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

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.

[31] This variable is also used by Bénabou et al. (2015) to measure people's general openness to novelty.

[32] 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.

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

[34] See Bento (2021) 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.

Below we estimate several simple ordinary least squares (OLS) regressions with additional country-level controls, including log GDP per capita, 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).[35] 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.[36]

Regression Results and Discussions. In addition to the scatter plots shown in Figure 1(a) to Figure 1(e), 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 1(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. All in all, the cross-country patterns seems to support the relevance of our theory.

Nevertheless, we are certainly 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 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

[35]These control variables are also used in Bénabou et al. (Forthcoming).

[36]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.

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.

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 (Not for Publication)

In this appendix, we explain our calibration analysis in detail. Before proceeding, it is beneficial to note that the equilibrium of our model is restricted by the following two inequalities. First, the economy can grow only when

$$\kappa > \frac{4}{L^2}\left(1+\frac{1}{m}\right)\frac{1}{m} \tag{B1a}$$

from (31). Here, we define $m \equiv \beta(\mu-1)$ for descriptive simplicity. Second, by Lemma 4, the economy grows perpetually if and only if

$$\frac{\kappa L - \sqrt{(\kappa L)^2 - \frac{4\kappa}{m}\left(1+\frac{1}{m}\right)}}{2\left(1+\frac{1}{m}\right)} < \varepsilon^{\sigma-1} < \frac{\kappa L + \sqrt{(\kappa L)^2 - \frac{4\kappa}{m}\left(1+\frac{1}{m}\right)}}{2\left(1+\frac{1}{m}\right)}. \tag{B1b}$$

If calibrated parameters do not satisfy (B1a), ε_- and ε_+ are not well defined, in which case the economy is caught in an underdevelopment trap. The economy grows perpetually if and only if both (B1a) and (B1b) hold, i.e., $\varepsilon \in (\varepsilon_-, \varepsilon_+)$.

A. Growth Rate:

Incorporating $x(t,j) = x^a(t)$ for $j \in A$ and $= x^n(t)$ $j \in N$ for (5) yields

$$u(t) = \left(A(t)\left(x^a(t)\right)^{\frac{\sigma-1}{\sigma}} + N(t)\left(\varepsilon x^n(t)\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}. \tag{B2}$$

Substituting (11) and (13) into (B2) yields

$$u(t) = \frac{E(t)}{P(t)}\left(\frac{P(t)}{w(t)}\right)^{\sigma}\mu^{-\sigma}\left(A(t)+\varepsilon^{\sigma-1}N(t)\right)^{\frac{\sigma}{\sigma-1}}. \tag{B3}$$

which implies $u(t) = E(t)/P(t)$ in the use of (20). Therefore, the economic growth rate in our model may be defined as

$$g(t) \equiv \frac{u(t+1)}{u(t)} = \frac{E(t+1)/P(t+1)}{E(t)/P(t)}. \tag{B4}$$

In the equilibrium with positive long-run growth, as shown in Proposition 1, the economy, with $\varepsilon^{\sigma-1} \in \left(\varepsilon_-^{\sigma-1}, \varepsilon_+^{\sigma-1}\right)$, alternates between the new product development (NPD) regime and the existing product development (EPD) regime perpetually. Thus, we should regard an average growth rate of these two regimes in the calibration analysis. By (24) and (25), with (20),

$$\frac{E(t)}{P(t)} = (L-\Theta)\left[A(t)+\varepsilon^{\sigma-1}N(t)\right]^{\frac{1}{\sigma-1}} \tag{B5}$$

holds in the NPD regime. By (27) and (29), with (20),

$$\frac{E(t)}{P(t)} = \frac{\left[A(t)+\varepsilon^{\sigma-1}N(t)\right]^{\frac{1}{\sigma-1}}}{1+m}\left[L+\frac{1}{\kappa}\frac{A(t)}{N(t)}\right] \tag{B6}$$

holds in the EPD regime, provided that we restrict the analysis to the interior equilibrium with $\rho(t+1) < 1$.

Without any loss of generality (see footnote 37), we may assume that period t is the NPD regime in which $N(t+1) = \Theta A(t)$ (from (25)) and $A(t+1) = A(t)$. Given that the NPD and EPD regimes alternate on an equilibrium path, period $t-1$ and period $t+1$ are the EPD regime. In the EPD regime, $t+1$, we may further derive from (30)

$$A(t+2) = \frac{mA(t+1)}{1+m}\left(1+\kappa L\frac{N(t+1)}{A(t+1)}\right) = \frac{mA(t)}{1+m}\left(1+\kappa L\Theta\right), \tag{B7}$$

which uses $N(t) = 0$, $N(t+1) = \Theta A(t)$, $N(t+2) = 0$, and $A(t+1) = A(t)$.

We consider an average growth rate over the two periods by $1+\gamma(t) \equiv \sqrt{g(t)g(t+1)}$. Using $N(t) = 0$ and $N(t+2) = 0$, from (B4) and (B5), we can obtain

$$1+\gamma(t) = \sqrt{\frac{E(t+2)/P(t+2)}{E(t)/P(t)}} = \left(\frac{A(t+2)}{A(t)}\right)^{\frac{1}{2(\sigma-1)}}, \tag{B8}$$

noting that period $t+2$ becomes the NPD regime again. Therefore, substituting (B7) into (B8) yields a constant average growth rate:[37]

$$\tilde{g}(t) = \left(\frac{m\left(1+\kappa L\Theta\right)}{1+m}\right)^{\frac{1}{2(\sigma-1)}} \equiv 1+\gamma. \tag{B9}$$

We set aside the issue on scale effects by $L = 1$. It is, then, useful to rewrite (B9) as

$$\kappa\Theta = \left(1+\frac{1}{m}\right)\Gamma - 1, \tag{B9'}$$

where $\Gamma \equiv (1+\gamma)^{2(\sigma-1)}$.

B. R&D share:

The R&D share in GDP for calibration should also be an average value of the NPD and EPD regimes. We first see the NPD regime. Since the investment for NPD is $w(t)R^N(t) = w(t)\left(N(t+1)/A(t)\right) \equiv I^N(t)$, the R&D investment share in GDP can be defined as $s^A(t) \equiv I^N(t)/(E(t)+I^N(t))$, which generates

$$s^N(t) = \frac{\Theta}{\Theta+\mu\left(L-\Theta\right)} \equiv s^N, \tag{B10}$$

which uses $E(t)/w(t) = \mu\left(L-\Theta\right)$ for the NPD regime. Since the investment for EPD is $w(t)R^A(t) = w(t)\rho(t+1)N(t)/\chi(t) \equiv I^A(t)$, the R&D investment share in GDP can be defined as $s^A \equiv I^A(t)/(E(t)+I^A(t))$. Further, we obtain

$$s^A(t) = \frac{\kappa L\Theta m - 1}{\kappa L\Theta\left(\mu+m\right)+\mu-1} \equiv s^A, \tag{B11}$$

which uses $E(t)/w(t) = \mu(L+A(t)/\kappa N(t))/(1+\beta\left(\mu-1\right))$ and $A(t)/N(t) = 1/\Theta$ (noting that period $t-1$ is the NPD regime). We can have an average R&D share as

$$s \equiv (s^N+s^A)/2. \tag{B12}$$

[37] By using (B6) instead of (B5), we can prove that the second equality of (B8) also holds if we assume period t is the EPD regime (and periods $t-1$ and $t+1$ are the NPD regime). A formal proof is available upon request.

By substituting (B9'), (B10), and (B11) into (B12), with $\varkappa \equiv (1+\gamma)^{2(\sigma-1)}$, obtain

$$\Theta = \frac{\left(2s - \frac{\Gamma-1}{\Gamma\left(1+\frac{\mu}{m}\right)-1}\right)\mu}{1+(\mu-1)\left(2s - \frac{\Gamma-1}{\Gamma\left(1+\frac{\mu}{m}\right)-1}\right)}, \tag{B12'}$$

in which we have used $L=1$.

C. Calibration of (κ, ε):

In our calibration system, (B9') and (B12') jointly determine the calibrated value of κ using empirical values of the growth rate γ and the R&D share s. Then, by the definition of Θ, ε is calibrated by

$$\varepsilon = (m - \Theta(1+m))^{-1/(\sigma-1)} \tag{B13}$$

with (B12'), noting $L=1$ again.

D. Real GDP:

To simulate the growth path, we define the real GDP by: $E(t)/P(t) + I^i(t)/P(t) \equiv Y^i(t)$. By (B5) and (B6),

$$Y^i(t) = \begin{cases} (L-\Theta)\left[A(t)+\varepsilon^{\sigma-1}N(t)\right]^{\frac{1}{\sigma-1}} + \frac{w(t)}{P(t)}\frac{N(t+1)}{A(t)} & \text{if } i=N \\ \frac{\left[A(t)+\varepsilon^{\sigma-1}N(t)\right]^{\frac{1}{\sigma-1}}}{1+m}\left[L+\frac{1}{\kappa}\frac{A(t)}{N(t)}\right] + \frac{w(t)}{P(t)}\frac{\rho(t+1)N(t)}{\chi(t)} & \text{if } i=A \end{cases} \tag{B14}$$

noting $I^i(t) = w(t)R^i(t)$. Recall that $N(t+1) = \Theta A(t)$ (by (25)), $N(t)=0$, and $A(t+1) = A(t)$ for the NPD regime ($i=N$) and that $N(t) = \Theta A(t-1)$, $A(t) = A(t-1)$, and $\rho(t+1)$ following (29) for the EPD regime ($i=A$). Then, (B13) becomes

$$Y^i(t) = \begin{cases} \left(L - \frac{\mu-1}{\mu}\Theta\right)A(t)^{\frac{1}{\sigma-1}} & \text{if } i=N \\ \frac{\left(1+\varepsilon^{\sigma-1}\Theta\right)^{\frac{1}{\sigma-1}}}{1+m}\left(\left(1+\frac{m}{\mu}\right)L+\frac{\mu-1}{\mu\kappa\Theta}\right)A(t)^{\frac{1}{\sigma-1}} & \text{if } i=A \end{cases}, \tag{B15}$$

which uses (20).

E: The effects of ε on the growth rates:

By (B15), the economy grows from the NPD period, t, to the EPD period, $t+1$, at a constant rate,

$$g^N \equiv \frac{\overbrace{\frac{(1+\varepsilon^{\sigma-1}\Theta)^{\frac{1}{\sigma-1}}}{1+m}\left(\left(1+\frac{m}{\mu}\right)L+\frac{\mu-1}{\mu\kappa\Theta}\right)}^{\text{from } Y^A}}{\underbrace{L-\frac{\mu-1}{\mu}\Theta}_{\text{from } Y^N}} - 1, \tag{B16}$$

which uses $A(t+1) = A(t)$. Conversely, it grows from the EPD period, t, to the NPD period, $t+1$, at

$$g^A = \frac{L-\frac{\mu-1}{\mu}\Theta}{\frac{(1+\varepsilon^{\sigma-1}\Theta)^{\frac{1}{\sigma-1}}}{1+m}\left(\left(1+\frac{m}{\mu}\right)L+\frac{\mu-1}{\mu\kappa\Theta}\right)}\underbrace{\left(\frac{m}{1+m}(1+\kappa L\Theta)\right)^{\frac{1}{\sigma-1}}}_{\text{from } A(t+1)/A(t) \text{ by EPD}} - 1, \tag{B17}$$

which uses $\frac{A(t+1)}{A(t)} = \frac{m}{1+m}(1 + \kappa L\Theta)$ from (B7).

As it may seem, (B16) and (B17) are complex; in fact, there are four potential effects of an increase in the love ε of novelty in the model.

1. Since higher ε encourages the NPD investment, it leaves less labor resources for production, reducing $Y^N(t)$. This is reflected in the term $\frac{\mu-1}{\mu}\Theta$ in (B16).
2. As a result of a larger NPD investment, there are more new products made in the next EPD period, which directly encourages production and increasing $Y^A(t)$. This is reflected in the term $(1 + \varepsilon^{\sigma-1}\Theta)^{\frac{1}{\sigma-1}}$ in (B17).
3. While encouraging production, more new products also imply more "seeds" for EPD, increasing EPD investments and leaving less resources for production. It reduces $Y^A(t)$, as reflected in the term $\frac{\mu-1}{\mu\kappa\Theta}$ in (B16).
4. As a result of a larger EPD investment, $A(t)$ grows faster, and the next NPD regime enjoys more old goods, which encourages production and increasing $Y^N(t)$. This is reflected in the term from $A(t+1)/A(t)$ by EPD in (B17).

Effects 1 and 2 affect g^N positively and g^A negatively; effects 3 and 4 affect g^N negatively and g^A positively. Therefore, the total effects of higher ε on g^N and g^A are ambigous. In our calibrated model, the positive effect dominates for g^N while the positive and negative effects interact with each other to create an inverted U-shaped effect for g^A.