ISSN (Print) 0473-453X
Discussion Paper No. 1204
ISSN (Online) 2435-0982

ECONOMIC STIMULUS EFFECTS OF PRODUCT INNOVATION UNDER DEMAND STAGNATION

Daisuke Matsuzaki
Yoshiyasu Ono

March 2023

The Institute of Social and Economic Research
Osaka University
6-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan

March 2023

Economic stimulus effects of product innovation under demand stagnation*

by

Daisuke Matsuzaki† and Yoshiyasu Ono‡

Abstract

When faced with economic stagnation, innovation, product innovation in particular, is often cited as an effective stimulus because it is thought to encourage household consumption and lead to higher demand. Using a secular stagnation model with wealth preference, we examine the effects of product innovation on employment and consumption. Two types of product innovation are examined: quantity-augmenting-like innovation and addictive innovation. The former works as if a larger quantity were consumed although the actual quantity remains the same. The latter reduces the elasticity of the marginal utility of consumption. We find that the former reduces both consumption and employment whereas the latter expands them.

JEL classification: O33, E31, E24

Keywords: demand stagnation, product innovation, consumer price index, economic stimulus

---

*) The authors wish to thank M. Akesaka, K. Hashimoto, N. Hidano, N. Kikuchi and R. Mikami for helpful comments. This work was financially supported by the JSPS KAKENHI Grants (JP20H05631 and JP20K01661), the program of the Joint Usage/Research Center for "Behavioral Economics" at ISER of Osaka University, and the Asahi Glass Foundation. The authors are solely responsible for any errors.

† Faculty of Economics, Toyo University, 5-20-28 Hakusan, Bunkyo, Tokyo 112-8606, JAPAN. E-mail: matsuzaki@toyo.jp

‡ Institute of Social and Economic Research, Osaka University, 6-1, Mihogaoka, Ibaraki, Osaka 567-0047, JAPAN. E-mail: ono@iser.osaka-u.ac.jp

1. Introduction

Many advanced countries have experienced long stagnation with aggregate demand shortages, and innovation is often emphasized as an important economic stimulus along with fiscal and monetary policies.[1] There are two kinds of innovation: process innovation and product innovation. The former improves production efficiency whereas the latter improves commodity quality and utility. With respect to process innovation, Ono (1994, 2001) proposed a model of secular stagnation owing to wealth preference,[2] and showed that in the presence of aggregate demand shortages, increases in productivity arising from process innovation decrease labor demand, worsen deflation and consequently reduce employment and consumption. In contrast, product innovation increases the utility of consumption; thus it seems to enhance consumption and employment. However, we find that this is not necessarily the case.

This study uses Ono's secular stagnation model with liquidity (or wealth) preference, mentioned above, to examine the effects of product innovation on consumption and employment. It finds that there are different types of product innovation and that they may increase or decrease consumption and employment because they increase not only the value of consumption, which encourages households to consume more, but also the value of money (financial assets), which encourages households to hold money.

---

[1] For example, action plan for a "New Form of Capitalism" in Japan, creation of a new Department for Science Innovation and Technology in Britain, CHIPS and Science Act in the USA, "France 2030", and creation of the German Agency for Transfer and Innovation (DATI).

[2] Recently, Michau (2018) and Michaillat and Saez (2022) have also treated a model with wealth preference and found that secular demand stagnation occurs because the marginal utility of wealth stays strictly positive. Illing, Ono and Schlegl (2018) and Mian, Straub and Sufi (2021) have considered wealth preference and analyzed depressed aggregate demand.

Product innovation is an important issue for economic growth, but almost no studies have examined the effect of product innovation on aggregate demand under demand stagnation.[3] As economic stimulus policies, fiscal and monetary policies are much more broadly discussed. To fill this void between theoretical research and policymaking, we study the effects of product innovations that directly influence the utility of consumption on aggregate demand and employment.

After providing a general formula for the effects of product innovation on employment and real consumption, we specify two types of product innovation. One type of product innovation makes households feel as if they were consuming a larger quantity of a given commodity despite actually consuming the same quantity. We call this quantity-augmenting-like product innovation. The other reduces the elasticity of the marginal utility of consumption, which we describe as addictive innovation. By applying utility functions that include these innovations in the general formula, we explore the effects of the two product innovations on employment and consumption.

2. A single-commodity economy

First, we consider an economy with a single commodity x, where x is its quantity, and product innovation. A representative household's utility of consumption is represented by

$$U = u(x;\gamma); \quad u_x(\equiv \frac{\partial u}{\partial x}) > 0,\ u_{xx} < 0,\ u_\gamma > 0, \tag{1}$$

[3] Since Krugman (1980), product innovation has often been discussed in the context of "love of variety" and treated as a factor influencing firms' location choices and economic growth. Recent examples are Baldwin and Martin (2004), Davis and Hashimoto (2016), Iwaisako and Tanaka (2017) and Kane and Peretto (2020). However, it is not regarded as a demand stimulus. Johdo (2008) may be the only exception. While he considers the love of variety and examines the effect of an increase in product variety on aggregate demand, we focus on product innovation that enhances the utility of an existing product.

where γ is a product innovation parameter. Innovations typically require development costs and resources, which affect economic activity through changes in both aggregate supply and demand: a crowding-out effect without demand shortages, and a demand-stimulus effect in the presence of demand shortages. However, in order to focus on the pure effect of product innovation on economic activity, we ignore these cost effects and analyze the effect of an exogenous rise in γ.

2-1. Firms

A representative firm is competitive and produces x using only labor with constant productivity θ. Given that the nominal wage is W and that the nominal price of x is P_x, the firm will infinitely expand employment and output if $P_x\theta > W$ but will cease production if $P_x\theta < W$. Therefore, to achieve equilibrium in the commodity market, it must always hold that

$$P_x\theta = W. \tag{2}$$

2-2. Households

Real total consumption c is given by

$$c = p_x x, \quad p_x = \frac{P_x}{P}, \tag{3}$$

where p_x is the real price of x and P is the consumer price index (CPI). Using (3) we rewrite consumption utility U given by (1) as follows:

$$U = u(\frac{c}{p_x}; \gamma).$$

When product innovation occurs and γ changes such that u increases, the consumer price index P must fall and change the real commodity price $p_x(= P_x/P)$ such that the level of real consumption c that yields the same utility remains unchanged.[4] Mathematically, a rise in γ varies p_x so that U is unchanged for a given $c(= p_x x)$; hence, using the properties of $u(x;\gamma)$ given in (1) we obtain

$$0 = -u_x x \frac{dp_x}{p_x} + u_\gamma d\gamma \;\; \Rightarrow \;\; \frac{1}{p_x}\frac{dp_x}{d\gamma} = \frac{u_\gamma}{u_x x} > 0. \tag{4}$$

Intuitively, product innovation that increases utility raises the value of x so that the CPI (which is P) falls if the nominal price P_x is the same, and consequently, $p_x(= P_x/P)$ rises.

The household's lifetime utility is then represented as

$$\begin{gathered} \int_0^\infty \big(U(c;\gamma) + v_T(m) + v_W(a)\big) e^{-\rho t} dt, \\ v_T{}' > 0,\;\; v_T{}'' < 0,\;\; v_T{}'(\infty) = 0,\;\; v_W{}' > 0,\;\; v_W{}'' < 0, \\ U(c;\gamma) \equiv u\left(\frac{c}{p_x(\gamma)};\gamma\right), \end{gathered} \tag{5}$$

where ρ is the subjective discount rate, $v_T(m)$ is the utility of money m $(= M/P)$ for the transaction motive and $v_W(a)$ is the utility of holding assets a owing to wealth preference. Assets a consist of real money m and interest-bearing asset b with the nominal interest rate $R = r + \pi$, where r is the real interest rate and $\pi\big(= \dot{P}/P\big)$ is the CPI inflation rate. The household's labor endowment is normalized to unity but unemployment may appear, and then the realized labor supply (= demand) n is less than 1. Therefore, the flow budget equation and asset constraint are

[4] This approach is consistent with the hedonic approach. The hedonic hypothesis presented by Rosen (1974) is used for the impact of product innovation on real prices. Feldstein (2017) shows that it is used to estimate the CPI.

$$\dot{a} = ra + wn - Rm - c + z, \quad n \leq 1,$$
$$a = m + b, \tag{6}$$

where w is the real wage and z is government transfers.

The Hamiltonian function H of the household behavior mentioned above is

$$H = U(c;\gamma) + v_T(m) + v_W(a) + \lambda[ra + wn - Rm - c + z],$$

where λ is the co-state variable and p_x is invariant over time. Given that $x = c/p_x$, the first-order optimal condition is

$$\rho + \xi \frac{\dot{c}}{c} + \pi = \frac{v_T{}'(m)}{U_c(c;\gamma)} + \frac{v_W{}'(a)}{U_c(c;\gamma)} = R + \frac{v_W{}'(a)}{U_c(c;\gamma)},$$
$$\text{where } \; U_c(c;\gamma) = \frac{u_x(x;\gamma)}{p_x}, \;\; \xi \equiv -\frac{cU_{cc}}{U_c} = -\frac{xu_{xx}}{u_x} > 0. \tag{7}$$

The left-hand side is the intertemporal marginal rate of substitution in consumption c, the middle is the marginal benefit of holding money m and the right-hand side is the marginal benefit of holding interest-bearing asset b. The transversality condition is

$$\lim_{t\to\infty} \lambda a \exp(-\rho t) = 0. \tag{8}$$

2-3. Markets

The commodity market equilibrium is

$$x = \frac{c}{p_x} = \theta n. \tag{9}$$

Given that p_x is constant over time, from (2) and (3), we have

$$\frac{\dot{P}_x}{P_x} = \frac{\dot{P}}{P} (\equiv \pi) = \frac{\dot{W}}{W}.$$

When full employment ($n = 1$) prevails, $x = \theta$, and W moves in parallel with P. In the presence of demand shortages, in contrast, W falls slowly, depending on the deflationary gap, and P moves in parallel with W:

$$\frac{\dot{W}}{W}(= \pi) = \alpha(n - 1) \quad \text{if} \quad n < 1, \tag{10}$$

where α is the adjustment speed of W. This is because workers do not accept rapid falls in W but welcome any increase in W, no matter how rapid it is.

Firm equities have no value because firm profits are zero under linear technology and the net supply of bonds is assumed to be zero. Therefore, the total supply of b is zero:

$$b = 0, \quad a = m.$$

The nominal money supply is M^s and its expansion rate is $\mu(= \dot{M}^s/M^s)$. The government transfers seigniorage μm^s to households:

$$z = \mu m^s.$$

From the money market equilibrium condition, $m^s(= M^s/P) = m$, we obtain $\dot{m}/m = \mu - \pi$. As $\dot{W}/W$ must be positive for the adjustment of W to support the full-employment steady state, the inflation rate must be non-negative; hence,

$$\mu \geq 0.$$

Given that $a = m$, the dynamics of m mentioned above and the dynamics of c represented by (7) formulate autonomous dynamics with respect to m and c:

$$\frac{\dot{c}}{c} = \frac{1}{\xi}\left(\frac{v'(m)}{U_c(c;\gamma)} - \pi - \rho\right) \quad \text{where} \quad v(m) \equiv v_T(m) + v_W(m),$$
$$\frac{\dot{m}}{m} = \mu - \pi. \tag{11}$$

3. Product innovations

Having established the model, we now examine the effects of product innovation. Before dealing with the case of stagnation, we consider the standard case with full employment, where $n = 1$ and $x = \theta$ from (9), as a benchmark. From (4), a rise in γ raises the real price p_x; therefore, both real consumption $c(= p_x\theta)$ and the utility of consumption $u(\theta;\gamma)$ increase.

Proposition 1: *Under full employment, product innovation increases real consumption and the utility of consumption.*

3-1. Stagnation steady state

Full employment, mentioned above, may not be reached. In the full employment steady state, where $n = 1$, $\dot{c} = 0$ and $\dot{m} = 0$, from (9) and (11) it must hold that

$$\rho + \mu = \frac{v'\left(\frac{M^S}{P}\right)}{U_c(c;\gamma)} \quad \text{where} \quad U_c(c;\gamma) = \frac{u_x(x;\gamma)}{p_x}, \tag{12}$$

and $p_x = 1$ because P is initially set equal to P_x. However, if the marginal utility of asset holding has a positive lower bound β, namely,

$$v'(\infty) \equiv v_T'(\infty) + v_W'(\infty) = v_W'(\infty) = \beta > 0,$$

where $v_T'(\infty) = 0$ from (5), and if β satisfies

$$(\rho \leq)\, \rho + \mu < \frac{\beta}{u_x(\theta;\gamma)}\left(< \frac{v'\left(\frac{M^S}{P}\right)}{u_x(\theta;\gamma)} \text{ for any } P \right), \tag{13}$$

there is no $P(= P_x)$ that satisfies (12), implying that a full-employment steady state does not exist.[5]

If (13) is valid, the left-hand side of (12), representing the desire for consumption, is always smaller than the right-hand side, representing the desire for wealth (or money) accumulation, or the wealth premium, when $x = \theta$. Therefore, household demand for commodity x decreases below θ, which leads to demand shortage and causes W and P to fall. In this case, W (and P as well) falls in a sluggish manner, represented by (10), and $v'(m)$ eventually reaches β. From (7), (9), (10) and (11), n in the stagnation steady state satisfies[6]

$$\rho + \alpha(n-1) = \frac{p_x \beta}{u_x(\theta n;\gamma)}. \tag{14}$$

Since (13) implies that the left-hand side of (14) is smaller than the right-hand side when $n = 1$ (or $x = \theta$), in order for the solution of $n \in (0,1)$ to exist, the former is larger than the latter when $n = 0$ (or $x = 0$). Therefore, the former is less inclined than the latter as n increases. These properties are mathematically represented as follows:

$$\rho > \alpha, \quad \Omega = 1 + \frac{\alpha u_x^2 n}{u_{xx} \beta p_x x} > 0. \tag{15}$$

Note that deflation continues and m diverges to infinity in this steady state; however, the transversality condition (8) is valid as long as $\dot{m}/m (= \mu - \pi)$ is smaller than ρ.[7] Given that $\pi = \alpha(n-1)$, from (14), the transversality condition is equivalent to

---

[5] See Ono (1994,2001) and Michau (2018), who show the condition for the stagnation steady state to occur. Using parametric and non-parametric approaches, Ono, Ogawa and Yoshida (2014) empirically show that the utility of financial wealth is insatiable. Ono and Yamada (2018) use survey data and empirically find the validity of a status preference for money that makes the marginal utility of money constant and causes secular demand stagnation to occur.

[6] See Ono (1994, 2001) for the proof of saddle stability in the neighborhood of the stagnation steady state.

[7] When $\rho < \beta/u_x(\theta;\gamma) < \rho + \mu$, both the full-employment steady state and the stagnation steady state can hold. See Ono and Ishida (2014) for details on the conditions for the two steady states to appear.

$$\mu < \frac{p_x \beta}{u_x(\theta n; \gamma)}.$$

Totally differentiating (14) and applying (4), (9) and (15) to the result gives the effects of product innovation γ on total employment n and real consumption c as follows:

$$\Omega \frac{dn}{nd\gamma} = \Omega \frac{dx}{xd\gamma} = -\frac{u_\gamma}{u_{xx}x^2}\left(\frac{xu_{x\gamma}}{u_\gamma} - 1\right),$$
$$\Omega \frac{dn}{nd\gamma} < \Omega \frac{dc}{cd\gamma} = \Omega \left(\frac{dx}{xd\gamma} + \frac{u_\gamma}{u_x x}\right) = -\frac{u_\gamma}{u_{xx}x^2}\left(\frac{xu_{x\gamma}}{u_\gamma} - \frac{xu_{xx}}{u_x} - 1 - \frac{u_x \alpha n}{\beta p_x}\right). \quad (16)$$

The inequality in the second line of (16) implies the following property:

Lemma: *Suppose that unemployment occurs because of a shortage of demand. If product innovation increases employment, real consumption also increases.*

3-2. Various product innovations

We consider two types of innovation: one works as if consumption of the commodity increased although the actual quantity is unchanged, whereas the other decreases the elasticity of the marginal utility of the commodity. The former is quantity-augmenting-like innovation, whereas the latter is termed addictive innovation. We apply these to (16) and examine their effects on total employment n and real consumption c (or utility U).

We first assume the following utility function:

$$u(x;\gamma) = h(\gamma x); \quad h'(\gamma x) > 0, \; h''(\gamma x) < 0. \quad (17)$$

This implies that innovation works as if the consumption of the commodity increased by a factor of γ. From (17), we obtain the following two properties:

$$xu_x = \gamma u_\gamma = \gamma x h'(\gamma x) > 0, \; \frac{xu_{xx}}{u_x} = \frac{xu_{x\gamma}}{u_\gamma} - 1 = \frac{\gamma x h''(\gamma x)}{h'(\gamma x)} < 0.$$

Applying these properties to (16) yields

$$\Omega \frac{\gamma dn}{nd\gamma} = -1,$$
$$\Omega \frac{dc}{cd\gamma} = \Omega \left(\frac{dx}{xd\gamma} + \frac{u_\gamma}{u_x x} \right) = \frac{\alpha n u_x u_\gamma}{u_{xx} x^2 \beta p_x} < 0. \tag{18}$$

Noting that $\Omega > 0$ from (15), these properties give the following proposition:

Proposition 2: *If unemployment occurs because of a shortage of demand, quantity-augmenting-like product innovation, which affects utility as shown in (17), worsens both total employment and real consumption.*

Quantity-augmenting-like innovation makes households feel as if they were consuming γ times as much of the commodity as before, even though they are consuming the same quantity. If they then decrease their consumption of the commodity by a factor of γ and save the remaining income, both the marginal utility of consumption and that of money remain unchanged because the latter is constant at β in the stagnation steady state. Therefore, the wealth premium is the same as before and equals the time preference rate $\rho + \pi$ (representing the desire for consumption). However, households decrease real consumption because the demand for labor to realize the same real consumption decreases and deflation worsens, which makes it more advantageous for households to lower real consumption and increase money accumulation. Eventually, both total employment and real consumption decrease.

Intuitively, quantity-augmenting-like innovation increases both the value of the commodity and the value of money by a factor of γ because the value of money is measured by how much of the commodity can be purchased. Subsequently, the marginal utility of consumption decreases if the quantity of the commodity is held constant, while the marginal utility of money is unchanged to be β, so that the commodity is consumed less and total employment decreases, which worsens deflation and reduces real consumption.

Next, we consider addictive innovation using the following utility function:

$$u(x;\gamma) = \frac{x^{\gamma}-1}{\gamma} \quad \text{(where } \gamma < 1\text{);}$$

$$u_x = x^{\gamma-1} > 0,\ \gamma^2 u_\gamma = x^{\gamma}(\ln x^{\gamma} - 1) + 1, \qquad (19)$$

$$\xi = -\frac{x u_{xx}}{u_x} = 1 - \gamma > 0,\ u_{x\gamma} = x^{\gamma-1} \ln x.$$

We regard $x(= c/p_x) = 1$ as the survival level of consumption and examine the case where $x > 1$ because an increase in innovation γ does not affect utility ($u_\gamma = 0$) when $x = 1$ and increases utility ($u_\gamma > 0$) when $x > 1$. We describe an increase in γ as addictive product innovation because it works in such a way that it reduces the elasticity of the marginal utility of consumption $\xi(= 1 - \gamma)$.

Noting that initially $p_x = 1$, and that $1 > 1 - \Omega > 0$ from (15), we apply (19) to (16) and obtain

$$(-u_{xx})x^2\gamma^2\Omega \frac{dn}{nd\gamma} = \psi(x;\gamma) \equiv x^{\gamma}[1 - (1-\gamma)\ln x^{\gamma}] - 1,$$

$$\psi(1;\gamma) = 0,\ \ \psi(\infty;\gamma) < 0,\ \ \psi_x(x;\gamma) = \gamma^2 x^{\gamma-1}[1 - (1-\gamma)\ln x]; \qquad (20)$$

$$\Omega \frac{dn}{nd\gamma} < \Omega \frac{dc}{cd\gamma} = \frac{1}{(1-\gamma)x^{\gamma}}\left[\frac{x^{\gamma}-1}{\gamma} - \frac{u_\gamma u_x \alpha n}{\beta p_x}\right].$$

Noting that ψ is positive (and $dn/d\gamma > 0$) when $x(> 1)$ is close to 1 because $\psi(1;\gamma) = 0$ and $\psi_x(1;\gamma) = \gamma^2 > 0$, and negative when x is sufficiently large,[8] we summarize the above result as follows:

[8] This is obvious if $\gamma > 0$ because $\lim_{x\to\infty} x^{\gamma} = \infty$. However, if $\gamma < 0$, $\lim_{x\to\infty} x^{\gamma} = 0$. In this case, we use l'Hôpital's rule and find $\psi(\infty;\gamma) = -1 < 0$.

Proposition 3: *If the utility of consumption is given by (19) and unemployment owing to demand shortage appears, addictive product innovation may increase or decrease total employment and real consumption.*

Using consumption data for G7 countries, we examine whether addictive product innovation increases employment and real consumption. Because $x = 1$ is regarded as the survival level of consumption, as aforementioned, the threshold x^{ψ} that satisfies $\psi(x^{\psi}; \gamma) = 0$ in (20) also represents the ratio of the threshold level to the survival level. By comparing this with the ratio of household consumption per capita to the poverty line for G7 countries, we identify whether the addictive innovation leads to higher employment and real consumption.

Table 1: the threshold x^{ψ} below which $dn/d\gamma > 0$

$\xi(= 1 - \gamma)$	0.2	0.3	0.4	1.5	2
x^{ψ}	496	96.3	41.2	4.60	3.51

Table 2: the ratio of household consumption per capita to the poverty line (G7 countries)

	US (2010)	UK (2011)	Germany (2011)	France (2011)	Canada (2010)	Italy (2011)	Japan (2015)
household survey mean/poverty line	2.87	2.11	2.00	2.14	2.38	2.01	unavailable
household final consumption/ poverty line	4.27	2.78	2.33	2.21	2.56	2.71	1.93

(Data source) Appendix 2 of Jolliffe and Prydz (2016). They do not provide data for Japan; therefore, we use the poverty line in the report of Japan's Ministry of Health, Labor and Welfare (in Japanese), p.25, given by https://www.mhlw.go.jp/toukei/list/dl/20-21-h28_rev2.pdf, and household final consumption expenditure per capita estimated from the World Bank data, https://data.worldbank.org/indicator/NE.CON.PRVT.KN and https://data.worldbank.org/indicator/SP.POP.TOTL.

Table 1 shows the ratios of the threshold level to the survival level for various elasticities $\xi(= 1 - \gamma)$ because various levels of elasticity of the marginal utility of consumption are proposed in the literature: approximately 0.3 in microeconomic approaches such as Harrison et al. (2005), Anderson and Mellor (2008) and Meissner and Pfeiffer (2022), and 2 in the DSGE literature.[9] Table 2 shows the ratios of average household consumption to the poverty line for G7 countries. From the two tables, we find that the ratios in Table 2 are almost always smaller than x^{ψ}, and the only exception is the case where we adopt $\xi = 2$ and the ratio of US household final consumption to the national poverty line. This implies that addictive product innovation will almost always increase total employment and then, from Lemma, real consumption will also increase.

4. A two-commodity economy

Let us now turn to an economy with two commodities, x and y, and see if the results obtained in the single-commodity economy are still valid. We implicitly consider that x is the commodity on which product innovation takes place while y is the composite of all other commodities.

4-1. The model

[9] Hall (1988) and Guvenen (2006) state that $1/\xi$ to be much smaller than 1. Chiappori and Paiella (2011) also state that the median of the relative risk aversion ξ is 2. This is because in the standard framework without wealth preference a low relative risk aversion is inconsistent with a response of $\dot{c}/c$ to a change in the interest rate. However, in the presence of wealth preference this problem does not appear. See Appendix B for details.

Firms are competitive and produce commodity $j\,(=x,y)$ with constant labor productivity θ_j. Their profit maximization behavior leads to

$$P_j\theta_j = W \;\text{ and }\; p_j\theta_j = w \;\text{ for }\; j = x, y;\;\; \omega \equiv \frac{p_y}{p_x} = \frac{\theta_x}{\theta_y} = \text{constant}, \qquad (21)$$

where P_j and $p_j(= P_j/P)$ are respectively the nominal and real prices of commodity j. Nominal wage W moves as mentioned in (10). Since P_x and P_y satisfy (21), they move in parallel with W, and consequently P also does, implying that $w(= W/P)$ is constant over time.

The utility of consumption is assumed to be homothetic so that the CPI does not depend on total consumption. It is represented by

$$U = u(x, y; \gamma).$$

Given real consumption c, the representative household maximizes U subject to

$$p_x x + p_y y = c, \qquad (22)$$

and satisfies

$$\frac{u_y(x,y;\gamma)}{u_x(x,y;\gamma)} = \frac{u_y\left(\frac{x}{y},1;\gamma\right)}{u_x\left(\frac{x}{y},1;\gamma\right)} = \omega \;\;\Rightarrow\;\; \frac{x}{y} = \psi(\gamma), \qquad (23)$$

where u_j implies the partial derivative of u with respect to variable $j\;(= x, y, \gamma)$ and ω is constant from (21). Therefore, we obtain

$$p_x x = \delta(\gamma)c, \quad p_y y = (1-\delta(\gamma))c, \;\; \psi(\gamma)(= \tfrac{x}{y}) = \frac{\omega\delta(\gamma)}{1-\delta(\gamma)},$$
$$\delta(\gamma) = \frac{\psi(\gamma)}{\psi(\gamma)+\omega}, \;\; \delta'(\gamma) = \frac{(1-\delta)^2}{\omega}\psi'(\gamma), \qquad (24)$$

while U is represented as a function of c and γ, which satisfies

$$U(c;\gamma) = u\left(\frac{\delta(\gamma)c}{p_x}, \frac{(1-\delta(\gamma))c}{\omega p_x};\gamma\right),$$

$$U_c = \frac{u_x(x,y;\gamma)}{p_x} = \frac{u_y(x,y;\gamma)}{\omega p_x} > 0, \quad p_x^2 U_{cc} = \frac{\delta}{x}(u_{xx}x + u_{xy}y) < 0. \tag{25}$$

Given that the consumer price index P must be defined such that a change in γ does not affect U in (25) for a given $c(= C/P)$, by totally differentiating (25) where c is fixed and using (23), we find that $p_x(= P_x/P)$ satisfies

$$\frac{1}{p_x}\frac{dp_x}{d\gamma} = \delta\frac{u_\gamma}{u_x x} > 0. \tag{26}$$

Note that if $\delta = 1$ (i.e., the single-commodity case), (26) is equivalent to (4). The household's intertemporal behavior is the same as that in the single-commodity economy represented by (5) and (6) except that $U(c;\gamma)$ is given by (25). Thus, the first-order optimal condition is represented by (7) where U_c is given by (25). From (21), (24) and the market equilibria of the two commodities:

$$x = n_x\theta_x, \quad y = n_y\theta_y,$$

we find that each sector's employment n_j ($j = x, y$) and total employment $n(= n_x + n_y)$ are

$$n_x = \frac{x}{\theta_x} = \delta n, \ n_y = \frac{y}{\theta_y} = (1-\delta)n; \ n = \frac{c}{p_x\theta_x} = \frac{c}{p_y\theta_y}. \tag{27}$$

Before analyzing the case of unemployment, we consider the case of full employment ($n = 1$) as a benchmark. From (25) and (27), c and U are

$$c = p_x\theta_x = p_y\theta_y, \quad U = u\big(\theta_x\delta(\gamma), \theta_y(1-\delta(\gamma));\gamma\big). \tag{28}$$

Therefore, using (21), (23) and (26), we obtain

$$\frac{\gamma}{c}\frac{dc}{d\gamma} = \frac{\gamma}{p_x}\frac{dp_x}{d\gamma} > 0, \ \frac{dU}{d\gamma} = u_\gamma > 0.$$

These properties imply that Proposition 1, which holds in the single-commodity economy, also holds in the two-commodity economy; that is, product innovation increases real consumption if full employment is achieved in the steady state.

4-2. Stagnation steady state in the two-commodity economy

In the full-employment steady state, we still have (12) where U_c is given by (25) and c satisfies (28). Therefore, if (13) holds, the full-employment steady state does not exist and the stagnation steady state represented by (14) where U_c is given by (25) is reached. Then, using (27), we obtain

$$\rho + \alpha(n-1) = \frac{\beta}{U_c(c,\gamma)}, \ U_c(c,\gamma) = \frac{u_x(\delta(\gamma)\theta_x n, (1-\delta(\gamma))\theta_y n; \gamma)}{p_x}. \tag{29}$$

For the same reason that (15) is derived from (14), we have

$$\rho > \alpha, \quad \hat{\Omega} = 1 + \frac{u_{xy} y}{u_{xx} x} + \frac{\alpha u_x^2 n}{u_{xx} \beta p_x x} > 0. \tag{30}$$

Note that these conditions are the same as in (15) if only commodity x exists (i.e., $y = 0$). From (26), (27), (29) and (30), we obtain

$$\hat{\Omega}\frac{dn}{nd\gamma} = \hat{\Omega}\frac{dx}{xd\gamma} = -\frac{\delta u_\gamma}{u_{xx}x^2}\left(\frac{xu_{x\gamma} + yu_{y\gamma}}{u_\gamma} - 1\right),$$
$$\hat{\Omega}\frac{dc}{cd\gamma} = \hat{\Omega}\left(\frac{dx}{xd\gamma} + \frac{dp_x}{p_x d\gamma}\right) = -\frac{\delta u_\gamma}{u_{xx}x^2}\left(\frac{xu_{x\gamma} + yu_{y\gamma}}{u_\gamma} - \frac{xu_{xx} + yu_{xy}}{u_x} - 1 - \frac{u_x \alpha n}{\beta p_x}\right), \tag{31}$$

where the derivation is given in Appendix A. Note that, if $y = 0$, the two equations in (31) are the same as those in (16), which are valid in the single-commodity economy. From (26), (30) and (31), we find $(dc/c)/d\gamma > (dn/n)/d\gamma$, implying that Lemma also holds in the two-commodity economy.

First, we consider quantity-augmenting-like product innovation by assuming the following utility function:

$$u(x, y; \gamma) = h(\gamma x, y).$$

It satisfies

$$xu_x = \gamma u_\gamma = \gamma x h_1(\gamma x, y) > 0, \;\; u_y = h_2(\gamma x, y) > 0,$$

$$\frac{xu_{xx}}{u_x} = \frac{xu_{x\gamma}}{u_\gamma} - 1 = \frac{\gamma x h_{11}}{h_1}, \;\; \gamma u_{y\gamma} = xu_{xy} = \gamma x h_{12},$$

where h_i $(i = 1{,}2)$ is the partial derivative with respect to the i-th factor of $h(\gamma x, y)$. By applying these properties to (31) and noting that u_{xx} and U_{cc} in (25) are negative while $\hat{\Omega}$ in (30) is positive, we obtain

$$\hat{\Omega}\frac{\gamma dn}{nd\gamma} = -\delta\left(1 + \frac{yh_{12}}{\gamma x h_{11}}\right) = -\delta\left(1 + \frac{u_{xy}y}{u_{xx}x}\right) < 0,$$

$$\hat{\Omega}\frac{dc}{cd\gamma} = \frac{\delta\alpha n u_x u_\gamma}{u_{xx}x^2\beta p_x} < 0.$$

They imply that Proposition 2 also holds in the two-commodity economy: quantity-augmenting-like product innovation worsens both total employment and real consumption.

We next examine addictive product innovation using the following utility function:

$$u(x, y; \gamma) = \frac{x^\gamma y^\varepsilon - 1}{\gamma + \varepsilon} \;\; \text{(where } \gamma\varepsilon > 0, \; \gamma + \varepsilon < 1\text{);}$$

$$u_\gamma = \frac{x^\gamma y^\varepsilon[(\gamma + \varepsilon)\ln x - 1] + 1}{(\gamma + \varepsilon)^2}, \quad xu_{x\gamma} + yu_{y\gamma} = x^\gamma y^\varepsilon \ln x, \qquad (32)$$

$$u_x = \frac{\gamma x^{\gamma - 1} y^\varepsilon}{\gamma + \varepsilon}, \;\; u_y = \frac{\varepsilon x^\gamma y^{\varepsilon - 1}}{\gamma + \varepsilon}, \;\; -\frac{xu_{xx} + yu_{xy}}{u_x} = 1 - (\gamma + \varepsilon),$$

where addictive product innovation is represented by an increase in γ. By substituting the values in (32) into (31), we obtain

$$(-u_{xx})x^2(\gamma+\varepsilon)^2\hat{\Omega}\frac{dn}{\delta n d\gamma} = \hat{\psi}(x;\gamma,\varepsilon),$$

$$\hat{\psi}(x;\gamma,\varepsilon) \equiv x^{\gamma+\varepsilon}\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon}\left[1-\left(1-(\gamma+\varepsilon)\right)\ln x^{\gamma+\varepsilon}\right]-1,$$

$$\hat{\psi}_x(x;\gamma,\varepsilon) = \left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon}(\gamma+\varepsilon)^2 x^{\gamma+\varepsilon-1}\left[1-\left(1-(\gamma+\varepsilon)\right)\ln x\right]; \tag{33}$$

$$\hat{\Omega}\frac{dn}{nd\gamma} < \hat{\Omega}\frac{dc}{cd\gamma} = -\frac{\delta}{u_{xx}x^2}\left(\frac{x^{\gamma+\varepsilon}\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon}-1}{\gamma+\varepsilon} - \frac{u_\gamma u_x \alpha n}{\beta p_x}\right).$$

From (32) and (33) we derive the minimum x that holds when c equals the survival level, the threshold x above which an increase in γ leads to greater employment and real consumption, and the ratio of these two.

First, we obtain the minimum x. Applying u_x and u_y in (32) to (22) and (23) yields

$$p_x x = \frac{\gamma}{\gamma+\varepsilon}c, \quad p_y y = \frac{\varepsilon}{\gamma+\varepsilon}c, \quad y = \frac{\varepsilon}{\gamma\omega}x. \tag{34}$$

As mentioned at the outset of this section, x represents the product on which product innovation takes place while y represents the composite of all other products. By aligning the quantity units of x and y in such a way that the relative price ω is equal to one,[10] we can regard $y/x(=\varepsilon/(\gamma\omega))$ as the quantity ratio of the composite to the innovative product that households rationally determine. This is naturally larger than 1:

$$\left(\frac{y}{x}=\right)\frac{\varepsilon}{\gamma\omega} > 1, \quad \omega = 1. \tag{35}$$

By applying the third equation in (34) to u_γ given in (32) and using (35), we obtain

$$(\gamma+\varepsilon)^2 u_\gamma = \hat{\varphi}(x;\gamma,\varepsilon) \equiv x^{\gamma+\varepsilon}\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon}\left[\ln x^{\gamma+\varepsilon}-1\right]+1 > 0,$$

$$\hat{\varphi}(1;\gamma,\varepsilon) = 1-\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon} < 0, \quad \hat{\varphi}(\infty;\gamma,\varepsilon) > 0,$$

[10] In other words, the unit is the quantity of each commodity that is produced by a unit of labor.

$$\hat{\varphi}_x(x;\gamma,\varepsilon) = (\gamma+\varepsilon)^2\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon} x^{\gamma+\varepsilon-1}\ln x > 0.$$

Therefore, x and its minimum x_φ satisfy

$$1 < x_\varphi < x \quad \text{where} \quad \hat{\varphi}(x_\varphi;\gamma,\varepsilon) = 0 \ \ (\Leftrightarrow u_\gamma = 0). \tag{36}$$

We next obtain the threshold $x(= x_\psi)$. From (33), (35) and (36), $\hat{\psi}(x;\gamma,\varepsilon)$, the threshold x_ψ at which $\hat{\psi}(x_\psi;\gamma,\varepsilon) = 0$, and the minimum $x(= x_\varphi)$ given in (36) satisfy

$$\hat{\psi}(x_\psi;\gamma,\varepsilon) = (x_\psi)^{\gamma+\varepsilon}\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon}\left[1-\left(1-(\gamma+\varepsilon)\right)\ln(x_\psi)^{\gamma+\varepsilon}\right] - 1 = 0.$$

$$\hat{\psi}(x_\varphi;\gamma,\varepsilon) = (x_\varphi)^{\gamma+\varepsilon}\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon}(\gamma+\varepsilon)^2\ln x_\varphi > 0, \quad \hat{\psi}(\infty;\gamma,\varepsilon) < 0,$$

which implies

$$\hat{\psi} \gtreqless 0 \ \left(\Leftrightarrow \frac{dn}{d\gamma} \gtreqless 0\right) \ \text{ for } \ x \lesseqgtr x_\psi \ \text{ where } \ x_\varphi < x_\psi. \tag{37}$$

From (37) and Lemma, we find that Proposition 3, which holds in the single-commodity economy, also holds in the two-commodity economy: addictive product innovation may increase or decrease total employment and real consumption.

Under homothetic utility, the ratio x_ψ/x_φ is equal to the consumption ratio of the threshold and survival levels. Table 3 lists the ratios calculated for different pairs of (γ,ε). Note that γ and ε satisfy (35) and that the elasticity of the marginal utility of real consumption ξ is $1-(\gamma+\varepsilon)$ because substituting them into $u(x,y;\gamma)$ in (32) yields

$$U(c;\gamma,\varepsilon) = \frac{\left(\frac{\gamma}{\gamma+\varepsilon}\right)^{\gamma+\varepsilon}\left(\frac{\varepsilon}{\gamma\omega}\right)^{\varepsilon}\left(\frac{c}{p_x}\right)^{\gamma+\varepsilon} - 1}{\gamma+\varepsilon}, \quad \xi \equiv -\frac{U_{cc}c}{U_c} = 1-(\gamma+\varepsilon) > 0.$$

The parameter values in Table 3 satisfy these properties.[11]

---

[11] We do not treat the case where the elasticity of the marginal utility of consumption $1-(\gamma+\varepsilon)$ is larger than 1 in the two-commodity case. This is because the effect of a rise in γ on the demand ratio of the two

Table 3: the survival consumption level and the threshold (the two-commodity case)

$\xi(= (1-(\gamma+\varepsilon))$	0.2			0.3			0.4		
ε/γ	1	10	100	1	10	100	1	10	100
x_{ψ}/x_{φ}	496	162	150	96.3	30.8	28.5	41.2	13.4	12.4

By comparing x_{ψ}/x_{φ} in Table 3 with the G7 countries' data in Table 2, we find that the threshold ratios presented in Table 3 are all higher than the ratio of household consumption per capita to the poverty line for G7 countries in Table 2, which implies $dn/d\gamma > 0$ for G7 countries. Therefore, using Lemma, we find that addictive innovation increases both employment and real consumption in the two-commodity economy as well as in the single-commodity economy.

5. Concluding Remarks

Product innovation increases the utility of consumption and is expected to stimulate consumption. Therefore, it is often cited as an economic stimulus when a country faces secular stagnation because of a lack of aggregate demand. However, it increases not only the value of consumption but also the value of money because the value of money is measured by the commodities it can buy. Thus, depending on how it affects utility, it may increase or decrease real consumption and employment.

commodities is quite unrealistic. See Appendix B for details.

We consider two types of product innovation: quantity-augmenting-like and addictive product innovation. The former acts as if households were consuming a larger quantity of the commodity on which the innovation takes place although they actually consume the same quantity. The latter decreases the elasticity of the marginal utility of consumption.

Quantity-augmenting-like product innovation proportionally increases the value of the commodity and the value of money. Consequently, the marginal utility of consumption becomes smaller than that of wealth because the elasticity of the marginal utility of consumption is greater than that of the marginal utility of wealth, and real consumption decreases. Employment also declines because the product innovation decreases the quantity of the commodity that yields the same real consumption.

Addictive product innovation directly increases both the utility and marginal utility of consumption, of which the former also increases the value of money because the same amount of money can buy the commodity that gives higher utility. Therefore, it is generally ambiguous which of consumption and money raises its own marginal utility more, implying that the effects on real consumption and employment are also ambiguous. However, for a plausible value of the elasticity of the marginal utility of consumption, addictive innovation increases both employment and real consumption.

In conclusion, as an economic stimulus, addictive product innovation should be encouraged, while quantity-augmenting-like product innovation should not be encouraged, because the former stimulates aggregate demand and expands employment while the latter aggravates stagnation.

Appendices

Appendix A: Proof of (31)

From (24) and (29), we obtain

$$\hat{\Omega}\frac{dn}{nd\gamma}=\frac{1}{u_{xx}x^2}\Big(\delta u_\gamma - xu_{x\gamma} - (u_{xx}-\frac{u_{y\gamma}}{\omega})x^2\frac{\delta'}{\delta}\Big). \tag{A1}$$

Partially differentiating (23) with respect to x and γ yields

$$\frac{u_y(x,y;\gamma)}{u_x^2(x,y;\gamma)}\left(\frac{u_{yx}(x,y;\gamma)}{\omega}-u_{xx}(x,y;\gamma)\right)=\frac{u_y\left(\frac{x}{y},1;\gamma\right)}{yu_x^2\left(\frac{x}{y},1;\gamma\right)}\left(\frac{u_{yx}\left(\frac{x}{y},1;\gamma\right)}{\omega}-u_{xx}\left(\frac{x}{y},1;\gamma\right)\right),$$

$$\frac{u_y(x,y;\gamma)}{u_x^2(x,y;\gamma)}\left(\frac{u_{y\gamma}(x,y;\gamma)}{\omega}-u_{x\gamma}(x,y;\gamma)\right)=\frac{u_y\left(\frac{x}{y},1;\gamma\right)}{u_x^2\left(\frac{x}{y},1;\gamma\right)}\left(\frac{u_{y\gamma}\left(\frac{x}{y},1;\gamma\right)}{\omega}-u_{x\gamma}\left(\frac{x}{y},1;\gamma\right)\right),$$

$$-\left(\frac{u_{yx}\left(\frac{x}{y},1;\gamma\right)}{\omega}-u_{xx}\left(\frac{x}{y},1;\gamma\right)\right)\psi'=\frac{u_{y\gamma}\left(\frac{x}{y},1;\gamma\right)}{\omega}-u_{x\gamma}\left(\frac{x}{y},1;\gamma\right),$$

from which we find

$$u_{xx}(x,y;\gamma)-\frac{u_{yx}(x,y;\gamma)}{\omega}=\left(\frac{u_{y\gamma}(x,y;\gamma)}{\omega}-u_{x\gamma}(x,y;\gamma)\right)\frac{1}{y\psi'}. \tag{A2}$$

Applying δ' in (24) and (A2) to (A1) and gives

$$\hat{\Omega}\frac{dn}{nd\gamma}=\frac{1}{u_{xx}x^2}\Big(\delta u_\gamma-\frac{(1-\delta)xu_{y\gamma}}{\omega}-\delta xu_{x\gamma}\Big).$$

Given that $(1-\delta)x/\omega=\delta y$ from (27), the above equation implies the first equation in (31).

Since $c=p_x\theta_x n$ from the last equation in (27), $(dp_x/d\gamma)/p_x$ is given by (26), and $\hat{\Omega}$ is given in (30), from the first equation in (31) we obtain the second equation in (31).

Appendix B: The elasticity of the marginal utility of consumption

Without wealth preferences, as assumed in the standard model, the Ramsey equation in (7) reduces to

$$\rho + \xi \frac{\dot{c}}{c} + \pi = \frac{v_T{}'(m)}{U_c(c;\gamma)} = R.$$

Therefore, a change in R will vastly vary $\dot{c}/c$ if ξ is small. This is why the DSGE literature insists that ξ must be sufficiently large. In the presence of wealth preference, however, the Ramsey equation (7) is

$$\rho + \xi \frac{\dot{c}}{c} + \pi = R + \frac{v_W{}'(a)}{U_c(c;\gamma)}.$$

Therefore, a change in R can be absorbed by a change in the wealth premium $v_W{}'(a)/U_c(c;\gamma)$ without affecting $\dot{c}/c$ regardless of the value of ξ.

Furthermore, when the utility function is given by (32) and $\gamma < 0$, the effect of a rise in γ on the demand for x is quite unrealistic, as shown below: Under this utility function, x and y satisfy the third equation in (34); hence,

$$\frac{x}{y} = \frac{\gamma\omega}{\varepsilon}.$$

This shows that in the case where $\gamma > 0$, $\varepsilon > 0$ and thus $\xi = 1 - (\gamma + \varepsilon) < 1$, which we treat in the text, a rise in γ increases demand for x. Intuitively, an increase in the utility of x and a decrease in the elasticity (or the curvature) of the marginal utility of x, $-u_{xx}x/u_x = 1 - \gamma$ from (32), both due to a rise in γ, naturally 'increase' demand for x. In the case where $\gamma < 0$, $\varepsilon < 0$ and thus $\xi = 1 - (\gamma + \varepsilon) > 1$, however, a rise in γ (or equivalently, a decrease in $|\gamma|$) reduces demand for x. Intuitively, a rise in γ increases the utility of x and decreases the elasticity (or the curvature) of the marginal utility of x, and nevertheless, it 'decreases' demand for x, which is unrealistic. Therefore, we avoid the case where $\gamma < 0$, $\varepsilon < 0$ and $\xi > 1$ in the text.

References

Anderson, L. R., and Mellor, J. M. (2008) "Predicting health behaviors with an experimental measure of risk preference", *Journal of Health Economics*, 27(5), 1260–1274.

Baldwin, R. and Martin, P. (2004) "Agglomeration and regional growth", *Handbook of Regional and Urban Economics*, 4, 2671–2711.

Chiappori, P.-A. and Paiella, M. (2011) "Relative risk aversion is constant: Evidence from panel data", *Journal of the European Economic Association*, 9(6), 1021-1052.

Davis, C., and Hashimoto, K. (2016) "Industry concentration, knowledge diffusion and economic growth without scale effects", *Economica*, 82(328), 769-789.

Feldstein, M. (2017) "Underestimating the real growth of GDP, personal income, and productivity" *Journal of Economic Perspectives,* 31(2), 145–164.

Guvenen, F. (2006) "Reconciling conflict evidence on the elasticity of intertemporal substitution: A macroeconomic perspective", *Journal of Monetary Economics*, 53, 1451-1472.

Hall, R. E. (1988) "Intertemporal substitution in consumption", *Journal of Political Economy*, 96(2), 339-357.

Harrison, G. W., Johnson, E., Mcinnes, M. M., and Rutström, E. (2005) "Risk aversion and incentive effects: Comment" *American Economic Review*, 95(3), 897–901.

Illing, G., Ono, Y., and Schlegl, M. (2018) "Credit booms, debt overhang and secular stagnation", *European Economic Review*, 108, 78-104.

Iwaisako, T., and Tanaka, H. (2017) "Product cycles and growth cycles," *Journal of International Economics*, 105, 22-40.

Johdo, W. (2008) "Production subsidy as a macroeconomic policy in a stagnation economy" *Singapore Economic Review*, 53(2), 317–333.

Jolliffe, D., and Prydz, E. B., (2016) "Estimating international poverty lines from comparable national thresholds", *Journal of Economic Inequality*, 14, 185-198.

Kane, R. F., and Peretto, P. F. (2020) "More apples vs. better apples: Distribution and innovation-driven growth", *Journal of Economic Theory*, 185 (104964).

Krugman, P. (1980) "Scale economies, product differentiation, and the pattern of trade", *American Economic Review*, 70(5), 950-959.

Meissner, T., and Pfeiffer, P. (2022) "Measuring preferences over the temporal resolution of consumption uncertainty", *Journal of Economic Theory*, 200 (105379).

Mian, A., Straub, L., and Suffi, A. (2021) "Indebted demand", *Quarterly Journal of Economics*, 136(4), 2243-2307.

Michaillat, P., and Saez, E. (2022) "An Economical Business-Cycle Model." *Oxford Economic Papers*, 74 (2), 382–411.

Michau, J. B. (2018). "Secular stagnation: Theory and remedies" *Journal of Economic Theory*, 176, 552–618.

Ono, Y. (1994) *Money, Interest and Stagnation*, Clarendon Press: Oxford.

Ono, Y. (2001) "A reinterpretation of chapter 17 of Keynes's General Theory: Effective demand shortage under dynamic optimization" *International Economic Review*, 42(1), 207–236.

Ono, Y., and Ishida, J. (2014) "On persistent demand shortages: A behavioural approach", *Japanese Economic Review*, 65(1), 42–69.

Ono, Y., Ogawa, K., and Yoshida, A. (2004) "The liquidity trap and persistent unemployment with dynamic optimizing agents: Empirical evidence", *Japanese Economic Review*, 55(4), 355–371.

Ono, Y., and Yamada, K. (2018) "Difference or ratio: Implications of status preference on stagnation", *Australian Economic Papers*, 57(3), 346-362.

Rosen, S. (1974) "Hedonic prices and implicit markets: Product differentiation in pure competition", *Journal of Political Economy*, 82(1), 34–55.