Quality of Intermediate Goods: The Growth and Welfare Implications

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Abstract: This paper explores the implications of the quality of intermediate goods in an endogenous growth model. We show that a trade-off exists between the quality and the variety of products, which creates a wedge between the market-equilibrium quality and the socially optimal one. Relative to the social optimum, the equilibrium quality could be either under-supplied or over-supplied, depending on the productivity-enhancing effect as well as the IRTS and business-stealing effects. Besides, we examine the optimal fiscal policy for two distinct types of government spending, namely, the Barro-type government spending on infrastructure and the quality-related spending on cost reduction.

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1 Introduction

The production of goods involves two dimensions: quantity and quality, with the latter having been largely neglected in the literature. Anecdotally, in witnessing the recent advances in desk-top computing and integrated circuitry, we easily recognize the contribution of the quality upgrades of both consumption and intermediate products to economic growth and social welfare. On the one hand, the quality of consumption goods contributes to raising our standard of living and, on the other hand, the quality upgrading of intermediate products plays a prominent role in boosting the production of consumption goods (see Grossman and Helpman 1991 for the importance of these quality upgrades).[1]

The quality of intermediate goods has been increasingly important. The qualities of different intermediate goods are highly complementary in the production of the final goods and the production technology of final goods is greatly raised by applying higher quality (high-tech) devices and instruments. For example, fully automatic machines, computer-aided-design and computer-engineering-capabilities (CAD/CAE) equipment, transporting devices, robots, and telematics have greatly improved firms' productivity and significantly expanded their production capacity. These contributions have reflected a significantly high ratio of intermediate goods to GDP and a dramatic increase in the volume of intermediate goods trade. Grobovšek (2012) and Moro (2012) report that due to the quality upgrades, in the industrialized countries the share of intermediate goods in gross output has been around one half and it may be as high as 60% in Belgium and Korea.[2] Meanwhile, in the OECD countries the imports of intermediate goods have accounted for 56% of total imports (Miroudot et al. 2009) and in the manufacturing sector they have increased by around 23.4% per year over the period 1992-2003 (Halpern et al. 2011). More importantly, the evidence shows that firms improve their performance trajectories by importing higher quality inputs and by extracting knowledge from these foreign goods. Importing more varieties of high quality intermediate goods enhance the productivity and competitiveness of firms in either developed (such as France, see Bas and Strauss-Kahn 2011 and other OECD countries, see Halpern et al. 2011), or developing

[1] Bils (2005, 2009) estimates an annual quality growth for durables of about 5 percent since 1988. The importance of quality growth as a component of GDP growth seems to have increased over time.

[2] It is shown from the EU KLEMS Database in 2007 that this share lies between 0.4 and 0.6 for Australia, Austria, Belgium, Denmark, Finland, France, Germany (West Germany until 1991), Japan, Korea, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, the U.K. and the U.S., during the 1970-2004 period.

countries (such as India, see Goldberg et al. 2010).

In spite of the importance of product quality, the macroeconomic literature has not shed enough light on this issue.[3] In particular, most macroeconomic studies focus exclusively on the quality differentiation of consumption goods, while remaining silent on the quality differentiation of intermediate products. This paper attempts to provide the implications of the quality of intermediate goods for growth and welfare by building a simple and tractable theoretical model. To shed light on the interactions between the *quality of intermediate goods* and *the quantity of final goods*, our analytical framework is a variant of the model of Romer (1986) and Devereux et al. (1996) that incorporates the product quality into an endogenous growth model which is based on *increasing returns to production specialization* (IRTS). Intermediate goods are both horizontally (variety) and vertically (quality) differentiated. On the one hand, the optimally-decided quality of intermediate goods complements the production of the final goods, contributing to the *quantity* of GDP. On the other hand, the endogenously-determined variety of intermediate goods gives rise to two quite different externalities: the IRTS and *business-stealing* effects. The IRTS indicates, as in Ethier (1982) and Romer (1986), that entry increases the variety of intermediate goods, which is favorable to the production of final goods. Thus, more entrants are desirable to a society. By contrast, the business-stealing effect, as argued by Mankiw and Whinston (1986), indicates that a new entrant leads the incumbent firms to have a lower volume of sales by stealing their business, and potentially refers to excessive entry.

Our positive analysis shows that the quality of the market equilibrium is raised by keener competition, since tougher competition induces firms to produce higher quality intermediate goods in order to avoid competition with "neck-and-neck" rivals. Because producing high-quality goods is costly, there is a trade-off between the quality and the variety of products. As a result of the more pronounced IRTS, a higher level of product quality does not necessarily imply a higher economic growth rate. This differs from the studies on the quality of consumption, as in Stokey (1988) whereby there exists a positive relationship between income and the quality of consumption. In

[3] By contrast, the international trade literature provides evidence of the increasing importance of the quantity/quality distinction in describing current patterns of international trade. For example, Flam and Helpman (1987) develop a model of North-South trade where quality enters into an individual's utility function. Considering that richer countries have advantages in terms of producing higher-quality goods, they investigate the overlap of income distribution between poor and rich countries as the source of trade. Moreover, Copeland and Kotwal (1996) and Murphy and Shleifer (1997) extend the Flam-Helpman model to investigate the conditions that trade may not take place between rich and poor countries when their incomes differ.

addition, this trade-off between the quality and the variety of products also governs the consequence of product market competition (PMC) on economic growth. The conventional Schumpeterian paradigm indicates that monopoly power is viewed as the reward accruing to the successful firms from their innovative activities; the larger this reward is, the stronger is the incentive to innovate. Since tougher competition erodes the monopolistic rents that can be appropriated by successful innovators, more intense PMC is harmful to technological progress and hence economic growth (Romer, 1990 and Aghion and Howitt, 1992). This theoretical prediction is, however, not supported by empirical studies. Recent evidence, such as Aghion et al. (2005) and Aghion and Griffith (2005), shows that in the U.K. and U.S. industries there exists an inverted-U relationship between PMC and growth. By shedding light on the importance of the quality of intermediate goods, our result refers to a mixed PMC- growth relationship and, accordingly reconciles the recent empirical finding.

Our welfare analysis shows that there exists a wedge between the product quality of the market equilibrium and that of the social optimum. The quality of the market equilibrium is under-supplied and lower than that of the social optimum, if the business-stealing effect dominates the IRTS effect. By contrast, the quality of the market equilibrium is over-supplied and higher than that of social optimum if the IRTS effect dominates the business-stealing effect. This quality wedge creates room for welfare-improving government intervention. It is found that while the standard Barro type of government spending on infrastructure is incapable of raising the product quality, the government spending on the quality-related cost reduction can raise the equilibrium quality. To achieve the social optimum, the optimal government spending on infrastructure increases with the degree of IRTS and the effectiveness of the government expenditure on infrastructure, but decreases with the contribution of the intermediate-good quality to the real GDP and the efficiency of the government spending on the quality-related cost reduction. By contrast, the optimal government spending on the quality-related cost reduction increases if the quality-related policy is more effective and the contribution of product quality is more pronounced. The optimal government spending on the quality-related cost reduction does not correspond to the distortion caused by IRTS, since the Barro type of government spending on infrastructure can more effectively remedy it.

Related Literature

The literature on product quality can be traced to works by Segerstrom et al. (1990) and Grossman and Helpman (1991), who cast the patent-race paradigm in a dynamic, general-equilibrium setting and provide a theory of repeated quality innovations. Stokey (1988) and Aghion and Howitt (1992) build *endogenous* growth models to shed light on the importance of firms' R&D in an economy's performance, when innovation takes the form of higher-quality products. These traditional quality-ladder models focus on the vertical R&D, taking the number of product varieties as exogenously given. By contrast, our framework consists of both the endogenous variety and quality of products. As emphasized above, the endogenous variety of goods gives rise to the effects of IRTS and business stealing, which play a primary role in our analysis.

In addition, to differentiate from these studies which focus on quality innovations, we adopt a broad interpretation of quality improvement by including all of those activities that may raise the production of final goods via the adoption of high quality/technological devices and instruments. While R&D activities indeed play a crucial role in terms of improving product quality, we do not restrict our view to R&D activities. Instead, in our model, intermediate-good firms may upgrade their product quality if they are willing to incur relatively high costs. Meanwhile, a higher-quality product, on the one hand, gives the intermediate firm a competitive advantage over others and, on the other hand, contributes a larger level of output to the entire economy. In addition to R&D, such upgrade activities have been widely and increasingly applied by modern corporations to compete in the marketplace.

Peretto (1998, 1999) and Gil, Britoy and Afonso (2008) endogenize the market structure by considering both variety-expanded and quality-improved R&D. Their purposes are different from ours. While their studies attempt to match industrial organization facts and to be immune from the empirically implausible scale effect, our purpose is to look into how the quality of intermediate goods interacts with the quantity of final goods and how this interaction governs economic growth and social welfare. Besides, recently Alcalá (2009) and Wuergler (2010) have considered quality-differentiated consumption goods in examining consumers' quantity-quality choices and investigating their implications for growth and income inequality. All of the aforementioned studies restrict their focus in regard to the quality differentiation of consumption goods, while ignoring the importance of the quality differentiation of intermediate products. To the best of our knowledge, Fan's (2004, 2005) studies are exceptions, in that the quality of intermediate goods is involved. He considers that the qualities of intermediate goods are perfectly complementary in producing the quality of the final good, and focuses on examining the patterns of international trade. By shedding light on the productivity-enhancing effect (stemming from the differentiation of intermediate products) as well as the IRTS and business-stealing effects (stemming from the variety of products), we not only examine the relationship of growth with the product quality and the PMC, but also investigate the effects of various levels of government spending on growth and welfare. The purposes are obviously different.

2 The Model

There are two types of goods: a homogeneous final good, which is the numeraire and is produced by competitive firms, and differentiated intermediate goods, which allow for monopolistic competition between the intermediate-goods producers. Most notably, the final good is produced by the set of intermediate goods, which can be both horizontally (variety) and vertically (quality) differentiated. Households drive utility from the consumption of final goods. To balance its budget, the government levies an income tax to finance its expenditure on the Barro type of infrastructures (productive public expenditure) and quality-related cost reductions. Time t is continuous and, without confusion, the time index is suppressed throughout the paper.

2.1 Firms

The production side is built on the Dixit-Stiglitz (1977) model of monopolistic competition with modifications to formalize industrial specialization.

2.1.1 Final-good firms

The final consumption goods are produced through a combination of a variety of intermediate goods, which are both vertically and horizontally differentiated. The number of quality levels is denoted by n^v and each quality has n^s varieties. The total number of intermediate products is then $n = n^v \times n^s$. Besides, the quantity of an intermediate input with quality v and variety s is denoted by $y(s, v)$. Accordingly, the production function of the final good Y can be specified as:

$$Y = n^{1+\lambda-\frac{1}{\rho}} \left\{ \int\limits_{v\in[o,n^v]} \int\limits_{s\in[o,n^s]} [\eta(v)y(s,v)]^{\rho} ds dv \right\}^{\frac{1}{\rho}}, \ \eta(v) > 0 \text{ and } 0 < \rho < 1, \tag{1}$$

where we impose the restrictions of $\eta'(v) > 0$ and $\eta''(v) < 0$, implying that employing higher quality intermediate inputs yields more total outputs, while the marginal productivity of the quality of intermediate inputs is diminishing. The specification of $\eta(v)$ is not only highly consistent with the empirical finding[4], but also allows us to convert the product *quality* into the contribution to the *quantity* of GDP. The measure of GDP attracts a common criticism whereby it ignores the quality attribute entirely, but our specification of (1) mitigates this problem.

It is important to note that, if all intermediate goods are hired in the same quantities under a symmetric equilibrium, the final good output then becomes $Y = n^{1+\lambda}\eta(v)y$. This implies that the generalized form of (1) allows us to consider various cases by verifying λ: there are increasing returns to the quantities employed of a variety of intermediate goods if $\lambda > 0$, while there are decreasing returns to an expansion in such a variety if $\lambda < 0$. The case where $\lambda > 0$ will be emphasized in our analysis, since it echoes the importance of the IRTS of Romer (1987). In a traditional specification, such as in Dixit and Stiglitz (1977) and Devereux et al. (1996, 2000), the symmetric equilibrium potentially implies that the degrees of monopoly power and of IRTS share the same parameter (ρ in our terminology) and consequently it is difficult to distinguish what arises due to market imperfections and what is due to increasing returns.[5] To overcome this problem, we follow Béassy (1996, 1998) and specify (1) which enables us to clearly separate increasing returns from imperfect competition, so that both effects can be fully disentangled. This is crucial in our analysis since, as we will see later, IRTS play a crucial role in terms of affecting the macroeconomic equilibrium and the government's optimal policy.

Final-good producers behave competitively and choose intermediate goods $y(s,v)$ to maximize their profits, taking the prices $p(s,v)$ of intermediate inputs as given. That is,

$$\max_{\{y(s,v)\}} \pi^f = n^{1+\lambda-\frac{1}{\rho}} \left\{ \int\limits_{v\in[o,n^v]} \int\limits_{s\in[o,n^s]} [\eta(v)y(s,v)]^\rho ds dv \right\}^{\frac{1}{\rho}} - \int\limits_{v\in[o,n^v]} \int\limits_{s\in[o,n^s]} p(s,v)y(s,v) ds dv, \quad (2)$$

where the price of the final goods is normalized to 1 and $p(s,v)$ is then the relative price of the

[4] By analyzing nearly 400 quality award winner firms, Hendricks and Singhal (1997) found that firms in the test sample had been more successful in expanding output and controlling costs.

[5] In their models without the consideration of product quality, the production function is specified as: $Y = (\int\limits_{s\in[o,n^s]} y^\rho ds)^{\frac{1}{\rho}}$. Under symmetric equilibrium, this specification implies that $Y = n^{\frac{1}{\rho}} y$. Apparently, the degrees of monopoly power and of IRTS share the same parameter ρ.

intermediate product with quality v and variety s. The first-order condition for this optimization problem is:

$$p(s,v) = n^{\rho(1+\lambda)-1} Y^{1-\rho} \eta(v)^{\rho} y(s,v)^{\rho-1}, \tag{3}$$

which is the inverse demand function for intermediate goods. Other things being equal, the demand for intermediate goods increases with product quality $\eta(v)$.

2.1.2 Intermediate-good firms

Intermediate good producers employ capital $k(s,v)$ and labor $h(s,v)$ to produce their product and sell it to the final good producers at the profit-maximizing price. With an overhead cost ϕ (paid in units of intermediate good output), the production technology for an intermediate good with quality v and variety s is given by:

$$y(s,v) = z \left[\frac{k(s,v)}{\alpha(v,\widetilde{g})}\right]^{a} \left[\frac{h(s,v)}{\beta(v,\widetilde{g})}\right]^{1-a} G^{b} - \phi, \quad a > 0,\ b > 0 \text{ and } \phi > 0. \tag{4}$$

The production function exhibits a constant-returns-to-scale technology with the capital (labor) share being a $(1-a)$. In line with Romer (1986), the technology factor z is increasing in the economy's stock of knowledge, which is captured by the average economy-wide stock of capital $\bar{K}$, specifically, $z = z_0 \overline{K}^{\varphi}$, $z_0 > 0$. To capture the fact that producing high-quality goods is costly, we assume that $\alpha(v,\widetilde{g}) > 0$, $\beta(v,\widetilde{g}) > 0$ and $\alpha_v(v,\widetilde{g}) > 0$ and $\beta_v(v,\widetilde{g}) > 0$, implying that producing a high-quality intermediate good requires more capital and labor inputs than a low-quality one. In other words, the marginal costs of producing higher quality intermediate goods are higher.

Government expenditure has a positive external effect on private production, which is in line with the viewpoint proposed by Barro (1990) and also in conformity with Aschauer's (1988, 1989) empirical evidence. In our analysis, there are two types of government spending. One is a Barro type of government spending on infrastructure, denoted by G, which directly gives rise to an output-enhancing effect on private production. In line with Barro (1990), we assume that $G = gY$ where g is the ratio of the government spending on infrastructure to the gross output.

The other is the government spending on reducing the quality improving costs, denoted by $\widetilde{G}$, which may refer to the subsidy of the government on the production of high-tech products or on the replacement of the electricity-gorging machines. If we relate the production of higher quality to R&D activities, this spending can also refer to the public R&D spending for improving the product quality of the private firms (See Park, 1998, Morales, 2004, and Akcigit et al., 2012 for the related discussions). Like government spending on infrastructure, such a public expenditure is assumed to be proportional to output, i.e., $\widetilde{G} = \widetilde{g}Y$ where $\widetilde{g}$ is the ratio of the government spending on reducing the quality-improving costs to the gross output. To ensure a balabced-growth-path equilibrium, we assume that $\widetilde{g}$ (the government spending on reducing the quality-improving costs measured on a per unit of output basis) reduces the "marginal production costs" of capital and labor for quality improving (additional inputs needed to raise the product quality), i.e., $\alpha_{\widetilde{g}}(v, \widetilde{g}) < 0$, $\alpha_{v,\widetilde{g}}(v, \widetilde{g}) < 0$, $\beta_{\widetilde{g}}(v, \widetilde{g}) < 0$ and $\beta_{v,\widetilde{g}}(v, \widetilde{g}) < 0$.

Note that, according to the production function (4), the corresponding marginal cost of production MC is given by:

$$MC = \frac{1}{z}\left[(\frac{a}{1-a})^{1-a} + (\frac{1-a}{a})^{a}\right][\alpha(v, \widetilde{g})r]^{a}[\beta(v, \widetilde{g})w]^{1-a}. \tag{5}$$

Taking the factor prices r and w as given, the marginal cost of production is constant (independent of output) for an individual intermediate firm. Since $\alpha(v, \widetilde{g})$ and $\beta(v, \widetilde{g})$ are related to the unit cost of products, it is reasonable to specify that this unit cost is affected by the proportion of the cost-reduction spending for quality improving to the total outputs, $\widetilde{g}$ $(= \widetilde{G}/Y)$, rather than the total amount of the spending $\widetilde{G}$.

Given the demand function of final-good producers (3) and the production technology of intermediate good (4), the optimization problem of the intermediate-good firm is given by:

$$\begin{aligned}
\max_{\{k(s,v),h(s,v),v\}} \pi(s,v) &= p(s,v)y(s,v) - rk(s,v) - wh(s,v), \\
s.t. \quad y(s,v) &= z\left[\frac{k(s,v)}{\alpha(v,\widetilde{g})}\right]^{a}\left[\frac{h(s,v)}{\beta(v,\widetilde{g})}\right]^{1-a} G^{b} - \phi, \\
p(s,v) &= n^{\rho(1+\lambda)-1}Y^{1-\rho}\eta(v)^{\rho}y(s,v)^{\rho-1}.
\end{aligned}$$

The corresponding first-order conditions for this optimization problem are:

$$\frac{a\rho p(s,v)[y(s,v)+\phi]}{k(s,v)} = r, \tag{6}$$

$$\frac{(1-a)\rho p(s,v)[y(s,v)+\phi]}{h(s,v)} = w, \tag{7}$$

$$\frac{\eta'(v)}{\eta(v)} - \left[1 + \frac{\phi}{y(s,v)}\right]\left[a\frac{\alpha_v(v,\widetilde{g})}{\alpha(v,\widetilde{g})} + (1-a)\frac{\beta_v(v,\widetilde{g})}{\beta(v,\widetilde{g})}\right] = 0. \tag{8}$$

Equations (6) and (7) are the firm's demands for capital and labor, respectively. It follows from (6)-(8), together with the marginal cost of production (5), that the price markup is $\frac{p}{MC} = \frac{1}{\rho}$. Equation (8) equates the marginal benefit of raising product quality to its marginal cost. Since all intermediate firms are symmetric with identical technology and final-good firms are homogeneous with identical "tastes" on the quality of intermediate products, (8) also indicates that all intermediate-good firms produce goods with the same quality v in equilibrium.

We consider a symmetric equilibrium and, accordingly, simplify the notations as follows: $\pi(s,v) = \pi$, $y(s,v) = y$, $k(s,v) = k = \frac{K}{n} = \frac{\bar{K}}{n}$, $h(s,v) = h = \frac{H}{n}$ and $p(s,v) = p$. Under the symmetric equilibrium, the total output of final goods can be written as:

$$Y = n^{1+\lambda}\eta(v)y.$$

By substituting (6) and (7) into the free entry condition (i.e., the zero-profit condition) $\pi = 0$, we obtain:

$$y = \frac{\rho\phi}{1-\rho}. \tag{9}$$

Equation (9) indicates that a higher markup (a lower ρ) implies a higher profit of incumbents which induces more entrants. This gives rise to the *business-stealing* effect in the sense that a new entrant leads the incumbent firms to have a lower volume of sales by stealing their business. Thus, the output per firm y decreases as a response. By contrast, since a higher fixed cost ϕ increases the entry barriers, the output of each existing firm is then larger. With the aggregate consistency and the production function (4), (9) allows us to further derive the following numbers of intermediate-good firms (or good varieties):[6]

$$n = \left\{ z_0 \overline{K}^{\varphi} \left[\frac{1-\rho}{\phi}\right]^{1-b} \left[\frac{K}{\alpha(v,\widetilde{g})}\right]^{a} \left[\frac{H}{\beta(v,\widetilde{g})}\right]^{1-a} [\eta(v)g]^{b} \right\}^{\frac{1}{1-b(1+\lambda)}}. \tag{10}$$

By substituting (10) into (3), (2), (6) and (7), we rewrite the price of intermediate goods, the

[6] Here we impose the restriction of $1 - b(1+\lambda) > 0$ such that a larger number of firms results in a higher total stock of capital.

total outputs of final goods, the interest rate, and the wage rate as follows:

$$p = n^{\lambda}\eta(v) = \eta(v)\left\{z_0\overline{K}^{\varphi}\left[\frac{1-\rho}{\phi}\right]^{1-b}\left[\frac{K}{\alpha(v,\widetilde{g})}\right]^{a}\left[\frac{H}{\beta(v,\widetilde{g})}\right]^{1-a}[\eta(v)g]^{b}\right\}^{\frac{\lambda}{1-b(1+\lambda)}}, \tag{11}$$

$$Y = n^{1+\lambda}\eta(v)y = \frac{\eta(v)\rho\phi}{1-\rho}\left\{z_0\overline{K}^{\varphi}\left[\frac{1-\rho}{\phi}\right]^{1-b}\left[\frac{K}{\alpha(v,\widetilde{g})}\right]^{a}\left[\frac{H}{\beta(v,\widetilde{g})}\right]^{1-a}[\eta(v)g]^{b}\right\}^{\frac{1+\lambda}{1-b(1+\lambda)}}, \tag{12}$$

$$r = a\frac{Y}{K}, \quad w = (1-a)\frac{Y}{H}. \tag{13}$$

From (12), the restriction of $\varphi = \frac{1}{1+\lambda} - a - b$ is necessary such that the aggregate production function exhibits constant returns to scale in capital, thus generating perpetual growth. Equation (11) reveals that the price of intermediate goods increases with its quality. Equation (13) shows that the capital share and the labor share are constant and are a and $(1-a)$, respectively. In addition, substituting (9) into (8) yields the equilibrium quality, v^e, which satisfies:

$$\rho\frac{\eta'(v^e)}{\eta(v^e)} - a\frac{\alpha_v(v^e,\widetilde{g})}{\alpha(v^e,\widetilde{g})} - (1-a)\frac{\beta_v(v^e,\widetilde{g})}{\beta(v^e,\widetilde{g})} = 0 \tag{14}$$

Notice that in equilibrium the intermediate goods' quality can be recursively determined by (14). This is because under free entry each intermediate firm produces the same level of output.[7]

Moreover, given that intermediate-good firms produce goods with the same quality v in each period. Let $\varepsilon^{\eta}(v^e)$ be the elasticity of intermediate product quality to the output of the final good, and $\varepsilon^{\alpha}(v^e,\widetilde{g})$ and $\varepsilon^{\beta}(v^e,\widetilde{g})$ be the elasticity of product quality to the unit costs of production. Thus, equation (14) can be re-expressed as: $\rho\varepsilon^{\eta}(v^e) - a\varepsilon^{\alpha}(v^e,\widetilde{g}) - (1-a)\varepsilon^{\beta}(v^e,\widetilde{g}) = 0$. we have the following proposition:

Proposition 1. (Equilibrium Quality of Intermediate Goods) *Keener competition in the product market (a higher ρ) raises the equilibrium quality.*

Proof: From (14), we can derive:

$$\frac{\partial v^e}{\partial \rho} = \frac{\varepsilon^{\eta}}{a\frac{\partial \varepsilon^{\alpha}}{\partial v^e} + (1-a)\frac{\partial \varepsilon^{\beta}}{\partial v^e} - \rho\frac{\partial \varepsilon^{\eta}}{\partial v^e}} > 0,$$

because we have $\rho\frac{\partial \varepsilon^{\eta}}{\partial v^e} - a\frac{\partial \varepsilon^{\alpha}}{\partial v^e} - (1-a)\frac{\partial \varepsilon^{\beta}}{\partial v^e} < 0$ from the second-order condition of profit maximization.

[7] Notice that the second-order condition of the firm's profit maximization requires that $\rho\frac{\eta'(v^e)}{\eta(v^e)} - a\frac{\alpha_v(v^e,\widetilde{g})}{\alpha(v^e,\widetilde{g})} - (1-a)\frac{\beta_v(v^e,\widetilde{g})}{\beta(v^e,\widetilde{g})}$ is decreasing in v^e. Accordingly, (14) allows us to have a unique solution of product quality, provided that the condition $\rho\frac{\eta'(0)}{\eta(0)} > a\frac{\alpha_v(0,\widetilde{g})}{\alpha(0,\widetilde{g})} + (1-a)\frac{\beta_v(0,\widetilde{g})}{\beta(0,\widetilde{g})}$ holds ture.

■

Proposition 1 shows that tougher competition induces firms to produce higher quality intermediate goods in order to escape competition with "neck-and-neck" rivals. If adopting higher quality products is thought of as a kind of cost-reduction R&D, it is interesting to compare the result of Proposition 1 with those of existing studies. Our prediction is different from that of the conventional Schumpeterian models, which indicate that less competitive markets motivate more R&D, due to higher monopoly rents. However, our result supports the findings of Nickell (1996) and Aghion et al. (2001), who argue that the relationship between market competition and R&D is positive.

2.2 Households

There is a unit measure of identical, infinitely lived households. Each of them supplies one unit of labor inelastically, and chooses consumption C and capital K so as to maximize its lifetime utility. Given that the final good can be consumed, accumulated as capital, and paid for as taxes, the optimization problem of a representative household can be expressed as follows:

$$\underset{\{C,K\}}{Max} \int_0^\infty \ln C e^{-\theta t} dt, \tag{15}$$

$$s.t. \;\; \dot{K} = (1-\tau)(wH + rK + \Pi) - C - \delta K, \tag{16}$$

where τ is the income tax rate, θ is the time preference rate and δ is the capital depreciation rate. Thus, the budget constraint (16) indicates that the representative household is bound by a flow constraint linking capital accumulation to any difference between its disposable incomes (net of capital depreciation) and consumption expenditure. As an owner of firms, the household also receives aggregate profits Π in the form of dividends. However, due to free entry and exit, the profits of intermediate goods will be driven down to zero, i.e., $\Pi = 0$, in equilibrium. For simplicity, the labor-leisure choice is abstracted from the analysis. Nonetheless, our main results are also valid even if flexible labor supply is taken into account.

The optimal conditions for the household's problem yield the standard Keynes-Ramsey rule:

$$\frac{\dot{C}}{C} = r - \delta - \theta, \tag{17}$$

the individual budget constraint (16) with $\Pi = 0$, and the transversality condition $\lim_{t\to\infty} \frac{1}{C} K e^{-\rho t} =$

0.

2.3 Government

The government's flow budget constraint is written as:

$$\tau(wH + rK) = G + \widetilde{G}. \tag{18}$$

where G is the government spending on infrastructure, and $\widetilde{G}$ is the government spending on reducing the costs for improving input quality. As noted previously, we assume that $G = gY$ and $\widetilde{G} = \widetilde{g}Y$ to avoid the government spending being degenerated in an endogenous growth model. By incorporating the individual budget constraint, the government budget constraint and the firm's profits, we then have the following aggregate resource constraint:

$$\dot{K} = Y - C - (G + \widetilde{G}) - \delta K. \tag{19}$$

2.4 Balanced-Growth-Path Equilibrium

Under aggregate consistency, a competitive equilibrium is defined as a tuple of paths for quantities $\{C_t, K_t, Y_t, v_t, n_t\}_{t=0}^{\infty}$, prices $\{p_t, r_t, w_t\}_{t=0}^{\infty}$, and a tax policy variable $\{\tau_t\}_{t=0}^{\infty}$ that satisfy: (i) the firms' profit maximization conditions (6), (7) and (8); (ii) the household's utility maximization conditions (16) and (17); (iii) the government's budget constraint (18); and (iv) the market clearing conditions for the whole economy (19).

We are now ready to define the non-degenerate balanced-growth-path (BGP) equilibrium. Given the assumption of $\varphi = \frac{1}{1+\lambda} - a - b$, a BGP equilibrium is a tuple of paths such that each of the quantity variables, C, K, and Y, grows at a positive constant rate, while the price variables, p and r, as well as the product quality, v, are positively constant. Accordingly, the Keynes-Ramsey rule and the aggregate resource constraint can be re-written, respectively, as:

$$\frac{\dot{C}}{C} = a(1-\tau)\frac{Y}{K} - \theta - \delta, \tag{20}$$

$$\frac{\dot{K}}{K} = (1 - g - \widetilde{g})\frac{Y}{K} - \frac{C}{K} - \delta, \tag{21}$$

where

$$\frac{Y}{K} = \rho\left\{\eta(v^e)(\frac{1-\rho}{\phi})^{\lambda}\left[\frac{z_0 g^b}{\alpha(v^e,\widetilde{g})^a\beta(v^e,\widetilde{g})^{1-a}}\right]^{1+\lambda}\right\}^{\frac{1}{1-b(1+\lambda)}}.$$

Define $\frac{\dot{C}}{C} = \gamma$. We can see from (20) and (21) that along the BGP equilibrium, $\frac{\dot{C}}{C} = \frac{\dot{K}}{K} = \frac{\dot{Y}}{Y}$ is true, meaning that in the steady-state equilibrium the economy exhibits common growth in which consumption, capital, and output all grow at a common rate γ.

To solve the common balanced-growth rate, we define the transformed variables: $X = \frac{C}{K}$. Under the BGP equilibrium, the economy is characterized by $\frac{\dot{X}}{X} = \frac{\dot{C}}{C} - \frac{\dot{K}}{K} = 0$, and thus the equilibrium consumption-output ratio is given by:

$$X = [1 - g - \widetilde{g} - a(1-\tau)]\rho \left\{ \eta(v^e)(\frac{1-\rho}{\phi})^{\lambda} \left[\frac{z_0 g^b}{\alpha(v^e, \widetilde{g})^a \beta(v^e, \widetilde{g})^{1-a}} \right]^{1+\lambda} \right\}^{\frac{1}{1-b(1+\lambda)}} + \theta, \tag{22}$$

recalling that v^e is the product quality of the market equilibrium which is determined by (14). Moreover, it is easy from (20) to derive the balanced-growth rate as:

$$\gamma \equiv \frac{\dot{C}}{C} = a(1 - g - \widetilde{g})\rho \left\{ \eta(v^e)(\frac{1-\rho}{\phi})^{\lambda} \left[\frac{z_0 g^b}{\alpha(v^e, \widetilde{g})^a \beta(v^e, \widetilde{g})^{1-a}} \right]^{1+\lambda} \right\}^{\frac{1}{1-b(1+\lambda)}} - \theta - \delta. \tag{23}$$

Accordingly, we have:

Theorem 1. (Existence and Uniqueness of the Equilibrium) *Under the assumption of $\varphi = \frac{1}{1+\lambda} - a - b$, there exists a nondegenerate, unique balanced-growth-path equilibrium of the dynamic model with the consideration of product quality.*

Proof: The result follows immediately from (14), (22), and (23). ■

Under Theorem 1, (23) yields the following lemma:

Lemma 1. (The Relationship between Growth and Product Quality) *Under Theorem 1, there exists a non-monotonic correlation between economic growth and product quality.*

Proof: From (23) and (14), we obtain:

$$\frac{\partial \gamma}{\partial v} = \Psi \left\{ \frac{1}{1+\lambda} \frac{\eta'(v)}{\eta(v)} - [a \frac{\alpha_v(v, \widetilde{g})}{\alpha(v, \widetilde{g})} + (1-a) \frac{\beta_v(v, \widetilde{g})}{\beta(v, \widetilde{g})}] \right\} \gtreqless 0,$$

where $\Psi = \frac{a(1\text{-}g\text{-}\widetilde{g})\rho(1+\lambda)}{1\text{-}b(1+\lambda)} \left\{ (\frac{1\text{-}\rho}{\phi})^{\lambda} \eta(v) \left[\frac{z_0 g^b}{\alpha(v,\widetilde{g})^a \beta(v,\widetilde{g})^{1-a}} \right]^{1+\lambda} \right\}^{\frac{1}{1-b(1+\lambda)}}$. ■

This lemma indicates that a higher level of product quality does not necessarily imply a higher economic growth rate. The intuition is that both a higher quality and larger variety of intermediate goods may be favorable to the production of final goods, as shown in (12), and hence economic growth. While producing high-quality goods is costly, a higher product quality v is associated with a smaller number of firms n, due to fewer entrants, as shown in (10). As a result of this trade-off, the relationship between the product quality and the balanced-growth rate is non-monotonic. To be specific, if the extent of IRTS λ (i.e., the effect stemming from the decrease in the product variety) is not so large, the positive growth-quality relationship exists, which is similar to the result of Stockey (1988).[8] As will be clearer in the next section, this non-monotone is crucial, creating a quality wedge between the market competitive equilibrium and the social optimum.

Based on Proposition 1 and Lemma 1, the trade-off between the quality and variety of goods further results in the following corollary:

Corollary 1. (The Growth Effect of Product Market Competition) *More intense product market competition (a higher ρ) gives rise to an ambiguous effect on the balanced-growth rate.*

Proof: Given Proposition 1 and Lemma 1, (23) allows us to obtain:

$$\frac{d\gamma}{d\rho}=\frac{\partial\gamma}{\partial\rho}+\frac{\partial\gamma}{\partial v}\frac{\partial v}{\partial\rho}=\frac{a\rho z_0(\frac{1-\rho}{\phi})^{\lambda}\eta(v)}{\alpha(v,\widetilde{g})}\left[\frac{1}{(1\text{-}\rho)\rho}+\frac{\eta'(v)}{\eta(v)}\frac{\partial v}{\partial\rho}\right][1-\rho(1+\lambda)]\gtreqless 0 \text{ if } \lambda \lesseqgtr \frac{1-\rho}{\rho}. \blacksquare$$

Is more intense product market competition good or bad for growth? This question is important, since its answer will govern the development of antitrust and other competition policies. The conventional Schumpeterian paradigm indicates that monopoly power is viewed as the reward accruing to the successful firms from their innovative activities. Since tougher competition erodes such a reward, more intense PMC gives rise to a negative effect on economic growth. In a way that differs from their prediction, Corollary 1 indicates that more intense PMC may be beneficial, rather than harmful, to economic growth, provided that the extent of the IRTS λ is substantially low.

As shown in Proposition 1, tougher competition ρ motivates firms to adopt the strategy of high-quality products in order to escape competition, i.e., $\frac{\partial v^e}{\partial\rho} > 0$. Given the fact that high-quality products are associated with high production costs, this strategy deters potential competitors from entering the market, thereby resulting in a lower number of firms n. Lemma 1 indicates that as long as the extent of IRTS λ is relatively low, high-quality intermediate products foster the

[8] To be precise, in Stockey's (1988) model there is a positive relationship between output and the quality of consumption.

firms' productivity (on the production of the final good) and, accordingly, enhances economic growth. Recent evidence, such as Aghion et al. (2005) and Aghion and Griffith (2005), shows that in U.K. and U.S. industries there exists an inverted-U relationship between PMC and growth.[9] Our result then provides an explanation for the empirically non-monotonic relationship. Notably, to explain the inverted-U relationship, Aghion et al. (2005) develop a model of two types of intermediate sectors: a neck-and-neck sector in which firms are technological par with the other and a unleveled sector in which a leader firm lies one step ahead of its competitor, i.e., the follower. Given that competition discourages the followers from innovating, but encourages neck-and-neck firms to innovate, PMC and growth exhibit an inverted-U relationship. By contrast, in our study the interaction between product quality competition and increasing returns to product variety generates the inverted-U relationship.

3 Welfare Analysis

It is important to examine whether there exists a wedge between the product quality of the social optimum and that of the market equilibrium. If the answer is yes, this quality wedge will create room for welfare-improving government (social planner) intervention. To explore this important issue, we first examine the welfare-maximizing quality of intermediate goods and then derive the optimal government spending on both infrastructure (g) and the quality-related cost reduction ($\widetilde{g}$).

3.1 Optimal Product Quality vs. Market-Equilibrium Quality

Social welfare is measured by the lifetime utility of the representative household specified in (15). Along the common balanced-growth rate γ, the paths of consumption and capital are given by $C = C_0 e^{\gamma t}$ and $K = K_0 e^{\gamma t}$, respectively. Accordingly, social welfare is assumed to be bounded and can be computed as:

$$W = \int_0^\infty e^{-\theta t} \ln C dt = \frac{\gamma + \theta \ln C_0}{\theta^2}, \tag{24}$$

where $C_0 = \{[\frac{1-g-\widetilde{g}}{a(1-\tau)} - 1]\gamma + \frac{(1-g-\widetilde{g})}{a(1-\tau)}(\theta + \delta) - \delta\} K_0$.

Accordingly,

[9] Moreover, Blundell et al. (1995), Basu (1996) and Disney et al. (2003) have pointed to a positive correlation between PMC and productivity growth at the firm- and industry-level, thereby leading to a positive link between PMC and aggregate economic growth.

Proposition 2. (Product Quality) *If the IRTS is substantially high, i.e.,* $\lambda > \frac{1-\rho}{\rho}$*, the quality of the market equilibrium is over-supplied, being higher than that of the social optimum. On the contrary, if the IRTS are relatively low (*$\lambda < \frac{1-\rho}{\rho}$*), the equilibrium quality is under-supplied, being lower than that of the social optimum.*

Proof: From (24), we can obtain:

$$\frac{\partial W}{\partial v} \gtreqless 0 \Leftrightarrow \frac{\eta'(v)}{(1+\lambda)\eta(v)} - \left[a\frac{\alpha_v(v,\widetilde{g})}{\alpha(v,\widetilde{g})} + (1-a)\frac{\beta_v(v,\widetilde{g})}{\beta(v,\widetilde{g})}\right] \gtreqless 0. \tag{25}$$

By substituting the equilibrium quality in equation (14) into (25) and referring to Figure 1, we further have:

$$\frac{\partial W}{\partial v}\,|_{v=v^e} = \left(\frac{1}{1+\lambda} - \rho\right)\frac{\eta'(v^e)}{\eta(v^e)} \gtreqless 0 \text{ if and only if } \lambda \lesseqgtr \frac{1-\rho}{\rho}. \quad \blacksquare$$

Figure 1 indicates that the quality of intermediate goods v^e could be over-supplied or under-supplied, relative to the socially optimal level v^*.

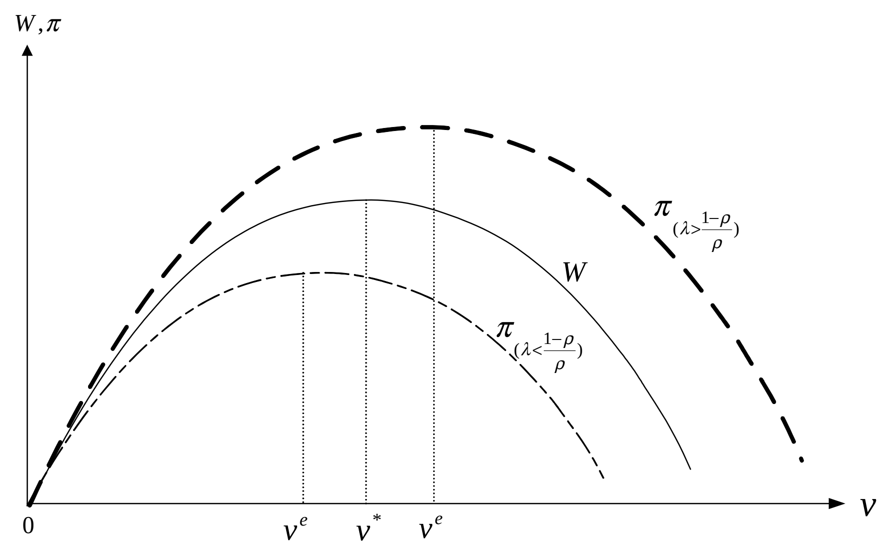

Figure 1. Optimal product quality vs. market-equilibrium quality

In the model, the total variety of intermediate products n $(= n^v \times n^s)$ gives rise to two distinct types of externalities, distorting the market equilibrium and in turn creating the wedge between v^* and v^e. Firstly, the IRTS, as stressed by Romer (1987), gives rise to a beneficial effect on the production of the final good, while the externality is not taken into account by individual firms. It turns out that a larger number of firms is desirable for the society. By contrast, the *business-stealing* effect indicates that entrants do not take into account the fact that they decrease the effective market size for their competition. This results in excessive entry, relative to the level of the social optimum. It turns out that the variety of intermediate products becomes less desirable for the society. Evidently, the effect of IRTS increases if λ is larger, while the business-stealing effect increases if the price markup $\frac{1}{\rho}$ is higher.[10]

As shown in (10), because producing high-quality goods is costly, a higher product quality v is associated with a smaller number of firms n, due to fewer entrants, while it compares to the optimal one. Given this fact, if the IRTS effect dominates the business-stealing effect ($\lambda > \frac{1-\rho}{\rho}$), a larger number of firms n is more favorable to social welfare. Since a higher product quality v is associated with a smaller number of firms n, the socially optimal quality of intermediate goods v^* is lower than that of the market equilibrium v^e, as shown in Figure 1. Under such a situation, the quality of the market equilibrium is over-supplied. By contrast, if the IRTS effect is dominated by the business-stealing effect ($\lambda < \frac{1-\rho}{\rho}$), a smaller number of firms becomes desirable for the society. Thus, the quality of the market equilibrium is under-supplied, relative to the quality in the social optimum.

Christopoulou and Vermeulen (2012) estimate that during 1981-2004 the weighted average price markup in the European area is 1.37, while Italy shows a higher markups of 1.61. This implies that in our model the measure of monopoly power ρ ranges from 0.62 to 0.73. In addition, Harrigan (1999) and Paul et al. (1999) show that the extent of IRTS $\lambda < 0.3$ in the OECD countries and in the US. Their estimates suggest that the case of $\lambda < \frac{1-\rho}{\rho}$ is more empirically possible; in other words, the equilibrium input quality is *more likely* to be *under-supplied* in reality.[11]

3.2 Optimal Government Spending on g and $\widetilde{g}$

In this sub-section we turn to the optimal government spending on infrastructure (g) and on the quality-related cost reduction ($\widetilde{g}$). In the following analysis, we assume that $\alpha(v, \widetilde{g}) = \beta(v, \widetilde{g}) =$

[10] As noted above, a higher markup (a lower ρ) implies a higher profit of incumbents which induces more entrants. Thus, the business-stealing effect is considered to be more pronounced. This point of view can be echoed in (9) in the sense that a lower ρ results in a lower output y per firm.

[11] Besides, according to Kraay and Raddatz's (2007) summary of the recent literature on the levels of increasing returns, the plausible extent of IRTS is around 0 to 0.44, while the magnitude of the external increasing returns varies across countries and industries.

$e^{v/\widetilde{g}^{\epsilon}}$, where $\epsilon > 0$ reflects the effectiveness of the cost-reduction expenditure (the higher the ϵ is, the larger is the reduction in the marginal cost of the intermediate-good production). Moreover, we specify that $\eta(v) = v^{\xi}$, where $0 \leqslant \xi \leqslant 1$, capturing the beneficial effect of the high-quality intermediate good on real GDP. With particular emphasis, these specifications ensure a unique quality solution of (14) and enable us to have an explicit solution for the optimal government spending.

Thus, we can establish:

Lemma 2. (Quality Effect of Government Spending) *The government spending on the quality-related cost reduction $\widetilde{g}$ has a positive effect on the equilibrium quality v^e, while the government spending on infrastructure g has no impact on the equilibrium quality.*

Proof: From (14) we can solve the quality of the market equilibrium as:

$$v^e = \rho \xi \widetilde{g}^{\epsilon}. \quad \blacksquare \tag{26}$$

Since the government spending on infrastructure g gives rise to an equal impact on the production of products with various qualities, it does not influence the firm's determination with regard to product quality. However, the government spending on the quality-related cost reduction $\widetilde{g}$ can directly reduce the intermediate firm's marginal cost, as shown in (5), thereby improving the product quality.

With Lemma 2, the first-order conditions for the socially optimal government spending are given by:

$$\begin{aligned} \frac{dW(g, \widetilde{g}, v^e(\widetilde{g}))}{dg} = 0 \quad &\Leftrightarrow \quad (1 - g - \widetilde{g}) \frac{b(1+\lambda)}{1 - b(1+\lambda)} \frac{(Y/K)}{g} - \frac{Y}{K} = 0, \\ &\Leftrightarrow \quad g = b(1 - \widetilde{g})(1 + \lambda), \end{aligned} \tag{27}$$

$$\begin{aligned} \frac{dW(g, \widetilde{g}, v^e(\widetilde{g}))}{d\widetilde{g}} = 0 \quad &\Leftrightarrow \quad (1 - g - \widetilde{g}) \left[\frac{\partial (Y/K)}{\partial \widetilde{g}} + \frac{\partial (Y/K)}{\partial v} v'(\widetilde{g}) \right] - \frac{Y}{K} = 0, \\ &\Leftrightarrow \quad \left[\frac{1}{\rho} - (1+\lambda) \right] \frac{\alpha_v(v, \widetilde{g})}{\alpha(v, \widetilde{g})} v'(\widetilde{g}) - (1+\lambda) \frac{\alpha_{\widetilde{g}}(v, \widetilde{g})}{\alpha(v, \widetilde{g})} = \frac{[1 - b(1+\lambda)]}{(1 - g - \widetilde{g})}, \\ &\Leftrightarrow \quad \widetilde{g} = \frac{(1-g)\epsilon\xi}{1 - b(1+\lambda) + \epsilon\xi}. \end{aligned} \tag{28}$$

In comparison with Barro (1990), we first ignore the government spending on reducing quality-improving cost, i.e., $\widetilde{g} = 0$. As such, the optimal government spending on infrastructure turns out to be $g^* = \tau = b(1+\lambda)$.[12] In Barro's (1990) model, the optimal public capital follows the rule of $g^* = \tau = b$, meaning that the optimal government rate (tax rate) must equal the output elasticity of public capital. This gives rise to a potential problem. In an endogenous growth model, the output elasticity of public capital is equated to a complementary share of income for private capital under a constant-returns technology for a sustained growth rate. As the income share for private capital reported in the empirical literature lies between 0.3 and 0.5, the optimal income tax rate (or the output elasticity of public capital) must lie between 50% and 70%, which is obviously too high to be empirically possible. On the one hand, the average marginal tax of OECD countries is located between 16.5% and 34%. On the other hand, as estimated by Aschauer (1989), the output elasticity of public capital for core infrastructure is around 0.24. In our model, given the restriction of $\varphi = \frac{1}{1+\lambda} - a - b$ for generating perpetual growth, the optimal public capital is $g^* = \tau = \frac{b}{\varphi+a+b}$. Given the plausible output elasticity of public capital $b = 0.24$ and the capital share in output $a = 0.35$, the optimal tax rate can be located within the empirically relevant range of actual data, provided that the extent of Romer's (1986) learning-by-doing (capital) externalities is well located at $\varphi \in (0, 0.135)$.

Based on (27) and (28), we arrive at the following proposition:

Proposition 3. (Optimal Government Spending) *In an economy with product quality considerations, the welfare-maximizing government spending is given by:*

$$\begin{aligned} g^* &= \frac{b(1+\lambda)}{1+\epsilon\xi}, \\ \widetilde{g}^* &= \frac{\epsilon\xi}{1+\epsilon\xi}. \end{aligned}$$

Proof: The result can be obtained from (26), (27) and (28). ■

Proposition 3 indicates that the optimal government spending on infrastructure, g^*, increases with the extent of IRTS (λ) and the effectiveness of the government expenditure on infrastructure (b), while it decreases with the contribution of the intermediate-good quality to the final-good production (ξ) and the effectiveness of the government spending on the quality-related cost reduction (ϵ). Intuitively, the government spending on infrastructure increases the private firm's profits and

[12] From (13) and (18), we can obtain: $\tau = (g + \widetilde{g})$.

accordingly, raises the total number of firms n $(= n^v \times n^s)$. When faced with higher IRTS λ, increasing g can intensify the beneficial external effect stemming from the IRTS, and therefore the optimal public capital g^* is increasing with λ. Moreover, the higher efficiency of the government expenditure on infrastructure b motivates the social planner to channel more resources into infrastructure. By contrast, if either the effectiveness of the government spending on the quality-related cost reduction ϵ is higher or the contribution of the intermediate-good quality to the final-good production ξ is greater, the social planner is inclined to adjust her resource allocation by lowering the expenditure on infrastructure g^*.

By focusing on $\widetilde{g}^*$, we show that the optimal government spending on the quality-related cost reduction, $\widetilde{g}^*$, increases with both the effectiveness of the cost-reduction expenditure (ϵ) and the productivity-enhancing effect of the intermediate-good quality (ξ). This consequence is straightforward: the optimal government spending on cost reduction increases when the cost-reduction policy is more effective and the contribution of product quality is more important. Given the fact that the Barro type of government spending on infrastructure has effectively accounted for the distortion caused by IRTS, the optimal $\widetilde{g}^*$ does not correspond to such a distortion and is independent of λ. Of particular note, in contrast to Devereux et al. (2000), neither two type of government spending corresponds to the firm's market power $(1/\rho)$ when we appropriately separate the effect of the IRTS from that of monopoly power and introduce an alternative competition dimension of product quality.

What is the relationship between the quality wedge $(v^* - v^e)$ and the optimal government spending $\widetilde{g}^*$? Proposition 3 indicates that the equilibrium quality is under-supplied (resp. over-supplied) $v^e > (<)\ v^*$, if $\lambda < \frac{1-\rho}{\rho} (\lambda > \frac{1-\rho}{\rho})$. One may wonder why the optimal cost-reduction spending $\widetilde{g}^*$ is still positive, even though the market quality has already been over-supplied (i.e., under the situation where $\lambda > \frac{1-\rho}{\rho}$). It follows from (28) that $\widetilde{g}^*$ has three effects on the social welfare. The first term $\frac{\partial(Y/K)}{\partial \widetilde{g}}$ refers to a positive effect through the reduction in costs, the last one $-\frac{Y}{K}$ refers to a negative effect caused by a distortionary income tax, and the middle term $\frac{\partial(Y/K)}{\partial v} v'(\widetilde{g})$ then reflects the direct quality effect. That is, in addition to the quality effect, the government spending can affect welfare by decreasing the production cost and increasing the tax distortion. The two conflicting effects allow us to derive a positive interior solution of $\widetilde{g}^*$. It is worth noting that considering that the government's expenditure is financed by a lump-sum tax, the quality-improved government spending is always beneficial to the social welfare (i.e., $\frac{dW}{d\tilde{g}} > 0$) if the equilibrium quality is under-supplied (i.e., $\lambda < \frac{(1+\rho)}{\rho}$). However, if the equilibrium quality is over-supplied ($\lambda > \frac{(1+\rho)}{\rho}$), an increase in the quality-improved government spending is not necessarily beneficial to the social welfare (i.e., $\frac{dW}{d\tilde{g}} \lesseqgtr 0$), depending on the relative magnitude of the cost-reduction effect and the direct quality effect.

4 Concluding Remarks

This study has investigated the role played by the product quality of intermediate goods in an economy characterized by market imperfection with free entry and exit and sustained growth. There is a trade-off between the quality and the variety of products. Tougher competition induces firms to produce higher quality intermediate goods in order to escape competition and, accordingly, the variety of products decreases. While higher quality intermediate goods give rise to a productivity-enhancing effect on the economy, PMC has a mixed impact on growth since a small number of firms leads to a deterioration in the IRTS. There exists a wedge between the product quality of the market equilibrium and that of the social optimum. The quality of the market equilibrium is under-supplied and lower than that of the social optimum, if the business-stealing effect dominates the IRTS effect. By contrast, the quality of the market equilibrium is over-supplied and higher than that of the social optimum if the IRTS effect dominates the business-stealing effect.

This quality wedge creates room for the government to achieve the social optimum by implementing various fiscal policies. We have found that while the Barro-type of government spending on infrastructure is incapable of raising the product quality, the government spending on the quality-related cost reduction can raise the equilibrium quality. To be more specific, the optimal government spending on infrastructure increases if the extent of the IRTS and the effectiveness of the government expenditure on infrastructure are higher, while it decreases if the contribution of the intermediate-good quality to the real GDP is reduced. By contrast, the optimal government spending on the quality-related cost reduction increases if the quality-related policy is more effective and the productivity-enhancing effect of product quality is more pronounced.

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