Integration, R&D and Economic Growth

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Abstract

To explore the performance of R&D along the growth path of an economy, this paper considers a vertically connected imperfectly competitive market structure in the context of an endogenous growth model, where the intermediate goods firms and final goods firms interact with each other and the government implements a subsidy/tax policy. Our findings show that the amount of aggregate profits generated after forward or backward integration is based on the number of intermediate goods firms in relation to the number of final goods firms. In addition, when the firms engage in forward integration, the R&D activities will lead to ambiguous results according to the degree of competition in the final goods markets. If the final goods market is more imperfectly competitive, there will be too little R&D activity at the market equilibrium. Since the market equilibrium economic growth rate is lower than the socially optimal economic growth rate, the government should implement a subsidy policy so as to increase economic growth. On the other hand, if the final goods market is perfectly competitive, then there is too much R&D activity, and the government should implement a tax policy to boost economic growth. Lastly, the government can enforce the optimal subsidy/tax rate to increase the welfare of balanced growth equilibrium to the level of social optimum.

Keywords: Endogenous Growth, R&D, Vertical Integration, Bargaining, Subsidy, Social Optimum

JEL Classification: L00, O30, O41

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Received 27 October 2015; revised 1 February 2016; accepted 12 September 2016.

經濟研究 (Taipei Economic Inquiry), 53:1 (2017), 51-85。
臺北大學經濟學系出版

1. Introduction

Market structure has recently become a popular research theme on the theory of industrial organization (IO). In addition, there is a branch of growth theory that introduces the intermediate goods market with imperfect competition to model technological progress/R&D activities that give rise to perpetual economic growth, as discussed by Romer (1990), Grossman and Helpman (1991b) and Aghion and Howitt (1992). Thus, incorporating market structure or market power into an R&D-based endogenous growth model is quite important. However, most of the above literature on the R&D endogenous growth model has generally not included the vertically-connected imperfectly competitive market in its models apart from Wang et al. (2010), who recently set up a model of the successively imperfectly competitive market structure and illustrated the double marginalization phenomenon. Traditional R&D-based growth models with a vertical market structure composed of two industries typically assume a perfectly competitive final goods market. In fact, the different types of market structures will affect the economic performance just as the industrial organization theory has pointed out. Thus, we incorporate an imperfectly competitive final goods market into the R&D-based growth model to explore how the market structure affects economic growth.

Besides the market structure, the field of endogenous growth theory usually ignores the firms' interactions and conduct, but those are the key themes that are highlighted under the vertically-connected market structure in industrial organization theory. When a vertically-connected market is imperfectly competitive, upstream firms can apply their bargaining power to impose vertical restraints on downstream firms and appropriate the profit of the downstream firms (see, for example, Tirole, 1988). Wang et al. (2010) found that the firms' bargaining structure can eliminate the double marginalization problem in successive monopolistically competitive market structures. Chemla (2003) analyzed the effect of competition among downstream firms on an upstream firm's payoff and on its incentive to integrate vertically. Hence, the firms' interaction will influence the market performance not only at the micro level, but also in the macro economy such as in terms of price, profits, benefits, government policy, and economic growth, etc. Hence, the different types of market structures and the conduct of the firm will influence the economic performance.

Both the OECD (1998) and the European Commission (1999) commissioned studies to examine the impact of buyer power on competition. Upstream and downstream firms generally possess their own market power in a vertically-connected imperfectly competitive market. Based on cost considerations, the final goods firms prefer negotiating to lower the prices of intermediate goods. On the other hand, intermediate goods firms would like to extract more rent from the downstream industry. Firms on both sides thus have incentives to engage in contract bargaining just as Bester (1993) pointed out that "in many markets prices are the outcome of bilateral negotiations, so that both the seller and the buyer take an active part in setting the price. Examples include not only the bazaar of a less developed nation, but also the market for used cars, real estate, antiques, and inputs for manufacturing firms." Several papers also explore the market power of upstream and downstream firms, such as Rubinstein (1982), Folwell et al. (1998), Sieg (2000), Chemla (2003), Chen (2003), Inderst and Wey (2003), Milliou et al. (2003), and Wang et al. (2010). Therefore, this paper adopts the framework of Wang et al. (2010) in considering the competition between upstream and downstream firms and optimizing economic performance.

Furthermore, profit is the key incentive for firms to produce and engage in R&D and the firms' conduct will affect their profit and then their R&D activities. Meanwhile, the government will play an important role in protecting the economy's performance. Some studies such as Jones and Williams (1998, 2000), Segerstrom (2000), Zeng and Zhang (2007) have claimed that the government should subsidize the R&D activities to increase the economic growth while there is too little R&D

activity in the economy. However, some studies support the view that a tax policy will help boost economic growth, such as Futagami and Doi (2004), Haruyama and Itaya (2006), Peretto (2007). Most importantly, Alvarez-Pelaez and Groth (2005) show that the market economy, which is based on expanding product variety, unambiguously generates too little R&D. Spencer and Brander (1983) introduce the international R&D rivalry and industrial strategy and d'Aspremont and Jacquemin (1988) discuss cooperative and noncooperative R&D for a duopoly with spillovers. In a way that differs from Wang et al. (2010), this paper will discuss the role of government in relation to R&D activities, the social optimum and remedial measures (taxes or subsidies).

Each intermediate firm holds a blueprint, and then allocates this blueprint to produce one kind of product. We assume that each intermediate goods firm can pay the R&D cost to secure the net present value of profit associated with the newly-developed product. The R&D activity is characterized by free entry (Romer, 1990; Grossman and Helpman, 1991b; Aghion and Howitt, 1992; Barro and Sala-i-Martin, 2004), because as long as engaging in R&D is lucrative, firms will increase their R&D in relation to the goods. In addition, Lai (2009) indicates that there are two kinds of R&D endogenous growth models, one being the quality ladder model (Grossman and Helpman, 1991a), and the other the expanding variety model (Romer, 1990).[1] The expanding variety model can be subdivided into two types, one being Romer's (1990) intermediate goods variety model, and the other Grossman and Helpman's (1991b) consumption goods variety model. We also assume our model processes the expanding variety R&D model and blueprints can be created only by labor in order to conduct research.

There has already been much discussion in the literature on the determination of intermediate goods price under the assumption of downstream firms having no control power (Gal-Or, 1991; Abiru et al., 1998; Lai et al., 2010). In order to extend the analysis to encompass

[1] Rivera-Batiz and Romer (1991) use this specification in the framework that they describe as the lab-equipment model of R&D.

forward integration, our model follows Wang et al. (2010) to establish a bargaining process to determine the price of intermediate goods as well as discusses the integrations (forward and backward) of the firms. Although Lai et al. (2010) develops a monopolistic competition macroeconomic model, and discusses the determination of relevant macro variables under both vertical separation and vertical integration regimes. However, they do not consider the factors that influence the rate of economic growth and the role of government in R&D activities. Unlike Lai et al. (2010) our model can explain how the vertical integration influences the economic growth and the government optimum policy (tax or subsidy).

Based on the above views, we attempt to introduce the spirit of industrial organization, such as the market structure, the conduct of the firms, government policy and economic performance into the growth model and explore how the market structure and the government policy influence the conduct of the firms, and how the interaction between the final goods firms and the intermediate goods firms through a franchising contract affects economic performance. In an imperfectly competitive and vertically-connected market structure, the upstream and downstream firms bargain over the intermediate good price and franchise fee, and the government levies subsidies/taxes in relation to the R&D activities referred to in this paper. A contract bargaining equilibrium will be achieved through negotiation between upstream and downstream firms. The government implements its policy to adjust the market R&D activities and economic growth so that they are consistent with the social optimum.

We present four periods in our model. In the first period, the government levies a tax on the households and a subsidy on the R&D sector. In the second period, the final goods firms and intermediate goods firms negotiate with regard to the franchising contract which includes the franchise fee and the price of intermediate goods through the Nash efficient bargaining process. In other words, the intermediate goods firms overall have no bargaining power to determine the prices of intermediate goods as in the traditional R&D endogenous growth model. The final goods firms in a monopolistically competitive industry now exercise partial control over the input price. In the third period, the final goods firms facing consumers' demands set the prices of final goods to maximize their profits. In the last period, consumers determine the expenditure plan to maximize their lifetime utility. This study proceeds by solving the model backwards.

The remainder of the paper is organized as follows. Section 2 introduces the theoretical model. Section 3 analyzes the balanced growth equilibrium of the economy. Section 4 discusses the social optimum. Section 5 discusses the welfare. Finally, Section 6 summarizes the main findings of this research and concludes the paper.

2. The Model

Consider an R&D-driven economy characterized by endogenous growth, which consists of final goods, intermediate goods and R&D sectors. The market structures of both the final and intermediate goods are monopolistically competitive. Furthermore, each intermediate firm holds a blueprint, and then allocates this blueprint to produce one kind of product. We also assume that each intermediate goods firm can pay the R&D cost to secure the net present value of profit associated with the newly-developed product. The R&D activity is characterized by free entry, and blueprints can be created only by labor in order to conduct research. The R&D sector is separated from the input producer. Hence, the free entry condition applies separately only to R&D activities (Grossman and Helpman, 1991b). Households consume composite consumption goods and are characterized by diversified preferences. The government subsidizes the R&D activities.

2.1 Households

The representative household lives infinitely and is endowed with a constant aggregate flow of labor L that is supplied inelastically. The household's discounted utility is given by

$$V = \int_0^\infty e^{-\rho t} U(C(t))dt, \tag{1}$$

where

$$U(C) = \ln C, \tag{2}$$

$$C \equiv m\left(\frac{1}{m}\int_{j=0}^{m} c_j^{\frac{(\sigma-1)}{\sigma}} dj\right)^{\frac{\sigma}{(\sigma-1)}}, \quad \sigma > 1. \tag{3}$$

Equations (1) and (2) indicate that utility is a unitary elasticity function that is discounted by a constant pure rate of time preference ρ.[2] C represents a composite of consumption goods which consists of a bundle of closely-related product varieties according to equation (3). This type of CES functional form follows the crucial insights of Dixit and Stiglitz (1977). $j \in [0, m]$ represents the varieties produced by different downstream firms, where m is the number of different varieties, and c_j consists of consumption goods of variety *j*. Commodities supplied by different producers are imperfect substitutes with a constant elasticity of substitution σ.

The household invests in R&D activities or expenditure plans and owns the firms in the upstream and downstream industries. Hence the household receives the profits from both the intermediate goods and final goods sectors. The budget constraint describes the total spending on consumption goods plus investment in new blueprints as being equal to total income which includes labor income plus the total profits from the upstream and the downstream firms. It is therefore given by

$$E + p_N \dot{n} = wL + n\pi + m\Pi - T, \tag{4}$$

where

$$E = PC = \int_{j=0}^{m} p_j c_j dj. \tag{5}$$

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2 We drop the time argument to simplify the notation.

E refers to total spending on consumption goods, and P represents the aggregate consumption price index. p_j is the price of consumption good j. p_N in equation (4) is the cost or value of a new blueprint. $\dot{n}$ is the number of new blueprints in a given time period, while w is the wage rate common to all sectors in the economy under the assumption of perfect elasticity. π and Π are the profits of the intermediate goods and final goods sectors, respectively. T is a lump-sum tax paid to the government.

First of all, the representative household separately chooses an optimal consumption and investment plan to maximize its discounted utility, subject to the budget constraint. The current-value Hamiltonian associated with this decision problem is given by

$$H = \ln C + \lambda\left(\frac{wL + n\pi + m\Pi - PC - T}{p_N}\right), \tag{6}$$

where λ is the co-state variable for n. The first-order conditions are as follows:

$$\frac{1}{C} = \frac{\lambda}{p_N}P, \tag{7}$$

$$\dot{\lambda} = \rho\lambda - \frac{\pi}{p_N}\lambda. \tag{8}$$

By combining these two expressions, we obtain the Keynes-Ramsey rule as

$$\frac{\dot{C}}{C} = \frac{\pi}{p_N} + \frac{\dot{p}_N}{p_N} - \rho - \frac{\dot{P}}{P}. \tag{9}$$

Equation (9) indicates that the return on blueprints/investment, which includes the dividend (π) plus the capital gains ($\dot{p}_N$) expressed in terms of the blueprint minus the rate of time preference and inflation rate of the aggregate consumption price, equals the real consumption growth rate.[3]

Secondly, given the definition of composite consumption in equation (3) and the budget constraint in equation (5), the household chooses its consumption levels for each available product variety, c_j, to maximize utility. Accordingly, the solutions for the consumption of variety j are obtained

$$c_j = m^{-1}\left(\frac{p_j}{P}\right)^{-\sigma} C, \tag{10}$$

where

$$P = \left(m^{-1}\int_0^m p_j^{\,1-\sigma} dj\right)^{\frac{1}{(1-\sigma)}}. \tag{11}$$

Equation (10) gives the demand for goods c_j. Equation (11) expresses the aggregate consumption price index.

2.2 Final Production

Final goods are produced by monopolistically competitive firms. Each firm produces y_j with a continuum of intermediate goods x_i. According to Dixit and Stiglitz (1977), the production function can be set by

$$y_j \equiv \left(\int_0^n x_{ij}^{\frac{1}{\alpha}} di\right)^{\alpha}, \quad \alpha > 1, \tag{12}$$

where x_{ij} represents the amount of intermediate goods i used by firm j. $i \in [0, n(t)]$ is the range of intermediate goods existing at time t. $-1/(1-\alpha)$ explains the elasticity of substitution between final goods.

The producer j in the final goods sector chooses a price to maximize its profit

[3] The transversality condition is $\lim_{t\to\infty} \lambda n e^{-\rho t} = 0$ to ensure that neither debt nor assets will be left at the end of the planning horizon.

$$\Pi_j = p_j y_j - \int_0^n p_{ij}^x x_{ij} di - nf_j, \tag{13}$$

subject to the demand function (equation (10)), the production function (equation (12)), and the clearness condition for the final goods market, $y_j = c_j$. p_{ij}^x in equation (13), is the price of the intermediate goods i, and f_j represents the franchise fee that the producer j pays to the upstream firm in order to obtain the right and know-how.

Under the symmetry perspective, $x_{ij} = x_j$, $p_{ij}^x = p_j^x$, $\forall i$, and the production function in equation (12) becomes $y_j = n^{\alpha} x_j$. Then we substitute $x_{ij} = x_j = n^{-\alpha} y_j$ and $y_j = c_j$ into equation (13). To maximize profit, the typical final goods firm j charges a monopolistic markup price to consumers as follows:

$$p_j = \frac{\sigma}{n^{\alpha-1}(\sigma-1)} p_j^x. \tag{14}$$

The pricing rule depends on the market power ($\sigma/(\sigma-1)$) of final goods firms, the number of intermediate goods firms, and the prices of intermediate goods (p_j^x).

Substituting equation (14) into equation (13) yields the profit function of the typical downstream firm j as

$$\Pi_j = \left[\frac{1}{n^{\alpha-1}(\sigma-1)} p_j^x\right] m^{-1} \left[\frac{\sigma}{n^{\alpha-1}(\sigma-1)} \frac{p_j^x}{P}\right]^{-\sigma} Y - nf_j, \tag{15}$$

where $Y \equiv m\left\{\left[\int_{j=0}^{m} y_j^{(\sigma-1)/\sigma} dj\right] \Big/ m\right\}^{\sigma/(\sigma-1)} = C$ since $y_j = c_j$.

2.3 Intermediate Goods and R&D Sectors

Intermediate goods are produced by monopolistically competitive firms that have perpetually protected patents for their goods. The firm in the monopolistically competitive industry manufacturing intermediate goods creates a blueprint for new intermediate goods from its R&D sector. To simplify the analysis, labor is the only input used to produce intermediate goods. One unit of intermediate goods is produced with one unit of labor. Each intermediate goods firm produces and sells a slightly unique variety of goods x_i to each final goods firm to maximize its profit, taking the actions of all other producers in the intermediate goods sector as given. Hence the profit is

$$\pi_i = \int_0^m (p_{ij}^x x_{ij} - w l_{ij}^x + f_{ij}) dj, \tag{16}$$

where l_{ij}^x is the amount of labor used by firm i, and f_{ij} is the franchise fee received from the final-good firm. The production function is set as $x_{ij} = l_{ij}^x$.

By combining the production functions of intermediate and final goods, and the clearness condition $y_j = c_j$,[4] we can rewrite the profit function for the intermediate goods firm as

$$\pi_i = (p_i^x - w) m n^{-\alpha} m^{-1} \left(\frac{p_i^x}{P} \right)^{-\sigma} Y + m f_i. \tag{17}$$

To produce new intermediate goods, the upstream firm allocates the only factor of production (labor) to develop a new blueprint. We follow Romer (1990) to assume that the production function in the R&D sector is given by

$$\dot{n} = \delta n L_N, \tag{18}$$

where L_N is the amount of labor hired in the R&D sector of all upstream firms, δ is a productivity parameter (we assume $\delta = 1$) and $\dot{n}$ is the number of new blueprints created for a given period of time. The more labor the R&D sector employs or the more varieties the intermediate goods market has, the more new blueprints are produced per unit of time.

The free-entry condition implies that the blueprint cost or value is as follows:

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4 To simplify the analysis, we assume that the franchise fee received from final goods firms is identical to that in all other contracts.

$$p_N = \frac{(1-s)w}{n}. \tag{19}$$

Since the profit for creating a new blueprint is equal to $p_N \dot{n} - (1-s)wL_N$ and the profit should be zero. s is the government subsidy for R&D activities. Equation (19) indicates that the blueprint's value is equal to its cost.

2.4 Government

The government's budget balance requires

$$T = swL_N. \tag{20}$$

The government's revenue is obtained from its lump-sum tax T, and its expenditure on subsidizing R&D activities is swL_N.

2.5 Decentralized Contract Bargaining

In the second period, the representative intermediate goods firm i and the representative final goods firm j bargain over the franchising contract (p^x, f) simultaneously. Following equations (15) and (17), the division of rent between firm i and firm j is obtained by maximizing the Nash product

$$\Omega = (\Pi_j - \Pi^0)^\theta (\pi_i - \pi^0)^{1-\theta}, \tag{21}$$

where Π^0 and π^0 denote the minimum profits of firm j and firm i in the case of a breakdown in bargaining. That is, once bargaining breaks down, downstream and upstream firms will both mark up their prices based on marginal cost.[5] $\theta \in (0,1)$ is a parameter that denotes the relative bargaining strength of firm j. With $\theta \to 0$, the model indicates that intermediate goods firm i has full bargaining power to decide the intermediate goods price. To keep the analysis simple, we assume that there exists an identical bargaining power for all final goods firms with

[5] The contents of Π^0 and π^0 are provided in Appendix 1.

decentralized status. The same is true for all intermediate goods firms.

Decentralized bargaining means that there is no coordination between different bargaining units. All bargaining takes place simultaneously and bargaining partners treat all rival intermediate goods prices and franchise fees as given.

According to the Nash bargaining solutions derived by maximizing equation (21), both firm j and firm i select an optimal franchise fee and intermediate price as follows:

$$p^x = w, \tag{22}$$

$$f = \theta \frac{\pi^0}{m} + (1-\theta)\frac{TR_j - TVC_j}{n} - (1-\theta)\frac{\Pi^0}{n}. \tag{23}$$

Then the price of final goods and the aggregate consumption price index are given respectively as

$$p_j = \frac{\sigma}{n^{\alpha-1}(\sigma-1)} w, \tag{24}$$

$$P = \frac{\sigma}{n^{\alpha-1}(\sigma-1)} w. \tag{25}$$

Equations (22) and (23) show the optimal bargaining contract in a vertically-connected imperfectly competitive market structure. That means the optimal contract corresponds to the vertical integration result. Equation (22) describes the pricing rule for intermediate goods that results from the competitive behavior arising between the final goods firm and the intermediate goods firm, with both firms simultaneously engaging in optimization. The main difference between our bargaining contract and the traditional franchise contract is that the final goods firm has the bargaining power required to determine the contract's content. Aggregate rent is maximized or optimized by setting the price of intermediate goods equal to marginal cost, namely, the derived demand is perfectly elastic, and not to the markup price. This result is consistent with the empirical evidence in Villas-Boas (2007). It also indicates that double marginalization does not occur. Furthermore, the optimal franchise fee, as in equation (23), depends on bargaining power θ. Firm i will extract rent if firm j has no bargaining power ($\theta \to 0$), or firm j will backwardly integrate into firm i. Similarly, rent will vanish if firm i has no bargaining power ($\theta \to 0$). Hence, firm i will hold the original profit (π^0) when bargaining breaks down. In this situation, firm i will integrate forwards into firm j.

By substituting the results into equations (15) and (17), the profits of firm j and firm i can be written as

$$\Pi = \theta \frac{1}{m} \frac{1}{n^{\alpha-1}(\sigma-1)} wY - \left[\theta - \frac{(1-\theta)\sigma}{\sigma-1}\right] \frac{1}{m} \frac{1}{n^{\alpha-1}(\sigma-1)} wY^0, \quad (26)$$

$$\pi = (1-\theta) \frac{1}{n} \frac{1}{n^{\alpha-1}(\sigma-1)} wY + \left[\theta - \frac{(1-\theta)\sigma}{\sigma-1}\right] \frac{1}{n} \frac{1}{n^{\alpha-1}(\sigma-1)} wY^0, \quad (27)$$

where superscript 0 denotes the case of non-integration. If firm j is weaker than firm i in terms of the bargaining power relating to the franchising contract, more rent will be extracted from the patent holder in the intermediate goods market.

2.5.1 Aggregate Profit after Vertical Integration

In the extreme case of forward integration ($\theta \to 1$), the profits of firm j and firm i are as follows:

$$\Pi' = \frac{1}{m} \frac{1}{n^{\alpha-1}(\sigma-1)} w(Y - Y^0), \quad (28)$$

$$\pi = \pi^0 = \frac{1}{n} \frac{1}{n^{\alpha-1}(\sigma-1)} wY^0. \quad (29)$$

Obviously, the sum of the profit after forward integration ($F = \Pi' + \pi^0$) is more than that where there is no integration ($\Pi^0 + \pi^0$).

Furthermore, in the case of backward integration ($\theta \to 0$), the profits of firm j and firm i will be

$$\Pi = \Pi^0 = \frac{\sigma}{\sigma-1}\frac{1}{m}\frac{1}{n^{\alpha-1}(\sigma-1)}wY^0, \tag{30}$$

$$\pi' = \frac{1}{n}\frac{1}{n^{\alpha-1}(\sigma-1)}w(Y - \frac{\sigma}{\sigma-1}Y^0). \tag{31}$$

The sum of the profit after backward integration ($B = \Pi^0 + \pi'$) is more than that where there is no integration ($\Pi^0 + \pi^0$).

Proposition 1.

The amount of aggregate profits generated by the intermediate goods and final goods firms is in accordance with the forward integration or backward integration that takes place between the firms. If the number of intermediate goods firms is greater than that of the final goods firms, the sum of the profit which is created after forward integration is greater than that after backward integration. On the other hand, if the number of final goods firms is greater than that of the intermediate goods firms, the sum of the profit after backward integration is greater than that after forward integration.

In comparing the profits from forward and backward integration

$$F - B = \left(\frac{1}{m} - \frac{1}{n}\right)\frac{1}{n^{\alpha-1}(\sigma-1)}w\left(Y + \frac{1}{\sigma-1}Y^0\right) \gtrless 0 \quad \text{if} \quad n \gtrless m. \tag{32}$$

Equation (32) indicates that the relative profits between the two types of integration depend on the numbers of final goods firms and intermediate goods firms. According to whether the number of intermediate goods firms is larger than that of the final goods firms, forward integration will be preferred. This is because the final goods firms have greater monopoly power in which case their profit is larger than in the case of the intermediate goods market. Hence, the final goods firms and intermediate goods firms will engage in forward integration which is more profitable in this instance. Otherwise, backward integration will be better for the firms. Similarly, when the number of final goods firms exceeds the number of intermediate goods firms, backward integration will result in higher profits. Because the intermediate goods firms have more monopoly power, they will generate more profit. The firms will then resort to backward integration, which is beneficial for them. Furthermore, regardless of whether the firms engage in forward or backward integration, the problem of double marginalization does not occur (recall equation (22)).

3. Market Equilibrium

To complete the discussion, we still have to incorporate the equilibrium condition for the labor market and the final goods market. The labor market equilibrium condition states that total labor demand is equal to total labor supply ($L_x + L_N = L$), and that labor is perfectly mobile across the intermediate goods sector and the blueprint industry. Since the labor is allocated to the intermediate goods sector and to the R&D industry, the labor market equilibrium condition will be rewritten as

$$mnl^x + \frac{\dot{n}}{n} = L. \tag{33}$$

Next, by combining equation (3) with $c = y$ and $x = l^x$, and considering the clearness condition for the final goods market in the symmetric equilibrium, we have

$$C = Y = n^{\alpha-1} L_x .\text{[6]} \tag{34}$$

Therefore, the whole equilibrium conditions of the economy can be described as the following equations and the regarding endogenous variables are p_N, p_j, P, Π, π, L_x, C, n.

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[6] See Appendix 2.

$$\frac{\dot{C}}{C} = \frac{\pi}{p_N} + \frac{\dot{p}_N}{p_N} - \rho - \frac{\dot{P}}{P}, \tag{9}$$

$$p_N = \frac{(1-s)w}{n}, \tag{19}$$

$$p_j = \frac{\sigma}{n^{\alpha-1}(\sigma-1)} w, \tag{24}$$

$$P = \frac{\sigma}{n^{\alpha-1}(\sigma-1)} w, \tag{25}$$

$$\Pi = \theta \frac{1}{m} \frac{1}{n^{\alpha-1}(\sigma-1)} wY - \left[\theta - \frac{(1-\theta)\sigma}{\sigma-1}\right] \frac{1}{m} \frac{1}{n^{\alpha-1}(\sigma-1)} wY^0, \tag{26}$$

$$\pi = (1-\theta) \frac{1}{n} \frac{1}{n^{\alpha-1}(\sigma-1)} wY + \left[\theta - \frac{(1-\theta)\sigma}{\sigma-1}\right] \frac{1}{n} \frac{1}{n^{\alpha-1}(\sigma-1)} wY^0, \tag{27}$$

$$mnl^x + \frac{\dot{n}}{n} = L, \tag{33}$$

$$C = Y = n^{\alpha-1} L_x. \tag{34}$$

We can therefore derive the growth rate of the economy. Using equations (19), (25), (27) and (34), we obtain

$$\frac{\dot{p}_N}{p_N} = (\alpha-2)\frac{\dot{n}}{n} + \frac{\dot{P}}{P}, \tag{35}$$

$$\frac{\pi}{p_N} = \frac{(1-\theta)}{(1-s)(\sigma-1)} L_x + \frac{1}{(1-s)}\left[\theta - \frac{(1-\theta)\sigma}{\sigma-1}\right] \frac{1}{\sigma-1} L_x{}^0, \tag{36}$$

where $L_x{}^0$ is the quantity of labor employed by the intermediate goods sector in a non-vertically integrated market structure.

From equations (9) and (33)-(36), the dynamics of the model is given as follows:

$$\frac{\dot{C}}{C}=\frac{(1-\theta)}{(1-s)(\sigma-1)}L_x+\frac{1}{(1-s)}\left[\theta-\frac{(1-\theta)\sigma}{\sigma-1}\right]\frac{1}{\sigma-1}L_x^{\,0}+(\alpha-2)\frac{\dot{n}}{n}-\rho, \quad (37)$$

$$\frac{\dot{n}}{n}=L-L_x, \quad (38)$$

$$\frac{\dot{C}}{C}=(\alpha-1)\frac{\dot{n}}{n}+\frac{\dot{L}_x}{L_x}. \quad (39)$$

Combining equations (37)-(39), we obtain the dynamic transitional mechanism for L_x

$$\frac{\dot{L}_x}{L_x}=\frac{(1-\theta)+(1-s)(\sigma-1)}{(1-s)(\sigma-1)}L_x+\frac{1}{(1-s)}\left[\theta-\frac{(1-\theta)\sigma}{\sigma-1}\right]\frac{1}{\sigma-1}L_x^{\,0}-L-\rho. \quad (40)$$

Since the coefficient of L_x, $\left[(1-\theta)+(1-s)(\sigma-1)\right]/[(1-s)(\sigma-1)]$, is positive, equation (40) is a differential equation with a divergent solution. This means that L_x jumps to a steady state immediately. Therefore, $\dot{L}_x=0$. Its steady state value is

$$\hat{L}_x=\frac{(1-s)(\sigma-1)}{(1-\theta)+(1-s)(\sigma-1)}\left\{(L+\rho)-\frac{1}{(1-s)}\left[\theta-\frac{(1-\theta)\sigma}{\sigma-1}\right]\frac{1}{\sigma-1}L_x^{\,0}\right\}.^{7} \quad (41)$$

Hence, from equations (37)-(39) and (41) the equilibrium balanced growth rates for consumption, output and R&D expressed by γ_C, γ_Y and γ_n can be derived as follows:

$$\gamma_n=\max\left\{0,\frac{\theta}{(1-\theta)+(1-s)(\sigma-1)}\frac{\sigma-1}{\sigma}(L+\rho)-\rho\right\},$$

$$\gamma_C=\gamma_Y=(\alpha-1)\gamma_n. \quad (42)$$

Equation (42) explains the growth rate of the economy. The effect of the government's R&D subsidy policy is positive on the economic growth. Increasing the R&D subsidy will enhance the economic growth rate.

[7] $L_x^{\,0}=(\sigma-1)(L+\rho)/\sigma$. See Appendix 3.

4. Social Optimum

The program of the social planner is thus

$$\max \quad U = \int_0^\infty \ln C_t e^{-\rho t} dt, \tag{43}$$

$$\text{s.t.} \quad \frac{\dot{n}}{n} = L - L_x,^{8} \tag{44}$$

$$C = Y = n^{\alpha-1} L_x. \tag{45}$$

The Hamiltonian function for this program is

$$H = \ln(n^{\alpha-1} L_x) + \kappa n (L - L_x). \tag{46}$$

The first-order conditions are

$$\frac{\partial H}{\partial L_x} = \frac{1}{L_x} - \kappa n = 0, \tag{47}$$

$$\frac{\partial H}{\partial n} = (\alpha - 1)\frac{1}{n} + \kappa (L - L_x) = -\dot{\kappa} + \kappa \rho, \tag{48}$$

which combined together yield

$$\frac{\dot{L}_x}{L_x} = (\alpha - 1) L_x - \rho.^{9} \tag{49}$$

Therefore, a social optimal rate of growth is given by

$$\gamma_n^{SO} = L - \frac{\rho}{\alpha - 1}. \tag{50}$$

According to equation (50), we find that there is a negative relationship between the elasticity of substitution and the social optimal rate of growth. This result is supported by Benassy (1998).

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8 See Appendix 4.

9 $\tilde{L}_x = \rho / (\alpha - 1)$.

By comparing the social optimum with the market outcome

$$\gamma_n^{SO}-\gamma_n=\left[1-\frac{\theta(\sigma-1)}{[(1-\theta)+(1-s)(\sigma-1)]\sigma}\right]L$$
$$+\frac{\alpha-2}{\alpha-1}\rho-\frac{\theta(\sigma-1)}{[(1-\theta)+(1-s)(\sigma-1)]\sigma}\rho \gtrless 0.^{10} \tag{51}$$

Proposition 2.

(i) *When the firms engage in forward integration, if there is too little R&D in the imperfectly competitive final goods market, then the government should implement a subsidy policy. On the other hand, if there is too much R&D in the perfectly competitive final goods market, the government should implement a tax policy.*

(ii) *When the firms engage in backward integration, there will be too little R&D activity.*

Suppose the firms engage in forward integration ($\theta \to 1$). From equation (51) we have

$$\gamma_n^{SO}-\gamma_n=\left[1-\frac{1}{(1-s)\sigma}\right]L+\frac{\alpha-2}{\alpha-1}\rho-\frac{1}{(1-s)\sigma}\rho \gtrless 0. \tag{52}$$

The R&D activities will lead to ambiguous results according to the degree of competition (σ) in the final goods market. If the final goods market is more imperfectly competitive, which means that σ is large enough, there will be too little R&D activity at the market equilibrium. Even if the distortion in market power in the intermediate goods market is eliminated by the final goods firms' use of a two-part tariff, a distortion will nevertheless remain due to the imperfect competition in the final goods market. Since the market equilibrium economic growth rate is lower than the socially optimal economic growth rate, the government should implement a subsidy policy for R&D activities. In

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[10] See Appendix 5.

the extreme case where there is perfect competition ($\sigma \to 1$) in the final goods market, there will be too many R&D activities in the market equilibrium. In this case, the market equilibrium economic growth rate will be higher than the socially optimal economic growth rate, and thus the government should implement the tax policy.[11] Moreover, the optimal subsidy/tax rate is

$$s = 1 - \frac{L+\rho}{\sigma\left[(L+\rho) - \frac{1}{\alpha-1}\rho\right]} \gtrless 0. \tag{53}$$

If the final goods market is perfectly competitive, $\sigma \to 1$, the government should tax the R&D activities ($s < 0$). If σ is large enough, the government should subsidy the R&D activities ($s > 0$).

Suppose the firms engage in backward integration ($\theta \to 0$). From equation (51) this becomes

$$\gamma_n^{SO} - \gamma_n = L + \frac{\alpha-2}{\alpha-1}\rho > 0. \tag{54}$$

Equation (54) indicates that the socially optimal economic growth rate is greater than the decentralized economic growth rate. There will be too little R&D activity at the market equilibrium.

5. Welfare

We integrate the utility function (1) over time to express the welfare function as:

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[11] From equation (52) and $\sigma \to 1$, we obtain

$$\gamma_n^{so} - \gamma_n = \{1 - [1/(1-s)]\}L + [(\alpha-2)\rho/(\alpha-1)] - [\rho/(1-s)].$$

Rearrange the above equation

$$\gamma_n^{so} - \gamma_n = [-sL/(1-s)] + \rho - [\rho/(\alpha-1)] - [\rho/(1-s)].$$

Then we have

$$\gamma_n^{SO} - \gamma_n = \{[-sL/(1-s)] - [\rho/(\alpha-1)] - [s\rho/(1-s)]\} < 0.$$

$$V = \frac{1}{\rho}\ln C_0 + \frac{1}{\rho^2}\gamma, \tag{55}$$

where C_0 is the initial growth equilibrium level of consumption which can describe balanced growth level (C_0^n) or social optimum level (C_0^{SO}) respectively; γ is the growth rate which can describe balanced growth rate (γ_n) or social optimum growth rate (γ_n^{SO}) respectively. Therefore the welfare of social optimum (V_n^{SO}) and the welfare of balanced growth equilibrium (V_n) are expressed as follows:

$$V_n^{SO} = \frac{1}{\rho}\ln C_0^{SO} + \frac{1}{\rho^2}\gamma_n^{SO}, \tag{56}$$

$$V_n = \frac{1}{\rho}\ln C_0^n + \frac{1}{\rho^2}\gamma_n. \tag{57}$$

The difference between above two equations is

$$V_n^{SO} - V_n = \frac{1}{\rho}\ln C_0^{SO} + \frac{1}{\rho^2}\gamma_n^{SO} - \frac{1}{\rho}\ln C_0^n - \frac{1}{\rho^2}\gamma_n, \tag{58}$$

where $C_0^{SO} = n^{\alpha-1}\tilde{L}_x$, $C_0^n = n^{\alpha-1}\hat{L}_x$. Substituting C_0^{SO}, C_0^n into above equation, we obtain

$$V_n^{SO} - V_n = \frac{1}{\rho}\left[\ln\frac{\tilde{L}_x}{\hat{L}_x} + \frac{\gamma_n^{SO} - \gamma_n}{\rho}\right] \gtreqless 0. \tag{59}$$

The equation (59) means that the relative degree of welfares of social optimum and balanced growth equilibrium depends on the relative degree of social optimum growth rate and balanced growth rate.

Proposition 3.

The government can enforce the optimal subsidy/tax rate to increase the welfare of balanced growth equilibrium to the level of social optimum.

Suppose that firms engage in forward integration ($\theta \to 1$), substituting the optimal subsidy/tax rate (equation (53)) and $\hat{L}_x$, $\tilde{L}_x$, γ_n^{SO}, γ_n into equation (59) we obtain

$$V_n^{SO} - V_n = 0. \tag{60}$$

Equation (60) means that the government can enforce the optimal subsidy/tax rate to regulate the welfare. The welfare of balanced growth equilibrium will equal to the welfare of social optimum.

This article has considered three distortions which are including imperfect competition of the final goods market and intermediate goods market and both of them bargaining over the intermediate goods price. But according our research the government once implements the optimal subsidy/tax policy to R&D sector, the welfare of balanced growth equilibrium will be equal to the welfare of social optimum. This is because Nash bargaining can successfully eliminate the distortion between two sectors.

6. Conclusion

There has already been much discussion in the literature on the determination of the franchise fee and intermediate goods price under the assumption of downstream firms having no control power. In order to extend the analysis to encompass forward integration, our model establishes a bargaining process to determine the contract between the upstream and downstream firms. We show that if the number of intermediate goods firms is greater than that of the final goods firms, the aggregate profits which are created after forward integration will be greater than in the case where backward integration takes place. On the other hand, if the number of final goods firms is greater than that of the intermediate goods firms, the aggregate profits which are generated after the backward integration will exceed those generated in the case of forward integration.

In comparison with the social optimum, when the final goods market is relatively imperfectly competitive and there is too little R&D activity under market equilibrium, the government should implement a subsidy policy. In the extreme case of perfect competition, where there is too much R&D activity under market equilibrium, the government should implement a tax policy.

Furthermore, the government can enforce the optimal subsidy/tax rate to increase the welfare of balanced growth equilibrium to the level of social optimum.

Appendix 1

A successively imperfect competitive economy consists of two types of firms – upstream firms and downstream firms. They maximize their profits respectively by a traditional method described as follows:

Firm j in the final goods market optimizes its production plan. The profit maximizing problem is

$$\max_{x_j^0} \ \Pi_j^0 = p_j^0 y_j^0 - \int_0^{n_t} p_{ij}^{x^0} x_{ij}^0 di, \tag{A1}$$

subject to equation (10), equation (12) and $y_j^0 = c_j^0$. (Note: Superscript 0 denotes the case of traditional pricing, corresponding to negotiation breakdown. That is, the upstream firm and downstream firm do not integrate.)

In the symmetric equilibrium, $x_{ij}^0 = x_j^0$, $p_{ij}^{x^0} = p_j^{x^0}$, $\forall i$, the first-order condition is given by

$$x_j^0 = (\frac{\sigma-1}{\sigma})^{\sigma}(P^0)^{\sigma(\sigma-1)} m^{1-\sigma}(C^0)^{\sigma-1} n^{\sigma(\alpha-1)-\alpha}(p_j^{x^0})^{-\sigma}. \tag{A2}$$

Equation (A2) reflects the demand for intermediate goods.

Firm i in the intermediate goods market chooses the price to maximize its profit

$$\max_{p_i^{x^0}} \pi_i = mp_i^{x^0} x_i^0 - mwl_i^{x^0}, \tag{A3}$$ [12]

subject to its production function ($x_i^0 = l_i^{x^0}$) and equation (A2).

The first-order condition is thus given by

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[12] Under the assumptions of the final goods firms with the same production function and symmetrical equilibrium, equations (A3) and (A4) can be established.

$$p_i^{x^0} = \frac{\sigma}{\sigma - 1} w. \tag{A4}$$

Equation (A4) indicates that firm i among the intermediate goods firms charges a markup price that is above the marginal cost of firm j among the final goods firms. This is the solution in the traditional R&D growth model.

Substituting equation (A4) into (A2) and using equations (10) and (12), we obtain the equilibrium demand for intermediate goods. Then the price of the final goods is given by

$$p_j^0 = \frac{1}{n^{\alpha-1}} (\frac{\sigma}{\sigma - 1})^2 w. \tag{A5}$$

Equations (A5) and (A4) state that double marginalization takes place due to successive markups. That is, both the upstream firm and downstream firm set the markup price for their consumers.

Following equation (A5), we can obtain the aggregate consumption price index (P^0) as well as the profits (π^0, Π^0) of the intermediate goods and final goods firms, respectively. The results are as follows:

$$P^0 = \frac{1}{n^{\alpha-1}} (\frac{\sigma}{\sigma - 1})^2 w, \tag{A6}$$

$$\pi^0 = \frac{1}{n^{\alpha} (\sigma - 1)} wY^0, \tag{A7}$$

$$\Pi^0 = \frac{1}{m} \frac{\sigma}{\sigma - 1} \frac{1}{n^{\alpha-1} (\sigma - 1)} wY^0. \tag{A8}$$

Appendix 2

We show the market clearing condition, $Y = C$, as follows:
According to equation (4) and free entry condition in R&D sector, $p_N \dot{n} - (1-s)wL_N = 0$, we can obtain

$$(1-s)wL_N = wL + n\pi + m\Pi - T - PC. \tag{A9}$$

Since $L = L_x + L_N$, equation (A9) can be rewritten by

$$-swL_N = wL_x + n\pi + m\Pi - T - PC. \tag{A10}$$

Impose government's budget constraint, $T = swL_N$, on (A10)

$$0 = wL_x + n\pi + m\Pi - PC. \tag{A11}$$

Then substitute equations (26), (27) into (A11)

$$0 = wL_x + n\left\{(1-\theta)\frac{1}{n}\frac{1}{n^{\alpha-1}(\sigma-1)}wY + \left[\theta - \frac{(1-\theta)\sigma}{\sigma-1}\right]\frac{1}{n}\frac{1}{n^{\alpha-1}(\sigma-1)}wY^0\right\}$$
$$+ m\left\{\theta\frac{1}{m}\frac{1}{n^{\alpha-1}(\sigma-1)}wY - \left[\theta - \frac{(1-\theta)\sigma}{\sigma-1}\right]\frac{1}{m}\frac{1}{n^{\alpha-1}(\sigma-1)}wY^0\right\} - PC. \tag{A12}$$

Rewrite the equation (A12)

$$0 = wL_x + \frac{1}{n^{\alpha-1}(\sigma-1)}wY - PC. \tag{A13}$$

From equations (3) and (12) we have

$$L_x = mnl^x = mnx = mnn^{-\alpha}y = mnn^{-\alpha}m^{-1}Y = \frac{1}{n^{\alpha-1}}Y. \tag{A14}$$

Substituting equation (A14) into (A13), we obtain

$$0 = \frac{\sigma}{n^{\alpha-1}(\sigma-1)}wY - PC. \tag{A15}$$

Substituting equation (25) into (A15), we obtain

$$0 = PY - PC. \tag{A16}$$

Therefore, we derive the market clearing condition as:

$$Y = C.$$

Appendix 3

The dynamics of the non-integrated economy are

$$(\frac{\dot{C}}{C})^0 = \frac{1}{(\sigma - 1)} L_x^{\,0} + (\alpha - 2)(\frac{\dot{n}}{n})^0 - \rho, \tag{A17}$$

$$(\frac{\dot{n}}{n})^0 = L - L_x^{\,0}, \tag{A18}$$

$$(\frac{\dot{C}}{C})^0 = (\alpha - 1)(\frac{\dot{n}}{n})^0 + \dot{L}_x^{\,0}. \tag{A19}$$

Combining equations (A17)-(A19), we derive the dynamic equation for $L_x^{\,0}$

$$\frac{\dot{L}_x^{\,0}}{L_x^{\,0}} = \frac{\sigma}{(\sigma - 1)} L_x^{\,0} - L - \rho. \tag{A20}$$

Since the coefficient $\sigma/(\sigma-1)$ is positive, for stability we let $\dot{L}_x = 0$. Its steady state value is

$$L_x^{\,0} = \frac{\sigma - 1}{\sigma}\left(L + \rho\right). \tag{A21}$$

Appendix 4

Substituting equations (20), (26) and (27) into (4)

$$PC + p_N\dot{n} = wL + n\left\{(1-\theta)\frac{1}{n}\frac{1}{n^{\alpha-1}(\sigma-1)}wY + (\theta - \frac{(1-\theta)\sigma}{\sigma-1})\frac{1}{n}\frac{1}{n^{\alpha-1}(\sigma-1)}wY^0\right\}$$
$$+m\left\{\theta\frac{1}{m}\frac{1}{n^{\alpha-1}(\sigma-1)}wY - (\theta - \frac{(1-\theta)\sigma}{\sigma-1})\frac{1}{m}\frac{1}{n^{\alpha-1}(\sigma-1)}wY^0\right\} - swL_N. \quad \text{(A22)}$$

Rewrite the above equation

$$p_N\dot{n} = wL + \frac{1}{n^{\alpha-1}(\sigma-1)}wY - PC - sw(L-L_x). \quad \text{(A23)}$$

Substituting equations (25) and (34) into above equation and rearrange, we can obtain

$$\frac{\dot{n}}{n} = \frac{wL + \frac{1}{n^{\alpha-1}(\sigma-1)}wn^{\alpha-1}L_x - \frac{\sigma}{n^{\alpha-1}(\sigma-1)}wn^{\alpha-1}L_x - sw(L-L_x)}{np_N}, \quad \text{(A24)}$$

$$\frac{\dot{n}}{n} = \frac{(1-s)wL - (1-s)wL_x}{np_N}. \quad \text{(A25)}$$

Substituting equation (19) into above equation

$$\frac{\dot{n}}{n} = \frac{(1-s)wL - (1-s)wL_x}{n\frac{(1-s)w}{n}}. \quad \text{(A26)}$$

Rewrite the equation, we can obtain the equation (44)

$$\frac{\dot{n}}{n} = L - L_x.$$

Appendix 5

Equation (51) implicitly defines a subsidy function s in terms of the degree of integration, θ, as follows:

$$s = 1 - \frac{\theta(L+\rho)}{\left(L + \frac{\alpha-2}{\alpha-1}\rho\right)\sigma} + \frac{1-\theta}{\sigma-1}. \tag{A27}$$

The relationship between s and θ is ambiguous, as the following expression shows

$$\frac{\partial s}{\partial \theta} = -\frac{(L+\rho)}{\left(L + \frac{\alpha-2}{\alpha-1}\rho\right)\sigma} - \frac{1}{\sigma-1} = \frac{-(\sigma-1)(L+\rho) - \sigma L - \frac{\alpha-2}{\alpha-1}\sigma\rho}{\left(L + \frac{\alpha-2}{\alpha-1}\rho\right)(\sigma-1)\sigma} \gtrless 0. \tag{A28}$$

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整合、R&D與經濟成長

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摘　要

本文於 R&D 內生成長模型內鍵入連續的不完全競爭市場結構，討論中間財廠商與最終財廠商之間的互動，以及政府實施補貼政策或課稅政策對經濟成長的影響。我們發現中間財廠商與最終財廠商向前垂直整合或向後垂直整合的總和利潤大小，決定於中間財與最終財的廠商數目大小。在廠商向前垂直整合的例子中，若最終財市場的競爭程度較低，則市場經濟下產生的 R&D 較少，以致於存在較低的平衡成長率，因此政府應實行補貼 R&D 政策以提升經濟成長率；反之，若最終財市場為完全競爭，則 R&D 生產過多，因此政府應實行課稅政策以讓平衡成長率接近社會最適成長率。在福利水準方面，若政府採行最適補貼（或課稅）政策，將使得競爭均衡的福利水準等於社會最適的福利水準。

關鍵詞：內生成長、R&D、垂直整合、談判、補貼、社會最適

JEL 分類代號：L00, O30, O41

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投稿日期：民國 104 年 10 月 27 日；修訂日期：民國 105 年 2 月 1 日；接受日期：民國 105 年 9 月 12 日。