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Abstract

This letter explores the different implications of patent breadth and R&D subsidies on economic growth and endogenous market structure in a Schumpeterian model. We find that the two policy instruments have the same positive effect on economic growth when the model exhibits scale effects under a fixed number of firms. When the model becomes scale-invariant under an endogenous number of firms, patent breadth increases economic growth but decreases the number of firms, whereas R&D subsidies increase the number of firms but decrease economic growth.

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1 Introduction

In this letter, we consider a simple Schumpeterian growth model to explore the different implications of two important policy instruments, patent breadth and R&D subsidies, on economic growth and endogenous market structure (EMS) measured by the number of firms in equilibrium. We find that these two policy instruments have the same positive effect on economic growth when the model exhibits scale effects under a fixed number of firms.[1] Interestingly, when the model does not exhibit scale effects under an endogenous number of firms, the two policy instruments have drastically different implications on economic growth and market structure. Specifically, patent breadth increases economic growth but decreases the number of firms, whereas R&D subsidies increase the number of firms but decrease economic growth. We explain the intuition of these results in the main text.

This study relates to the literature on R&D-driven economic growth; see Romer (1990), Segerstrom *et al.* (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992) for seminal studies. Subsequent studies in this literature often apply variants of the R&D-based growth model to analyze the effects of policy instruments, such as patent breadth and R&D subsidies, on economic growth and innovation; see for example, Segerstrom (2000), Li (2001), Goh and Olivier (2002), Iwaisako and Futagami (2012), Chu (2011), Chu and Furukawa (2011) and Chu *et al.* (2012). However, these studies do not analyze the effects of patent policy on EMS;[2] therefore, the present study contributes to the literature with a novel analysis of patent breadth in a Schumpeterian growth model with EMS. Furthermore, we contrast the different effects of patent breadth and R&D subsidies. For example, Li (2001) finds that both of these policy instruments contribute to increasing economic growth in a Schumpeterian growth model that exhibits scale effects. However, we find that under a scale-invariant Schumpeterian growth model with EMS, the effects of patent breadth and R&D subsidies become drastically different suggesting the importance of taking into consideration EMS when performing policy analysis in R&D-based growth models.[3]

The rest of this letter is organized as follows. Section 2 presents the Schumpeterian growth model with EMS. Section 3 analyzes the effects of patent breadth and R&D subsidies.

2 A Schumpeterian growth model with EMS

In summary, the model is based on a monopolistically competitive version of the R&D-based growth model with in-house R&D and EMS in Peretto (1996). We incorporate into the model patent breadth and R&D subsidies to analyze their different implications on economic growth and market structure.

[1] See Laincz and Peretto (2006) for a discussion of scale effects in R&D-based growth models.

[2] See Peretto (1996, 1999) for seminal studies in R&D-based growth models with EMS and Etro (2012) for an excellent textbook treatment of this topic.

[3] Segerstrom (2000) also analyzes the effects of R&D subsidies in a scale-invariant R&D-based growth model and shows that R&D subsidies can have either positive or negative effects on economic growth. His interesting results are driven by a different mechanism that is the tradeoff between vertical and horizontal innovation; in contrast, economic growth in our model is solely based on quality improvement.

2.1 Households

There is a unit continuum of identical households, who have a lifetime utility function.

$$U = \int_0^\infty e^{-\rho t} \ln C_t dt, \tag{1}$$

where C_t denotes consumption of final goods (numeraire) at time t. The parameter $\rho > 0$ determines the rate of subjective discounting. Each household maximizes (1) subject to the following asset-accumulation equation.

$$\dot{A}_t = r_t A_t + w_t L - \tau_t - C_t. \tag{2}$$

A_t is the real value of assets owned by each household, and r_t is the real interest rate. The household has a labor endowment of L units and supplies them inelastically to earn a real wage rate w_t. The household also faces a lump-sum tax τ_t from the government. The familiar Euler equation is

$$\frac{\dot{C}_t}{C_t} = r_t - \rho. \tag{3}$$

2.2 Final goods

Final goods Y_t are produced by competitive firms that aggregate intermediate goods $X_t(i)$ for $i \in [0, N_t]$ using a standard CES aggregator given by

$$Y_t = \left(\int_0^{N_t} [X_t(i)]^{(\varepsilon-1)/\varepsilon} di \right)^{\varepsilon/(\varepsilon-1)}, \tag{4}$$

where $\varepsilon > 1$ is the elasticity of substitution. The conditional demand function for $X_t(i)$ is

$$X_t(i) = [p_t(i)]^{-\varepsilon} Y_t, \tag{5}$$

where $p_t(i)$ is the price of $X_t(i)$.

2.3 Intermediate goods and in-house R&D

There is a continuum of industries producing differentiated intermediate goods. Each industry is dominated by a monopolistic firm with the following production function.

$$X_t(i) = Z_t(i)[L_{x,t}(i) - \phi], \tag{6}$$

where $\phi > 0$ is a fixed operating cost, which is a common feature in this class of models with in-house R&D and EMS, and $L_{x,t}(i)$ is the number of workers employed in industry $i \in [0, N_t]$ for production. The law of motion for technology $Z_t(i)$ is

$$\dot{Z}_t(i) = \varphi Z_t(i) L_{z,t}(i), \tag{7}$$

where $\varphi > 0$ determines R&D productivity, and $L_{z,t}(i)$ is the number of workers employed in industry i for R&D.

The value of the monopolistic firm in industry i is

$$V_t(i) = \int_t^{\infty} \exp\left(-\int_t^u r_v dv\right) \pi_u(i) du, \tag{8}$$

where the flow profit at time t is

$$\pi_t(i) = p_t(i)X_t(i) - w_t L_{x,t}(i) - (1-s)w_t L_{z,t}(i), \tag{9}$$

where the parameter $s \in (0,1)$ is the rate of R&D subsidies. The monopolistic firm maximizes (8) subject to (5) and (7). The current-value Hamiltonian of this optimization problem is

$$H_t(i) = \pi_t(i) + \lambda_t(i)\dot{Z}_t(i). \tag{10}$$

We solve this optimization problem in the appendix and find that the unconstrained profit-maximizing markup ratio is $\varepsilon/(\varepsilon-1)$. To analyze the effects of patent breadth, we impose an upper bound $\mu > 1$ on the markup ratio.[4] Therefore, the equilibrium price becomes

$$p_t(i) = \min\left\{\mu, \frac{\varepsilon}{\varepsilon-1}\right\} \frac{w_t}{Z_t(i)}. \tag{11}$$

For the rest of this study, we assume that $\mu < \varepsilon/(\varepsilon-1)$. In this case, a larger patent breadth μ leads to a higher markup, and this implication is consistent with Gilbert and Shapiro's (1990) seminal insight on "breadth as the ability of the patentee to raise price".

2.4 Government

The government chooses an exogenous rate s of R&D subsidies. To balance the fiscal budget, the government levies a lump-sum tax τ_t on households. The balanced budget condition is

$$\tau_t = s w_t \int_0^{N_t} L_{z,t}(i) di. \tag{12}$$

3 Patent breadth versus R&D subsidies

Following Peretto (1996, 1999), we consider a symmetric equilibrium in which $Z_t(i) = Z_t$ for $i \in [0, N_t]$, by assuming that any new entry at time t has access to the level of aggregate technology Z_t.[5] Free entry implies $V_t = 0$, which determines the equilibrium number of firms. Imposing symmetry across $i \in [0, N_t]$ yields the labor-market clearing condition given by

$$L = N_t(L_{x,t} + L_{z,t}). \tag{13}$$

[4]See also Li (2001), Goh and Olivier (2002), Iwaisako and Futagami (2012), Chu (2011), Chu and Furukawa (2011) and Chu *et al.* (2012) for a similar formulation.

[5]Peretto (1996) justifies this assumption by arguing that knowledge is embodied in workers. Therefore, when a new firm recruits workers from existing firms, it also gains access to their knowledge.

Substituting (6) into (4) yields the aggregate production function of Y_t given by

$$Y_t = (N_t)^{\varepsilon/(\varepsilon-1)} Z_t \left(L_{x,t} - \phi\right). \tag{14}$$

The resource constraint implies $C_t = Y_t$.

At the steady state,[6] N_t and $L_{x,t}$ are stationary. Therefore, the steady-state equilibrium growth rate is

$$g \equiv \frac{\dot{C}_t}{C_t} = \frac{\dot{Y}_t}{Y_t} = \frac{\dot{Z}_t}{Z_t} = \varphi L_z. \tag{15}$$

We will show that the equilibrium growth rate is free of scale effects (i.e., g is independent of L) when the number of firms is endogenous.

Solving the dynamic optimization in (10),[7] we obtain

$$L_x = \frac{1-s}{\mu}\left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{\rho}{\varphi} + \phi, \tag{16}$$

which is decreasing in patent breadth μ and R&D subsidy s. Combining (16) and (13) yields

$$L_z = \frac{L}{N} - L_x = \frac{L}{N} - \frac{1-s}{\mu}\left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{\rho}{\varphi} - \phi. \tag{17}$$

Equation (17) shows that when the number of firms N is *exogenous*, the model exhibits scale effects (i.e., $g = \varphi L_z$ is increasing in L); in this case, $g = \varphi L_z$ would be increasing in patent breadth μ and R&D subsidy s. These results are standard in the literature; see for example Li (2001).

When the number of firms is *endogenous*, we have a free-entry condition given by $V_t = 0$, which requires $\pi_t = 0$. Substituting (6) and (11) into (9) yields

$$\pi_t = 0 \Leftrightarrow \mu w_t[L_x - \phi] = w_t L_x + (1-s) w_t L_z. \tag{18}$$

We use (16), (17) and (18) to solve for the steady-state equilibrium values of $\{L_z, N\}$.

$$L_z = \frac{\mu-1}{\mu}\left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{\rho}{\varphi} - \frac{\phi}{1-s}, \tag{19}$$

$$N = \left[\frac{\mu-s}{\mu}\left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{\rho}{\varphi} - \left(\frac{s}{1-s}\right)\phi\right]^{-1} L, \tag{20}$$

where N is increasing in L. Recall that the steady-state equilibrium growth rate is $g = \varphi L_z$; therefore, (19) shows that g is independent of L. This model features the following counterintuitive properties that the growth rate is decreasing in R&D productivity φ and increasing in the discount rate ρ due to endogenous entries. The intuition is that high R&D productivity and a low discount rate attract entries, and the resulting larger number of firms reduces the amount of labor available for each firm.

[6] One can show that the steady state is globally stable.

[7] Derivations are relegated to Appendix A.

As for the effects of patent breadth, L_z is increasing in μ, and N is decreasing in μ. Intuitively, a larger μ increases the markup and the profitability of each intermediate goods firm; as a result, R&D increases to satisfy the zero-profit free-entry condition. Because the increase in L_z is larger than the decrease in L_x, the number of firms N decreases to satisfy the resource constraint on labor.

As for the effects of R&D subsidies, L_z is decreasing in s, and N is increasing in s. Intuitively, an increase in s decreases the cost of R&D but also leads to a smaller L_x reducing the size and profitability of each intermediate goods firm. The negative profitability effect dominates the positive R&D-cost effect rendering a reduction in R&D L_z (unless the fixed operating cost ϕ is zero in which case the two effects cancel each other and R&D L_z would be unchanged). Finally, due to the reduction in L_z and L_x, the number of firms N increases to satisfy the resource constraint on labor.

We conclude this letter by summarizing our results in the following proposition.

Proposition 1 *Under an exogenous number of firms, the equilibrium growth rate is increasing in patent breadth and R&D subsidies. Under an endogenous number of firms, a larger patent breadth increases the equilibrium growth rate but decreases the equilibrium number of firms, whereas a higher rate of R&D subsidies increases the equilibrium number of firms but decreases the equilibrium growth rate.*

Appendix A

Derivations of L_x^*. Substituting (5), (6) and (9) into (10) yields

$$H_t(i) = (Y_t)^{1/\varepsilon}\,[Z_t(i)]^{(\varepsilon-1)/\varepsilon}[L_{x,t}(i)-\phi]^{(\varepsilon-1)/\varepsilon} - w_t L_{x,t}(i) - (1-s)w_t L_{z,t}(i) + \lambda_t(i)\varphi Z_t(i) L_{z,t}(i). \quad \text{(A1)}$$

The first-order conditions include

$$\frac{\partial H_t(i)}{\partial L_{x,t}(i)} = \frac{\varepsilon-1}{\varepsilon}\,(Y_t)^{1/\varepsilon}\,[Z_t(i)]^{(\varepsilon-1)/\varepsilon}[L_{x,t}(i)-\phi]^{-1/\varepsilon} - w_t = 0, \quad \text{(A2)}$$

$$\frac{\partial H_t(i)}{\partial L_{z,t}(i)} = -(1-s)w_t + \lambda_t(i)\varphi Z_t(i) = 0, \quad \text{(A3)}$$

$$\frac{\partial H_t(i)}{\partial Z_t(i)} = \frac{\varepsilon-1}{\varepsilon}\,(Y_t)^{1/\varepsilon}\,[Z_t(i)]^{-1/\varepsilon}[L_{x,t}(i)-\phi]^{(\varepsilon-1)/\varepsilon} + \lambda_t(i)\varphi L_{z,t}(i) = r_t\lambda_t(i) - \dot{\lambda}_t(i). \quad \text{(A4)}$$

Using (5) and (6), we can derive from (A2) the unconstrained profit-maximizing price in (11). Substituting (5), (11) and (A3) into (A4), we obtain

$$\frac{\mu}{1-s}\left(\frac{\varepsilon-1}{\varepsilon}\right)\varphi[L_{x,t}(i)-\phi] + \varphi L_{z,t}(i) = r_t - \frac{\dot{\lambda}_t(i)}{\lambda_t(i)}. \quad \text{(A5)}$$

Applying $r = \rho + g$ and imposing symmetry and balanced growth on (A5) yield (16). ■

References

[1] Aghion, P., and Howitt, P., 1992. A model of growth through creative destruction. *Econometrica*, 60, 323-351.

[2] Chu, A., 2011. The welfare cost of one-size-fits-all patent protection. *Journal of Economic Dynamics and Control*, 35, 876-890.

[3] Chu, A., and Furukawa, Y., 2011. On the optimal mix of patent instruments. *Journal of Economic Dynamics and Control*, 35, 1964-1975.

[4] Chu, A., Pan, S., and Sun, M., 2012. When does elastic labor supply cause an inverted-U effect of patents on innovation?. *Economics Letters*, 117, 211-213.

[5] Etro, F., 2009. *Endogenous Market Structures and the Macroeconomy*. New York and Berlin: Springer.

[6] Gilbert, R., and Shapiro, C., 1990. Optimal patent length and breadth. *RAND Journal of Economics*, 21, 106-112.

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

[8] Grossman, G., and Helpman, E., 1991. Quality ladders in the theory of growth. *Review of Economic Studies*, 58, 43-61.

[9] Iwaisako, T., and Futagami, K., 2012. Patent protection, capital accumulation, and economic growth. *Economic Theory*, forthcoming.

[10] Laincz, C., and Peretto, P., 2006. Scale effects in endogenous growth theory: An error of aggregation not specification. *Journal of Economic Growth*, 11, 263-288.

[11] Li, C.-W., 2001. On the policy implications of endogenous technological progress. *Economic Journal*, 111, C164-C179.

[12] Peretto, P., 1996. Sunk costs, market structure, and growth. *International Economic Review*, 37, 895-923.

[13] Peretto, P., 1999. Cost reduction, entry, and the interdependence of market structure and economic growth. *Journal of Monetary Economics*, 43, 173-195.

[14] Romer, P., 1990. Endogenous technological progress. *Journal of Political Economy* 98, S71–S102.

[15] Segerstrom, P., 2000. The long-run growth effects of R&D subsidies. *Journal of Economic Growth*, 5, 277-305.

[16] Segerstrom, P., Anant, T.C.A. and Dinopoulos, E., 1990. A Schumpeterian model of the product life cycle. *American Economic Review*, 80, 1077-91.