R&D in a Model of Search and Growth

Derek Laing; Theodore Palivos; Ping Wang

The American Economic Review, Vol. 85, No. 2, Papers and Proceedings of the Hundredth and Seventh Annual Meeting of the American Economic Association Washington, DC, January 6-8, 1995 (May, 1995), 291-295.

Stable URL:
http://links.jstor.org/sici?sici=0002-8282%28199505%2985%3A2%3C291%3ARIAMOS%3E2.0.CO%3B2-M

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/about/terms.html. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

The American Economic Review is published by American Economic Association. Please contact the publisher for further permissions regarding the use of this work. Publisher contact information may be obtained at http://www.jstor.org/journals/aea.html.

The American Economic Review
©1995 American Economic Association

JSTOR and the JSTOR logo are trademarks of JSTOR, and are Registered in the U.S. Patent and Trademark Office. For more information on JSTOR contact jstor-info@umich.edu.

©2003 JSTOR

http://www.jstor.org/
Wed Nov 5 05:58:51 2003

R&D in a Model of Search and Growth

By DEREK LAING, THEODORE PALIVOS, AND PING WANG*

Just how important a determinant of economic growth is the efficacy with which markets are organized? It is clear that in order to answer this question it is necessary to have both a well-articulated theory of economic growth and a precise notion of what it means for one market to be better organized than another. The newly developed theory of endogenous growth (pioneered by, among others, Paul M. Romer [1986], Robert E. Lucas [1988], Nancy Stokey [1988], and Gene Grossman and Elhanan Helpman [1991]) has equipped economists with a rigorous microeconomic foundation of the growth process. Since its original inception, research in this area has bifurcated: one strand of work has continued to emphasize the importance of capital accumulation (both physical and human) in environments in which agents are competitive price-takers; the other strand has a distinctly "neo-Schumpeterian" flavor, in which firms are price-setters and purposive innovative activity leads to technological advancement.

But what of the role played by market organization? The growth literature has remained relatively silent on this issue. The reason is that the canonical growth model is one in which trade—either competitive or monopolisticly competitive—is coordinated by the Walrasian auctioneer. Given that *ex hypothesi* trade is frictionless, it is meaningless to use this framework to discuss issues pertaining to improvements in market organization. However, beginning with the seminal contributions of Peter Diamond (1982), Dale T. Mortensen (1982), and Christopher Pissarides (1985), economists have begun to construct models that dispense with the auctioneer's coordinating function. In this setting it is possible to make precise the notion of an improvement in market efficacy, since search and bargaining frictions are explicitly incorporated as an integral part of the trading environment. Yet, it is only very recently that this literature has begun to explore the consequences for perpetual economic growth.

I. Search and Growth

A limited number of papers have looked at the effect of search and bargaining frictions in environments with perpetual growth. Recently, Phillipe Aghion and Peter Howitt (1994) have studied the effects of technological advancement on unemployment. In their model two basic forces determine the level of unemployment. First, the rate of *job destruction* depends (positively) upon the rate at which technological advancement renders incumbent firms obsolete. Second, a greater rate of technological advances promotes *job creation*, by raising the return from production and thus stimulating the entry of new firms. Aghion and Howitt show that either effect may dominate, since the level of unemployment can initially rise and then decline with the innovation rate. In an extension of their work, they consider endogenous learning-by-doing. This introduces a feedback effect between unemployment and the innovative activity, which gives rise to the possibility of multiple steady-state equilibria.

Charles Bean and Pissarides (1993) also explore the link between unemployment and growth by incorporating job search into an overlapping-generations variant of Romer's (1986) knowledge-spillover model. The young are deemed to be workers, while the old are entrepreneurs. Establishing a vacancy is costly, and the contact rate between

*Laing and Wang: Department of Economics Pennsylvania State University, University Park, PA 16802; Palivos: Department of Economics, Louisiana State University, Baton Rouge, LA 70809, and Department of Economics, Tilburg University, the Netherlands.

firms and workers depends positively on the number of participants on each side of the market. Search frictions give rise to rents, which are divided according to a Nash bargain upon a successful match. A reduction in the vacancy setup cost promotes entry and lowers unemployment. An increase in workers' bargaining strength has an ambiguous effect on economic growth, since an increase in wage income promotes growth but (induced) higher levels of unemployment reduce savings and growth.

In Laing et al. (1995), we also explore the link between unemployment and growth. Workers are assumed to choose their schooling effort before entering the labor market in search of employment. Unemployed workers and vacancies are randomly brought together via a stochastic matching technology, and upon a successful encounter, a wage will be negotiated. Importantly, education is deemed to affect each worker's *stock* of knowledge and the ability to *accumulate* additional human capital once employed (on-the-job learning). The possibility of multiple steady-state growth paths is established. Specifically, a thick labor market encourages workers to invest in costly schooling, which raises the surplus accruing to a successful match. A higher surplus induces entry by additional firms, which makes for a thick market (with low unemployment and high growth). A thin market (with low growth and high unemployment) can also be an equilibrium for similar, but opposite, reasons. A reduction in market frictions promotes growth and can eliminate all but the Pareto dominating equilibrium.

In a companion paper (Laing et al., 1994), we construct a neo-Schumpeterian model in which vertical improvements in product quality represent the primary engine of economic growth and in which search and bargaining frictions are an integral part of the trading environment. The possibility of *product diffusion* is established (i.e., more than one variety of the quality-differentiated product is traded at one time), and the pricing structure of each good on the product ladder is fully characterized. A reduction in market frictions enhances trade and spurs on innovative activity, which raises the rate of economic growth and, by quickening the pace of Schumpeterian creative destruction, shortens the length of the product cycle. Aggregate-demand management policies, by increasing the thickness of the market, may have a beneficial effect on welfare.

II. An Illustrative Model

Consider a discrete-time economy in which there are two theaters of economic activity: a goods market (characterized by search and matching) and an innovative sector, which (vertically) improves the quality of the traded product. The level of R&D expenditure determines the "contribution" made by each new innovation. Successful innovators license their blueprint to consumer-producers and accrue royalty income from each unit traded. We use this framework to establish the possibility of multiple Pareto-rankable equilibria and examine the long-run growth consequences of a reduction in market frictions.

The intuition underlying our findings is simple. First, consider a thick-market/high-growth equilibrium. A "thick" product market, by virtue of the large volume of trade, encourages innovative firms to conduct costly R&D activity. In turn, high levels of R&D activity (by raising the value of trade) induce agents to search intensively for trading partners, which then makes for a thick market. A thin-market/low-growth configuration can also be a steady-state equilibrium for analogous reasons. Second, consider a reduction in the severity of trade frictions. This lowers the cost of search, which induces agents to increase their search intensity. The induced greater volume of trade raises the returns from holding a patent, which enhances R&D activity and stimulates growth. The rest of this section formally sets out the model.

The goods market is populated by a continuum of infinitely-lived integrated consumer-producers of mass C who have access to a production technology which enables them to produce (instantly) a unit of an indivisible and perishable good at the beginning of each period. Once production occurs, agents enter the product market whereupon they search for a trading partner. After a successful match, trade is instantaneous and is quid pro quo. The probability of contacting a trading partner depends positively on: (i) each individual's search effort ℓ and (ii) the average search effort of all other individuals in the market ℓ'. Assumption 1 describes the matching technology,

ASSUMPTION 1: *The probability of matching in each period is* $m = \theta f(\ell, \ell')$ *where* $\theta > 0$ *and* $f(\cdot)$ *is a function which is strictly increasing and strictly concave in each argument and satisfies:* $f(0,0) = 0$, $f_{\ell\ell'} > 0$, $f(\ell, 0) = f(0, \ell') = 0$, *and the Inada conditions (i.e.,* $\lim_{z \to 0} f_z = \infty$ *and* $\lim_{z \to \infty} f_z = 0$ *where* $z = \ell, \ell'$*).*

The term θ parameterizes the market's trade frictions. An increase in θ raises the likelihood of matching and hence corresponds to a reduction in the severity of trade frictions. According to Assumption 1, search effort displays strategic complementarity, since an increase in others' average search effort ℓ' raises the marginal returns to individual search. This reflects the notion that trade occurs either if an agent *locates* or *is located by* a trading partner. With this formulation, individuals can increase the probability of trading and consuming, in any given period, if it proves profitable for them to do so.

We assume that R&D is the main driving force behind economic growth. In order to make our arguments as clear as possible, we model this sector parsimoniously. The R&D sector is contestable (implying that *ex ante* innovators earn zero expected profits), and in each period a single firm wins the patent race (inconsequential emendations follow if the innovative process is stochastic). The successful innovator licenses the blueprint to each producer-consumer and accrues royalty income on each unit of output traded. R&D expenditure determines the final gains from trade y_t according to

$$(1) \qquad y_t = a(x)[\gamma(x)]^t$$

where $a(x)$ is the scale of output and $\gamma(x) - 1$ is the rate of economic growth.[1]

ASSUMPTION 2: *The functions* $a(x)$ *and* $\gamma(x)$ *are strictly increasing and strictly concave in each argument;* $\gamma(x)$ *satisfies the boundary conditions* $\gamma(0) = \gamma_0 > 0$ *and* $\lim_{x \to \infty}\{r - [\gamma(x) - 1]\} > 0$.

The successful innovator earns royalty income from each successful transaction of $2s_0 a(x)[\gamma(x)]^{t+1}$, where $s_0 \in (0,1)$.

Search and R&D activities are accompanied by real costs. More specifically, the cost per unit of search effort equals $\tau_0[\gamma(x)]^t$ and the cost per unit of R&D expenditure equals $k_0[\gamma(x)]^t$, where $k_0 > 0$.[2]

We now specify the value $\widetilde{V}_t$ to being a trader (which under Assumption 2 is bounded). From Bellman's equation,

$$(2) \qquad \widetilde{V}_t = \{\theta f(\ell, \ell')a(x)(1 - s_0) - \tau_0 \ell\}[\gamma(x)]^t + (1 + r)^{-1}\widetilde{V}_{t+1}.$$

The first term is the expected value from consumption net of search costs; the second is the expected discounted future value of trade. Since all variables grow at the rate $\gamma(x) - 1$, it is convenient to transform (2) into an equivalent stationary problem by dividing through by $[\gamma(x)]^t$. The value in "effective units," V, is given by

$$(3) \qquad V = \frac{[\theta f(\ell, \ell')a(x)(1 - s_0) - \tau_0 \ell](1 + r)}{r - [\gamma(x) - 1]}.$$

The denominator $r - [\gamma(x) - 1] \leq r$ is the effective discount rate in an economy with ongoing growth.

[1] More precisely, the size of each innovation is $\gamma(x) \equiv \Gamma(x, R)$ where Γ exhibits constant returns to scale (CRS) and the (exogenous) stock of research capital is normalized to unity. As in Aghion and Howitt (1992), the CRS assumption allows us to equate each R&D firm's optimization problem with that of an aggregate problem involving a single firm.

[2] The term $\gamma(x)^t$ appears in each expression to ensure the existence of a balanced steady-state growth path.

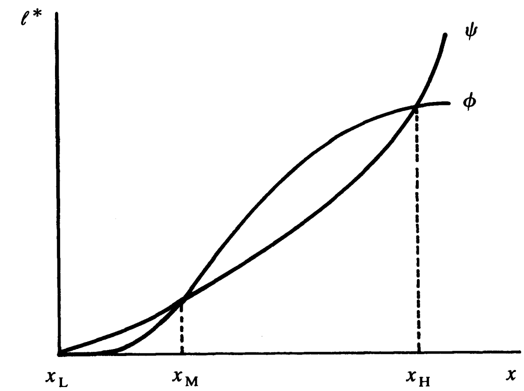

FIGURE 1. STEADY-STATE EQUILIBRIA

We next turn to the individual's optimal choice of search intensity. Each consumer-producer, taking ℓ' and x as given, seeks to maximize their utility net of search costs: $\max_{\ell}\{V - \tau_0 \ell, 0\}$. The first-order condition is

$$(4) \qquad \theta f_{\ell}(\ell, \ell')a(x)(1-s_0) \leq \tau_0$$

(with equality if $\ell > 0$), which says that the marginal benefit of search activity, the first term on the left-hand side of (4), equals its marginal cost, τ_0, at an interior maximum. Notice that only symmetric equilibria, in which $\ell = \ell'$ $(= \ell^*)$ are admissible. In addition to the trivial no-search, no-trade equilibrium, we can show that for each x there exists a unique $\ell^* > 0$ that solves (4). In Figure 1, we represent this relationship by $\ell^* = \phi(x;\theta)$. Totally differentiating (4), it is easily verified that: $\phi_x > 0$ and $\phi_\theta > 0$, indicating that either higher R&D activity or reduced market frictions, by increasing the returns to search, enhance search effort.

In order to close the model, it is necessary to characterize the R&D firm's optimal choice of expenditure x. The R&D firm seeks to maximize its present discounted value: $\gamma(x)a(x)2[s_0 mC](1+r)^{-1} - k_0 x$, taking the matching rate, $m = \theta f(\ell, \ell')$, as given. Assuming that $a(x)\gamma(x)$ is strictly concave in x the first-order condition for an interior solution can be written as

$$(5) \quad \{\gamma(x)_x a(x) + \gamma(x)a(x)_x\} \times \theta f(\ell, \ell')Cs_0(1+r)^{-1} = k_0/2.$$

Letting $\ell = \ell' = \ell^*$, equation (5) can be used to derive the economy's (inverse) R&D schedule: $\ell^* = \psi(x;\theta,C)$ (see Figure 1). Totally differentiating (5) implies: $\psi_x > 0$, $\psi_\theta < 0$, and $\psi_C < 0$, indicating that, by raising the volume of trade, a reduction in market frictions or an increase in the mass of consumers enhances R&D activity.

Using the properties of the $\psi(\cdot)$ and $\phi(\cdot)$ schedules it is possible to establish the following proposition.

PROPOSITION 1: *Under Assumptions 1 and 2, there exists at least one (and possibly multiple) nondegenerate steady-state equilibrium growth path(s).*

Figure 1 displays the possibility of multiple steady-state growth paths.[3] It is straightforward to show that the zero-search-effort solution corresponds to the low-R&D/low-growth equilibrium (x_L), while the high-search-effort solution corresponds to the high-R&D/high-growth equilibrium (x_H). It may be noted that more than the three illustrated steady-state equilibria may exist, since the $\psi(\cdot)$ and $\phi(\cdot)$ loci may intersect at a number of points.

Finally, standard comparative-static exercises yield the second proposition.

PROPOSITION 2: *In the neighborhood of the high-growth equilibrium, either an improvement in market efficacy resulting from a larger θ, or an increase in the mass of traders, C, raises the endogenous growth rate $\gamma(x^*)-1$.*

Intuitively, an increase in either θ or C enhances search activity. Higher search activity, promotes trade, which in turn raises the royalty income that accrues to success-

[3]An example is: $f(\cdot) = \ell^{0.26}\ell'^{0.24}$; $a(x) = \ln(x)$, $\gamma(x) = 10 + x^{0.45}$; $r = 20$, $\tau_0 = 10$, $s_0 = 0.5$, $k_0 = 20$, $\theta = 90$, and $C = 1$. Then, in addition to the trivial no-trade equilibrium $\ell^* = 0$, two interior solutions for x^* are: $x^* \in \{1.92, 7.28\}$.

ful innovators. This encourages R&D activity, leading to a higher rate of economic growth. In this way, our model captures an intimate nexus between market development and perpetual growth.

III. Concluding Remarks

The model developed in Section II above illustrates some important channels linking market organization and economic growth. In particular, with endogenous search effort and R&D activity, a reduction in trade frictions generates a higher growth rate. Despite its great simplicity, the framework is rich enough to capture the possibility of multiple steady-state equilibria and the growth-enhancing effects of a reduction in trade frictions. However, precisely because of its simplicity, a number of interesting issues cannot be addressed. Specifically, dynamic interactions between the innovative process and market participation are not permitted. More importantly, the assumptions made about R&D activity imply that only one good is traded at any point in time. As a consequence, the model captures neither the possibility of product diffusion nor the induced dispersion of prices. These and other issues are explored in Laing et al. (1994).

REFERENCES

Aghion, Phillipe and Howitt, Peter. "A Model of Growth Through Creative Destruction." *Econometrica*, March 1992, *60*(2), pp. 323–51.

______. "Growth and Unemployment." *Review of Economic Studies*, July 1994, *61*(3), pp. 477–94.

Bean, Charles and Pissarides, Christopher. "Unemployment, Consumption and Growth." *European Economic Review*, May 1993, *37*(4), pp. 837–54.

Diamond, Peter. "Aggregate Demand Management in Search Equilibrium." *Journal of Political Economy*, August 1982, *89*(4), pp. 881–94.

Grossman, Gene and Helpman, Elhanan. "Quality Ladders in the Theory of Growth." *Review of Economic Studies*, January 1991, *43*(1), pp. 43–62.

Laing, Derek; Palivos, Theodore and Wang, Ping. "Vertical Innovation, Product Cycles, and Endogenous Growth in Search Equilibrium." Working paper, Pennsylvania State University, December 1994.

______. "Learning, Matching, and Growth." *Review of Economic Studies*, January 1995, *62*(1), pp. 115–29.

Lucas, Robert E. "On the Mechanics of Economic Development." *Journal of Monetary Economics,* July 1988, *22*(1), pp. 3–42.

Mortensen, Dale T. "Property Rights and Efficiency in Mating, Racing, and Related Games." *American Economic Review*, December 1982, *72*(5), pp. 968–79.

Pissarides, Christopher. "Short-Run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages." *American Economic Review*, June 1985, *75*(3), pp. 676–90.

Romer, Paul M. "Increasing Returns and Long-Run Growth." *Journal of Political Economy*, October 1986, *94*(5), pp. 1002–37.

Stokey, Nancy. "Learning by Doing and the Introduction of New Goods." *Journal of Political Economy*, August 1988, *96*(4), pp. 701–17.