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Agricultural R&D and Economic Growth

by

Elias Dinopoulos

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East Lansing, Michigan 48824

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Patrick Diskin is a Graduate Assistant in the Department of Agricultural Economics, MSU.

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SUMMARY

The paper develops a dynamic general-equilibrium model of Schumpeterian growth which is fueled by industrial and agricultural R&D. The former is private and results in better production processes, whereas the latter is government-financed (public and applied) R&D and generates better crop varieties. The arrival of innovations in either sector is stochastic.

The model is used to calculate the steady-state equilibrium and the growth-maximizing mix of agricultural and industrial R&D investments. It is also used to highlight the properties of social rates of return (ROR) of R&D which are based on partial-equilibrium calculations. These measures overestimate the true agricultural social ROR and underestimate the true industrial social ROR of R&D investments. This systematic bias increases with the size of the R&D project under evaluation.

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1. INTRODUCTION

In the past two decades, the economic performance of most sub-Saharan African countries has been disappointing (Jones and Kiguel, 1994). This record is attributed in part to the need for further macroeconomic reforms, even in countries having undertaken structural adjustment programs, and in part due to the failure of the agricultural sector, which forms the dominant sector in most sub-Saharan economies. Despite the adverse macroeconomic policies and poor overall performance of agricultural sectors, a number of successes in agricultural research and development (R&D) have been quantified (see Oehmke and Crawford (1993) for a review). Based on partial-equilibrium calculations rates of returns (RORs) to investment in African agricultural research were sufficiently large for Oehmke and Crawford to recommend maintaining or increasing slowly the real levels of funding. The pattern of simultaneous success in agricultural R&D and stagnant or slow agricultural growth begs the question: How can agricultural R&D best be used to stimulate broad-based economic growth?

Recent developments in growth theory, under the heading of endogenous growth, emphasize the pivotal role of endogenous technological progress through research and development (R&D) investments on long-run growth.[1] Since agriculture represents the most significant sector in many developing countries, the combination of high ROR for agricultural investments and low aggregate economic growth raises several important analytical questions: What is the link (if any) between agricultural R&D and national economic growth? Do the consumer and producer surplus calculations used to represent the social benefits of R&D in ROR computations adequately measure the aggregate economic benefits of R&D? Does the partial equilibrium approach, which is used routinely in ROR calculations, introduce any systematic bias to the magnitude of ROR? If the contribution of agricultural R&D to economic growth is positive, are there any ROR based rules to indicate whether there is overinvestment or under investment in agricultural R&D?

The present paper can be viewed as the first step toward addressing the above questions. A dynamic general-equilibrium model of economic growth is developed in which total factor productivity (TFP) growth is fueled by two types of sector-specific R&D investments: Agricultural R&D and industrial R&D. The most important qualitative difference between the two types of R&D is that agricultural R&D can be imitated instantaneously and therefore is financed through government expenditures, whereas industrial R&D cannot be imitated and can be financed through temporary monopoly profits. The model uses analytical insights from the neo-Schumpeterian approach to economic growth which emerged in the late 1980s.[2]

Several findings are interesting. The expected long-run growth rate of the economy is an increasing and concave function of both agricultural and industrial R&D investments.

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[1] Dinopoulos (1994) provides a recent overview of Schumpeterian growth theory (Schumpeter, 1942) which is one branch of endogenous growth theory.

[2] Early neo-Schumpeterian models of growth include Romer (1990), Segerstrom, Anant and Dinopoulos (1990), Aghion and Howitt (1992), and Grossman and Helpman (1991).

Consequently, given R&D resource constraints, there exists a level of agricultural R&D which maximizes aggregate expected long-run growth. The model is also utilized to calculate the partial equilibrium social ROR of R&D investments in both sectors of the economy. The model shows that for any given level of agricultural or industrial R&D investment, the partial-equilibrium methodology overestimates the social ROR of agricultural R&D investments, and underestimates the social ROR of industrial R&D. This bias of partial equilibrium methods increases with the size of the project under consideration. Finally, the paper provides criteria for R&D project evaluation based on national growth maximization.

The next section develops the basic elements of the model. Section 3 derives the steady-state solution to the model. Section 4 characterizes the properties of growth-maximizing R&D investments. Section 5 analyzes the economics of ROR of R&D investments from the point of view of the model developed, and section 6 states several conclusions and suggestions for further research.

2. A MODEL OF LONG-RUN SCHUMPETERIAN GROWTH

The economy consists of two sectors, agriculture and industry, with each sector characterized by two activities: manufacturing of a final product and R&D services. Manufacturing of agricultural or industrial output uses a sector-specific factor (call it capital) and unskilled labor which is perfectly mobile intersectorally. The manufacturing of final goods is characterized by constant returns to scale. R&D services are modeled as an intermediate good and their production – in either agriculture or industry – requires skilled labor and exhibits diminishing returns. Skilled labor is used only in R&D activities, and it is perfectly mobile across the two sectors. The model abstracts from population growth, physical capital accumulation and unemployment or underemployment of resources.

The production structure of final goods is a special case of the specific-factors model which has been used extensively in both economic development and international trade. The production structure of R&D activities follows the neo-Schumpeterian approach to growth and emphasizes the scarcity of human capital (skilled labor) which is one of the most important impediments to growth in many developing countries. The assumption of diminishing returns to R&D is supported empirically (Thompson (1994), Arroyo, Dinopoulos, and Donald (1994)) and is needed to avoid corner solutions and no-growth traps (Segerstrom (1995)).

In this economy, Schumpeterian growth is fueled by two types of endogenous innovation activities: agricultural and industrial R&D. Agricultural R&D investments result in the discovery of better agricultural techniques of production or better crop varieties which increase the yield of agricultural output. The discovery of better agricultural techniques or varieties is stochastic, and the arrival of agricultural innovations is governed by a Poisson process whose intensity increases in agricultural R&D investment. In other words, higher levels of agricultural R&D accelerate the expected number of discoveries per unit of time and thus generate higher long-run growth in output. We also assume that perfect competition prevails in the agricultural sector in both product and factor markets. The assumption of perfect competition in agriculture even in the presence of process innovations can be justified on several grounds. First, most agricultural crops are homogeneous products. Second, a large variety of agricultural innovations are easily imitated. Improved, open-pollinated crop varieties are one example; asexually propagated planting materials such as cassava and many types of potato also allow easy transfer from farmer to farmer. Improved tillage practices such as bunds and tied ridges are easily copied by someone who has seen them, as are numerous other farm-management techniques. In general an innovating agricultural firm is unlikely to gain monopoly power.[3] Thus imitation of new varieties is almost instantaneous. Third, agriculture in most developing countries consists of thousands of small farmers whose income is very low to finance risky large scale R&D investments.

The assumption of perfect competition in agricultural final products implies that each

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[3] Exceptions include hybrid varieties, improved livestock breeds, patented materials, and those inputs and equipment that require specialized production knowledge such as improved tractors or better rollers.

individual farmer does not have an economic incentive to engage in R&D investment. Under constant returns to scale, the value of final output equals the cost of production at each instant in time. The absence of economic profits implies that the government has to finance agricultural R&D investments.[4] In other words, we model agricultural R&D as an applied but public activity, and assume that the government pays the wage bill of skilled workers engaged in agricultural R&D. We assume, therefore, that the transfer and development of agricultural technology is financed through domestic lump-sum taxes or foreign aid.

Many examples of agricultural R&D investments fit the above-mentioned process. Traditional breeding programs that use varietal screening trials are one example. Thousands of potential varieties might be screened to determine which genotypes express desirable characteristics in different environmental settings. The probability of finding a suitable variety increases with the number of varieties tested. Since the number of varieties tested increases with the number of researchers, the current model provides adequate representation of this area of agricultural research. Similarly, it represents a variety of on-station and on-farm testing and screening activities. Conceptual investigations and research also have been described as activities in which the arrival of innovative ideas contain a random component and are consistent with the model. In addition, agricultural R&D expenditures, particularly in developing countries, are financed primarily by the national government, international donors, or other public-sector agencies.

Production of the final industrial good occurs under constant returns to scale. Industrial R&D utilizes only skilled labor and exhibits instantaneous diminishing returns. The arrival of industrial innovations is governed by a Poisson process whose intensity is an increasing and concave function of R&D resources. Industrial R&D is modeled through stochastic and sequential R&D races. The winner of each R&D race enjoys temporary market power (there is no imitation by assumption), until it is replaced by the firm that wins the next R&D race. The random time intervals between industrial innovations, which follow an exponential distribution, serve as market-determined "patents" for the winner of R&D races. Consequently, the only qualitative difference between agriculture and industry is the market structure. The former is characterized by perfect competition and public R&D, whereas the latter exhibits temporary monopoly power and private R&D.

Private (industrial) R&D investments are financed through consumer savings. Consumers allocate their income between consumption and savings by maximizing their discounted lifetime utility. Consumer savings are then channeled to firms engaged in R&D through a financial sector which is not modeled explicitly.[5] The instantaneous interest rate equalizes the demand to the supply of savings at each instant in time.

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[4] Romer (1989) has an excellent discussion and analysis of market structure considerations related to R&D investments.

[5] Dinopoulos (1994) assumes that there is a stock market which helps consumers to diversify the aggregate risk. Aghion and Howitt (1992) describe how a banking sector can replicate the role of the stock market in financing private R&D expenditures.

The following subsections present the formal elements of the model, which utilizes building blocks from Dinopoulos and Kreinin (1994) and Dinopoulos and Syropoulos (1994). Although the private R&D component of the present model is similar to that used in the other two studies, the production structure of final goods and the modeling of agricultural R&D are different.

2.1. Consumer Behavior

The intertemporal utility function of the representative consumer is defined to be:

$$U = \int e^{-\rho t} \ln[z(t)]dt \tag{1}$$

where $\rho > 0$ is the constant subjective discount rate of the consumer, and $z(\cdot)$ is the instantaneous subutility function:

$$z(t) = X_1^{\theta} X_2^{1-\theta}. \tag{2}$$

Variable X_1 is the amount of agricultural output produced - and consumed - at each instant in time, X_2 is the quantity of industrial output, and $0 < \theta < 1$ is a constant parameter. Subscripts 1 and 2 denote variables and functions in the agricultural and industrial sectors, respectively. The Cobb-Douglas instantaneous utility function facilitates the exposition of the analysis; it allows the existence of a steady-state equilibrium with different sectoral growth rates by abstracting from cross price effects; and it is also convenient for highlighting the links between partial-equilibrium and general-equilibrium based calculations of ROR of R&D investments.

The instantaneous final output demands for each sector are:

$$X_1 = \frac{\theta C}{p_1}, \quad X_2 = \frac{(1-\theta)C}{p_2} \tag{3}$$

where C denotes the aggregate consumption expenditure at time t, and p_i is the price of product $I \in (1, 2)$. For simplicity of exposition, time arguments of variables are suppressed whenever possible.

The solution to the intertemporal maximization problem of the representative consumer provides the following equation of motion for aggregate consumption expenditure C(t):

$$\frac{\partial C}{\partial t} = (r - \rho)C \tag{4}$$

where r(t) is the instantaneous interest rate at time t. At the steady-state equilibrium consumption expenditure is constant over time, so that the instantaneous interest rate must be constant and equal to the subjective discount rate:

(5) $$r = \rho$$

Equation (5) is a standard result in Schumpeterian growth models (e.g., see Dinopoulos and Kreinin (1994), or Dinopoulos and Syropoulos (1994)).

2.2. Production Structure and R&D Investments

The production functions of final agricultural and industrial outputs are

(6) $$X_1 = A_1 L_1^{½} K_1^{½}$$

(7) $$X_2 = A_2 L_2^{½} K_2^{½}$$

where $A_i(t)$ is the level of total factor productivity (TFP) at time t; L_i and K_i denote the amount of unskilled labor and the specific factor in sector I ϵ (1, 2) respectively. Equations (6) and (7) state that at each instant in time, the production of final goods exhibits constant returns to scale and takes an identical Cobb-Douglas form for both sectors. The use of Cobb-Douglas production functions allows the derivation of explicit solutions and enhances the intuition of the analysis.

Because labor is assumed to be intersectorally mobile and there is no unemployment, the full employment condition for unskilled labor is:

(8) $$L_1 + L_2 = L$$

where L is the economy's endowment of unskilled labor. Observe that equations (2), (6), (7), and (8) describe the standard sector-specific factors model. The sector-specific factors K_1 and K_2 can be interpreted as land and capital respectively.

Technological innovations take the form of discrete and equal jumps in the level of total factor productivity. The arrival of innovations is stochastic, and their expected frequency depends positively on R&D resources. The following paragraphs formalize the evolution of TFP in each sector.

Consider the agricultural sector first, and assume that the TFP level A_1 is given by

(9) $$A_1(j) = \alpha_1^j, \qquad \alpha_1 > 1, \qquad j \in (0,1,2,\ldots\infty)$$

where α_1 is the constant proportional increment in TFP resulting from one innovation in agriculture, and j(t) is the total number of agricultural innovations at time t. To interpret (9), suppose that at time zero $j = 0$ and therefore the agricultural TFP is $A_1(0) = \alpha_1^0 = 1$. This implies that agricultural output is $X_1(0) = L_1^{½} K_1^{½}$ at time zero. If the first agricultural innovation occurs, then agricultural TFP increases to $A_1(1) = \alpha_1^1 = \alpha_1$ because $j = 1$ in (9). Ceteris paribus, agricultural output increases to $X_1(1) = \alpha_1 L_1^{½} K_1^{½} = \alpha_1 X(0)$. Consequently, the percentage increase in output caused by the first innovation is $[X(1) - X(0)]/X(0) = \alpha_1 - 1$. Equation (9) implies that the percentage increase in output is constant and equal after each innovation. For example, if $\alpha_1 = 1.1$, then agricultural output increases by 10 percent after each discovery.

The evolution of agricultural TFP is governed by the stochastic differential equation

$$dA_1 = (\alpha_1 - 1)\, A_1 ds_1 \tag{10}$$

where s_1 is a random variable that takes the value of unity with instantaneous probability $\phi_1 dt$ and the value of zero with instantaneous probability $1 - \phi_1 dt$. Equation (10) describes a memory less Poisson process with intensity ϕ_1. Assume also that ϕ_1 is an increasing and concave function of agricultural R&D services that takes the following explicit form where R_1 is the amount of

$$\phi_1 = \frac{R_1}{1 + R_1} \tag{11}$$

aggregate R&D services in agriculture. Equation (11) implies that $\partial\phi_1/\partial R_1 > 0$ and $\partial^2\phi_1/\partial^2 R_1 < 0$ (instantaneous diminishing returns to R&D). This functional form of the intensity of the Poisson process simplifies the algebra, but maintains the basic economic intuition.[6]

The production of R&D services utilizes only skilled labor according to the following function

$$R_1 = \delta_1 N_1 \tag{12}$$

where δ_1 is the constant productivity of skilled labor in agricultural R&D services, and N_1 is the number of skilled workers engaged in agricultural R&D.

The evolution of industrial TFP takes a very similar form to that of agricultural TFP. It is characterized by equal increments $\alpha_2 > 1$, by a Poisson process with intensity ϕ_2 which is an increasing and concave function of industrial R&D services R_2, and the amount of R&D services in industry is produced by skilled workers with constant productivity δ_2. The following equations describe the evolution of industrial TFP:

$$\begin{aligned} &A_2(k) = \alpha_2^k, \qquad \alpha_2 > 1, \qquad k \in (0,1,2,\ldots,\infty), \\ &dA_2 = (\alpha_2 - 1)A_2 ds_2 \end{aligned} \tag{13}$$

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[6] Dinopoulos (1994), Houser (1994), and Segerstrom (1995) provide alternative specifications of instantaneous diminishing returns to R&D.

where s_2 takes the value of unity with instantaneous probability $\phi_2 dt$ and the value of zero with instantaneous probability $1 - \phi_2 dt$.

(14) $$\phi_2 = \frac{R_2}{1 + R_2}$$

(15) $$R_2 = \delta_2 N_2.$$

The description of the model closes with the full employment condition of skilled labor:

(16) $$N_1 + N_2 = N$$

where N_1 is the level of agricultural R&D researchers, N_2 is the level of industrial R&D researchers and N is the fixed endowment of skilled labor in the economy.

The assumption of perfect substitutability between skilled agricultural and industrial laborers, while not an exact representation of reality, is a closer approximation than it may appear at first glance. At each instant in time some workers, for example plant breeders, may have trouble making a comparable contribution to industrial R&D. However, a number of agricultural researchers--engineers, packaging designers, some social scientists, laboratory technicians, and many others--may be easily transferable among agricultural and industrial activities. For example, marketing specialists involved in determining consumer preference for bread flours made from wheat mixed with sorghum could easily ascertain preferences regarding consumer electronics. Moreover, in the long run, the proportions of scientists specialized in agriculture or industry can be changed through training and education.

3. STEADY-STATE EQUILIBRIUM

The model is recursive and the steady-state equilibrium determines four endogenous variables which are constant over time: The aggregate consumption expenditure, C, industrial R&D services, R_2, the wage of unskilled workers, w, and the wage of skilled workers, w_s. Skilled labor is used as a numeraire in the model, and therefore $w_s = 1$. This section determines the steady-state values of the three remaining endogenous variables of the model, C, w, and R_2, for a given level of agricultural R&D services, $\bar{R}_1$.

Because temporary monopoly profits fuel the pace of industrial innovations, we start with the derivation of the zero-profit equilibrium condition in private R&D investments. Denote with $\psi_2(\cdot)$ the unit cost function that corresponds to $X_2 = L_2^{1/2} K_2^{1/2}$. Because X_2 exhibits constant returns to scale, ψ_2 is a function of the wage of unskilled workers and the rental of the sector-specific factor. The instantaneous profits of the sole winner of the jth race in the industrial sector are

$$\pi_2 = (p_2 - \frac{\psi_2}{\alpha_2^j})X_2 = (p_2 - \frac{\psi_2}{\alpha_2^j})\frac{(1 - \theta)C}{p_2} \tag{17}$$

which states that the maximum instantaneous profits are proportional to aggregate consumption where p_2 is the price of the product and X_2 is the quantity demanded. The winner of the jth race discovers a better process innovation that reduces its marginal costs to ψ_2/α_2^j which is strictly less than the marginal cost of the winner of the previous race (ψ_2/α_2^{j-1}). By charging a price slightly less than the marginal costs of the existing monopolist, the firm with the state-of-the-art technology can capture the total market. We assume that even if the price of the state-of-the-art product equals the marginal costs of the existing monopolist consumers buy the product produced by the latest technology, although in principle they are indifferent. The maximum level of instantaneous profits is obtained by setting $p_2 = \psi_2/\alpha_2^{j-1}$ in (17):

$$\pi_2 = \frac{(\alpha_2 - 1)}{\alpha_2}(1 - \theta)C \tag{18}$$

which states that the maximum instantaneous profits are proportional to aggregate consumption expenditure.

The flow of instantaneous profits serves as an incentive for firms to engage in industrial R&D investments. Let V denote the expected discounted profits for a firm in a typical R&D race. In the steady-state equilibrium, we have

$$V = \int_0^\infty \left[\int_0^y \pi_2 e^{-xr} \, dx \right] \phi_2 e^{-y\phi_2} \, dy \tag{19}$$

The term in square brackets is the flow of instantaneous profits discounted to time zero when the innovation occurs where $r(t) = \rho$ is the instantaneous steady-state interest rate. The duration of temporary monopoly profits lasts until time y when the next innovation occurs. Variable y is exponentially distributed with parameter ϕ_2 which is the intensity of the Poisson process that governs the arrival of industrial innovations. Therefore $\phi_2 e^{-y\phi_2}$ is the probability that the next innovation occurs at time y. The outer integral is the expectation operator over variable y.

Performing the integration in (19), we obtain a simple expression for the expected discounted profits of a successful innovator during an arbitrary R&D race

$$V = \frac{\pi_2}{r + \phi_2} = \frac{\pi_2}{\rho + [R_2/(1 + R_2)]} \tag{20}$$

A successful innovator discounts the flow of instantaneous profits π_2 using the instantaneous market interest rate $r(t) = \rho$ plus the instantaneous probability that the next innovation occurs which terminates its temporary monopoly power.

Let R_{2m} denote firm m's output of industrial R&D services. Then $R_2 = \sum_m R_{2m}$ is the industry-wide amount of R&D services. Assume that firm m's relative instantaneous probability of success is equal to its share of industrial R&D services during an arbitrary race:

$\phi_{2m}/\phi_2 = R_{2m}/R_2$. Finally, suppose that each firm in an R&D race behaves competitively and treats the industry-wide level of R&D services, R_2, as given when it chooses its own R&D level, R_{2m}. These assumptions imply that firm m's instantaneous probability of success is $\phi_{2m}dt$ where $\phi_{2m} = [R_{2m}/(1+R_2)]$.

The expected discounted profits of firm m during an arbitrary R&D race are

$$\frac{VR_{2m}dt}{(1 + R_2)} - \frac{R_{2m}dt}{\delta_2}. \tag{21}$$

The first term in (21) equals the expected discounted benefits for firm m. At each instant in time during a typical race, firm m obtains V with instantaneous probability $\phi_{2m}dt$. The second term in (21) equals the instantaneous R&D costs of firm m. It hires $N_{2m} = R_{2m}/\delta_2$ workers and pays each worker the prevailing wage, which is normalized to one, for an infinitesimal period of time dt.

Each firm in an arbitrary R&D race maximizes (21) with respect to R_{2m}, taking R_2 as given. Thus there are external decreasing returns to R&D, and the size of each firm is indeterminate. However, free entry into each R&D race drives (21) to zero and determines the industry-wide level of R&D investment R_2:

(22) $$V = \frac{(1 + R_2)}{\delta_2}$$

Substituting (20) and π_2 from (18) into (22), we obtain the first steady-state equilibrium condition:

(23) $$R_2(1+\rho) + \rho = \delta_2(1-\theta)\frac{(\alpha_2-1)}{\alpha_2}C$$

Equation (23) defines a positively sloped line in the R_2, C space. Higher values of aggregate consumption expenditure increase instantaneous monopoly profits and expected discounted profits as well. To maintain zero expected discounted profits, higher values of R&D investment are required.

The full employment condition for skilled labor provides another steady-state equilibrium condition

(24) $$\frac{R_1}{\delta_1} + \frac{R_2}{\delta_2} = N$$

which states that skilled labor can be allocated between agricultural R&D, $N_1 = R_1/\delta_1$, and industrial R&D, $N_2 = R_2/\delta_2$. Equation (24) defines a negatively sloped line in the R_1, R_2 space. In addition, since the government chooses the number of agricultural R&D researchers N_1 and therefore R_1, equation (24) determines the level of R_2 for any given level of R_1.

The third steady-state equation is derived from the full employment condition for unskilled labor. We assume that factor markets are perfectly competitive, and therefore the demand for manufacturing labor is determined through cost minimization. In the agricultural sector, this implies that the value of marginal product of unskilled labor equals the wage, i.e., $w = \theta C/2L_1$. Following the same reasoning, cost minimization in industry implies that $w = (1 - \theta)C/2L_2$. Substituting L_1 and L_2 into the full employment condition for unskilled labor (8), we obtain:

(25) $$\frac{1}{2}\frac{C}{w} = L$$

which establishes the final steady-state equilibrium condition. Equation (25) states that increases in aggregate consumption expenditure increase the demand for unskilled labor, and therefore increase the relative wage of unskilled workers.

For any given level of agricultural R&D, R_1, equations (23), (24) and (25) form a diagonal system determining the steady-state values of aggregate consumption expenditure, C, the wage of unskilled workers, w, and the level of industrial R&D, R_2. Indeed, explicit solutions can be obtained for all these variables and comparative steady-state analysis can be done readily. For example, consider the effects of an increase in agricultural R&D level R_1. Equation (24) implies that industrial R&D declines, equation (23) generates a reduction in aggregate consumption expenditure, which induces a reduction in the relative wage of unskilled workers (equation (25)).

What are the characteristics of the steady-state equilibrium with positive agricultural and industrial R&D investments? In the steady-state equilibrium, aggregate consumption expenditure and the allocation of resources across sectors is constant over time. New and better techniques of production are discovered indefinitely in both agriculture and industry. The random time intervals between consecutive innovations in each sector are exponentially distributed. Prices of final goods expressed in units of skilled labor decline over time. Temporary monopoly profits fuel industrial innovation, whereas government-financed R&D generates better crop varieties or better production techniques in agriculture.

4. GROWTH-MAXIMIZING R&D INVESTMENTS

An interesting application of the dynamic general-equilibrium model of Schumpeterian growth is to determine the allocation of skilled workers that maximizes aggregate long-run growth. Long-run Schumpeterian growth equals the expected change in the representative consumer's instantaneous utility:

$$G(R_1,R_2) = \partial[E\ln z(\cdot)]/\partial t = \theta\partial[E\ln X_1]/\partial t + (1-\theta)\partial[E\ln X_2]/\partial t,$$

where E stands for "expected," ln denotes the natural logarithm, and $z(\cdot)$ is defined in (2). The long-run aggregate growth is a weighted sum of agricultural and industrial long-run growth rates, where the weights are the proportions of total expenditure spent in each sector.

The definition of the production function implies that $E\ln X_i = (\ln\alpha_i)E(j_i) + ½\ln(K_iL_i)$ where j_i equals the number of innovations in sector I that have occurred from time zero to time t. In the steady-state equilibrium, K_i and L_i are constant over time, and j_i is a random variable governed by a Poisson distribution with intensity ϕ_i. Consequently, the expected number of innovations in sector I from time zero to t is simply $E(j_i) = t\phi_i$. As a result, the expected growth rate of output in sector I is $\partial[E\ln X_i]/\partial t = (\ln\alpha_i)\phi_i$, and the long-run Schumpeterian growth rate of the economy is

$$G(R_1,R_2) = \theta(\ln\alpha_1)\phi_1(R_1) + (1-\theta)(\ln\alpha_2)\phi_2(R_2) \tag{26}$$

where $\phi_1(R_1) = R_1/(1+R_1)$ and $\phi_2(R_2) = R_2/(1+R_2)$ are the intensities of the two independent Poisson processes. Expression (26) states that the aggregate long-run growth rate is a concave and increasing function of both agricultural and industrial R&D investments.

The government's maximization problem can be stated as follows:

$$\max_{R_1,R_2} G(R_1,R_2) \qquad \text{subject to} \quad \frac{R_1}{\delta_1} + \frac{R_2}{\delta_2} = N \tag{27}$$

The constraint in (27) is the full employment of skilled labor condition (16). Forming the Lagrangian, we can obtain closed form solutions for the growth-maximizing levels of R_1 and R_2:

$$\hat{R}_1 = \frac{\delta_1[\delta_2 N\Gamma - (1-\Gamma)]}{(\delta_1 + \delta_2\Gamma)} \tag{28}$$

$$\hat{R}_2 = \frac{\delta_2[\delta_1 N + (1-\Gamma)]}{(\delta_1 + \delta_2\Gamma)} \tag{29}$$

where $\Gamma = [\delta_1\theta(\ln\alpha_1)/\delta_2(1-\theta)(\ln\alpha_2)]^{½}$. Expressions $\delta_1\theta(\ln\alpha_1)$ and $\delta_2(1-\theta)(\ln\alpha_2)$ correspond to the maximum marginal contributions of labor engaged in agricultural and industrial R&D, respectively, to aggregate growth. If $\Gamma > 1$, then one can define agriculture as the growth-intensive sector since the potential contribution of research scientists to economic growth is greatest in this sector; if $\Gamma < 1$, then industry is the growth-intensive sector; and if $\Gamma = 1$, then both sectors are equally growth-intensive.

Equations (28) and (29) imply that $\hat{R}_1 > 0$ and $\hat{R}_2 > 0$ if Γ does not take extreme values, but satisfies the following condition.

$$1 + \delta_1 N > \Gamma > \frac{1}{1+\delta_2 N} \tag{30}$$

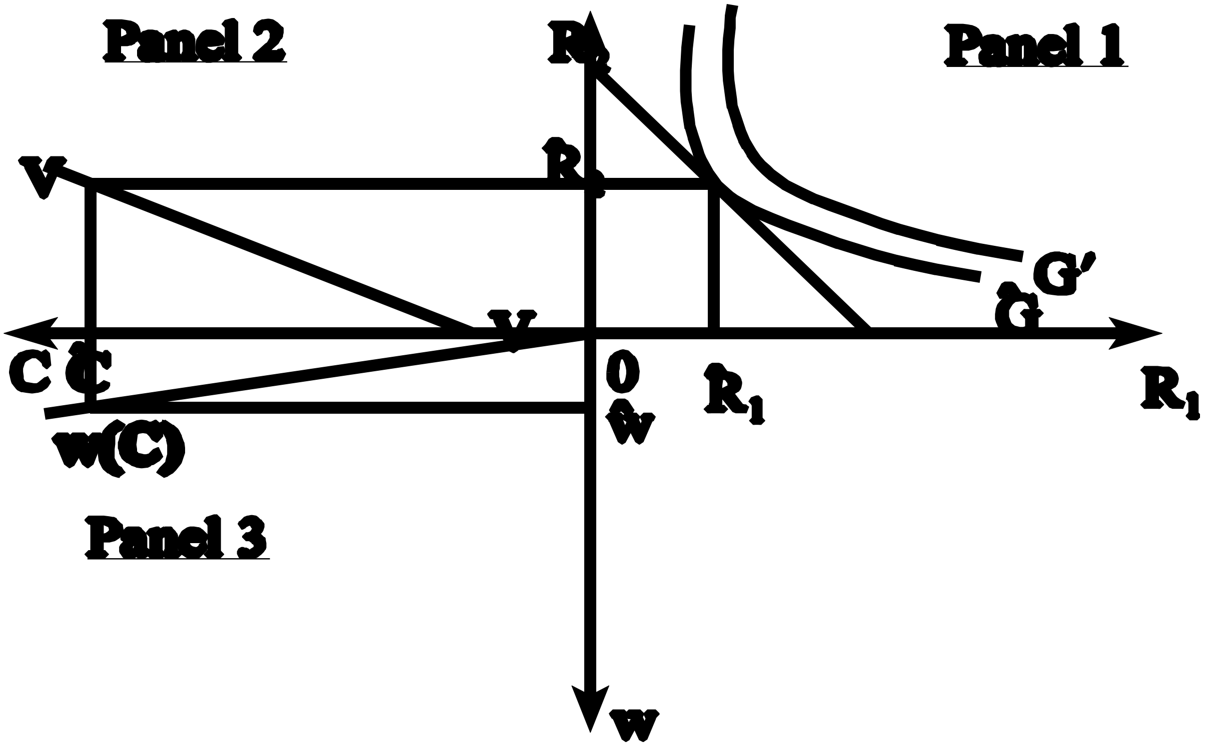
Condition (30) is readily satisfied for large values of skilled labor endowments N. For values of Γ greater or equal to $1 + \delta_1 N$, the government sets $\hat{R}_1 > 0$ and $\hat{R}_2 = 0$ because agriculture has high growth potential relative to industry. Similarly, if $1 + \delta_2 N \geq 1/\Gamma$, then $\hat{R}_2 > 0$ and $\hat{R}_1 = 0$ because the government chooses not to finance any agricultural R&D. If $\Gamma = 1$, equations (28) and (29) imply that $\hat{R}_1 = \hat{R}_2$.

Figure 1 illustrates the solution to (27) and the determination of other endogenous variables of the model. Panel 1 shows the solution to (27) in the R_1, R_2 space. The negatively sloped line NN is the full employment of skilled labor condition. Because $G(R_1, R_2)$ is a continuous, increasing and concave function of R_1 and R_2, there exist well-behaved iso-growth curves, two of which are plotted on panel 1. The tangency between iso-growth curve $\hat{G}(R_1,R_2)$ and line NN determines the growth-maximizing levels $\hat{R}_1$ and $\hat{R}_2$ which are given by equations (28) and (29). The positively-sloped line VV in panel 2 shows the zero-profit condition for industrial R&D (equation 23) in the R_2, C space. As a result, $\hat{R}_2$ determines the steady-state growth-maximizing consumption level $\hat{C}$ in panel 2. Panel 3 illustrates the determination of the unskilled labor wage rate $\hat{w}$ through the positively-sloped line w(C), which is the graph of equation (25) on the C, w space.

Figure 1 clearly demonstrates the role of instantaneous diminishing returns in R&D. If $\phi_i(R_i)$ is linear in R_i for I = 1, 2 (i.e., constant returns of scale in R&D), then the iso-growth curves become straight lines in the R_1, R_2 space, and the maximum long-run growth equilibrium occurs at a corner if $\Gamma \neq 1$, with $\hat{R}_1 = 0$ if $\Gamma < 1$, and $\hat{R}_2 = 0$ if $\Gamma > 1$.

Standard comparative steady-state analysis implies that economies with high endowments of skilled labor N experience higher rates of aggregate growth and have higher levels of both agricultural and industrial R&D investments. However, if $\Gamma > 1$, then as N increases the ratio $\hat{R}_1/\hat{R}_2$ increases; if $\Gamma = 1$, then higher values of N maintain the ratio of agricultural to industrial R&D levels equal to unity; and if $\Gamma < 1$, an increase in N reduces the ratio $\hat{R}_1/\hat{R}_2$.

Figure 1. Growth-Maximizing Steady-State Equilibrium



5. SOCIAL RATES OF RETURN (ROR) OF R&D INVESTMENTS

The social ROR is the interest rate that equalizes the discounted social benefits and costs of R&D. This is the most popular measure of the performance of R&D projects, and summarizes the time path of social net benefits of an R&D project in a single number. The higher the ROR of R&D, the most desirable is the R&D project. The RORs of various R&D projects are compared to the opportunity costs of resources devoted to R&D to determine whether there is under investment or overinvestment in R&D activities.

The extensive literature in agricultural and industrial economics includes calculations of the social ROR of R&D for a variety of products and countries. Echeverria (1990) reports social RORs to investments in agricultural technology; Oehmke (1995) updates this table for investments in African agricultural technology. For Africa, the range of these social RORs is from 3 to 135 percent with the average ROR about 50 percent, which is similar to agricultural RORs in the rest of the world. Nadiri (1993, Table 1) reports social RORs of industrial R&D which span the range between 20 percent and 100 percent with an average of about 50 percent. These studies suggest that the social RORs of R&D are high relative to returns of physical-capital investments, and that the variability of the ROR is also high. In addition, the above studies routinely use partial-equilibrium apparatus to calculate the social ROR and abstract from uncertainty issues associated with risky R&D investments.

The widespread use of social ROR of R&D raises several interesting questions. Is there any relationship between aggregate long-run economic growth and sectoral social ROR? Is there any systematic bias in the magnitude of partial-equilibrium based social ROR of agricultural or industrial R&D? How does uncertainty affect the ROR calculations in each sector? Can we use ROR-based criteria to detect under investment or overinvestment in agricultural (or industrial) R&D? The dynamic general-equilibrium model of Schumpeterian growth is equipped to provide answers to the above questions. An R&D project is well defined in the model and consists of a new process innovation.

5.1. Ex-post Returns to Research

Suppose that an agricultural economist were to evaluate the social ROR of an agricultural R&D project in an economy described by the model. Assume that the economy is in a steady-state equilibrium with $N_1 = R_1/\delta_1$ agricultural researchers engaged in public R&D. The agricultural R&D activity can be interpreted as an attempt to adapt existing crop varieties from abroad to conditions in the home country, an attempt to improve local varieties, or an attempt to develop process innovations in post-harvest handling, storing, processing, and retailing.

Abstracting from observability issues, the first step of calculating the social ROR of agricultural R&D is to construct the demand and supply curves for the final good X_1. Equation (3) defines the inverse demand curve for agricultural output

(31) $$p_1 = \frac{\theta C}{X_1}$$

where θC is the value of income spent on agriculture. Substituting (9) into (6), utilizing condition $w = p_1(\partial X_1/\partial L_1)$ and the definition of the production function, we can write the inverse supply curve of agricultural output as

(32) $$p_1 = \frac{2wX_1}{K_1\alpha_1^{2j}}$$

where w denotes the wage rate of unskilled workers; K_1 is the sector-specific input in agriculture; and j is the number of process innovations that have already occurred.

Figure 2 illustrates the initial equilibrium. Curve DD corresponds to equation (31) for a fixed value of income C, and line $0S^0$ is the graph of equation (32) for given w, K_1 and j. The initial equilibrium is shown by the intersection of supply $0S^0$ and demand DD at point E^0 which defines the following equilibrium values for price and quantity

(33) $$p_1^0 = \frac{1}{\alpha_1^j}\left[\frac{2\theta wC}{K_1}\right]^{1/2}$$

(34) $$X_1^0 = \alpha_1^j\left[\frac{\theta K_1 C}{2w}\right]^{1/2}$$

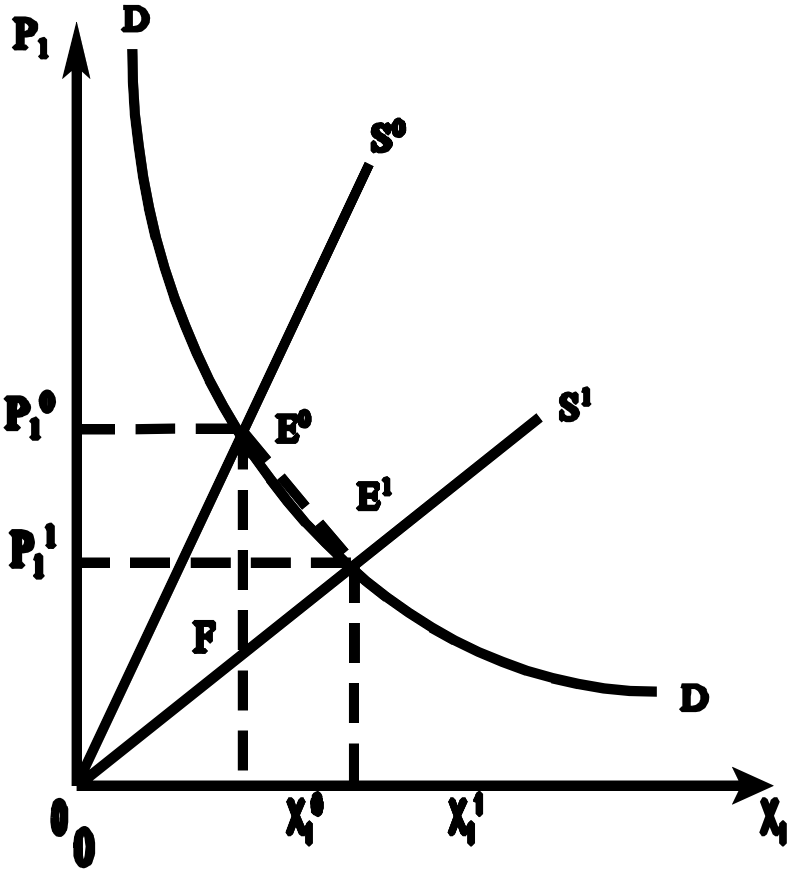
Suppose now invention j+1 occurs, then the supply curve shifts clockwise because the level of technology increases from α_1^j to α_1^{j+1}. Assuming that w and C remain fixed, the inverse demand curve is not affected and the new equilibrium corresponds to point E^1 which defines the new values of price and quantity

(35) $$p_1^1 = \frac{1}{\alpha_1^{(j+1)}}\left[\frac{2\theta wC}{K_1}\right]^{1/2}$$

(36) $$X_1^1 = \alpha_1^{(j+1)}\left[\frac{\theta K_1 C}{2w}\right]^{1/2}.$$

The partial equilibrium impact of a new innovation is to lower the price and to increase the quantity of the final agricultural product.

Figure 2. The Partial-Equilibrium Effect of an Agricultural Process Innovation



The instantaneous social benefits of the new innovation can be approximated by a partial-equilibrium measure of social surplus: the area of triangle $0E^0E^1$. Using straightforward geometry and equations (33) through (36), the instantaneous social benefits of the new discovery can be readily calculated:

$$B_1(\theta,\alpha_1,C) = \frac{\theta(\alpha_1 + 1)(\alpha_1 - 1)C}{2\alpha_1}. \tag{37}$$

The social benefits increase in the share of agricultural expenditure θ, the magnitude of the innovation α_1, and the steady-state income C. Following an identical methodology, one can calculate the instantaneous social benefits due to a better process innovation in the industrial sector:

(38)
$$(\theta,\alpha_2,C) = \frac{(1-\theta)(\alpha_2 + 1)(\alpha_2 - 1}{2\alpha_2}$$

Assume though that the agricultural economist has observed the duration (say t_1) of the R&D phase of the project. Then the historical social ROR is the value of I which solves the following equation:

(39)
$$\int_0^{t_1} \frac{R_1}{\delta_1} e^{-Ix}\, dx = \int_{t_1}^{\infty} B_1 e^{-Is} ds$$

Equation (39) states that a typical agricultural R&D project starts at time zero, for normalization purposes, the discovery of the new crop occurs at time t_1, and the instantaneous social benefits B_1 last for ever starting at time t_1.[7] The left-hand-side of (39) calculates the discounted costs of R&D expenditures $N_1 = R_1/\delta_1$ where N_1 is the number of skilled workers earning a wage equal to unity (due to normalization). The right-hand-side of (39) equals the discounted social benefits. Solving for the discount factor I from equation (39), we obtain the historical social ROR of agricultural R&D:

(40)
$$ROR_1^H = \frac{1}{t_1}\ln\left[1 + \frac{B_1\delta_1}{R_1}\right].$$

Equation (40) is a continuous time approximation to the standard partial-equilibrium formulae, where $B_1\delta_1/R_1$ is the instantaneous social benefit per dollar of R&D costs. Notice that the historical ROR increases in the level of instantaneous social benefits and the productivity of R&D researchers and decreases in the duration of the R&D project and the R&D costs (captured by R_1).

One can apply formula (40) by approximating B_1 with the average yearly social benefits of an innovation, and R_1/δ_1 with the average R&D costs. For example, Schwartz, Sterus, and Oehmke (1993, Table 2) provide information on costs and benefits of cowpea R&D investment in Senegal. According to their table, the average yearly social benefits correspond to $B_1 =$ \$2,742,000 (for scenario 1), the R&D costs per year are $R_1/\delta_1 =$ \$872,000 and t_1 is in the range between 4 and 6 years. The historical social ROR is 28 percent if $t_1 = 5$, it increases to 35 percent if $t_1 = 4$, and drops down to 23 percent if $t_1 = 6$. Schwartz, Sterns, and Oehmke

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[7] This could be easily modified by adding a term such as $e^{-\gamma s}$ where γ is the instantaneous decline in benefits. This formulation adds mathematical complexity to the model without providing any additional insights–if social benefits decay over time, the optimal investment and the ROR in research are lower.

(1993) report a 31 percent rate of return of R&D for this case.

This example suggests that the historical social RORs are very sensitive to the duration of the R&D phase. The magnitude of this problem is amplified by the presence of timing uncertainty between innovations. Uncertainty in t_1 implies a high variance of historical RORs of R&D investments. This property becomes apparent in various surveys of studies that have calculated social RORs. However, the high variability of historical RORs diminishes their desirability and usefulness for policy purposes, because case studies should be used to infer performance of future R&D investments.

5.2. Ex-ante Returns to Research

Ex-ante returns are measured by the expected social ROR to agricultural R&D. In the model developed, the time intervals between consecutive agricultural innovations t_1 are exponentially distributed with parameter $\lambda_1 = (1 + R_1)/R_1$ which equals the expected time between two innovations at the steady-state equilibrium. The expected social ROR is the interest rate I that equalizes the expected social discounted costs of an innovation to its expected social discounted benefits. In the partial-equilibrium framework, this ROR is defined by the following equation:

$$\int_0^{\infty}\left[\int_0^{t_1}\frac{R_1}{\delta_1}e^{-Ix}dx\right]\lambda_1 e^{-\lambda_1 t_1}dt_1 = \int_0^{\infty}\left[\int_{t_1}^{\infty}B_1 e^{-Is}ds\right]\lambda_1 e^{-\lambda_1 t_1}dt_1, \tag{41}$$

where the terms in square brackets are the left-hand-side and the right-hand-side of equation (39). The probability that the discovery of a new variety occurs at time t_1 is given by $\lambda_1 e^{-\lambda_1 t_1}$, and the outer integrals are the expectation operations over variable t_1, which is exponentially distributed with parameter λ_1. Performing the integration operation in (41) and solving for I, we obtain the expected ROR to agricultural R&D:

$$\mathrm{ROR}_1^{E} = \frac{\delta_1 B_1}{\lambda_1 R_1} = \frac{\delta_1 B_1}{1 + R_1}. \tag{42}$$

Similarly, the expected social ROR to industrial R&D can be calculated as

$$\mathrm{ROR}_2^{E} = \frac{\delta_2 B_2}{\lambda_2 R_2} = \frac{\delta_2 B_2}{1 + R_2}. \tag{43}$$

In our economy, the expected RORs are invariant over time and decline in R&D resources R_i for I = 1, 2. If innovations follow a Poisson distribution with parameter $1/\lambda_i = \phi_i$, then the expected ROR can be readily calculated by dividing the average instantaneous social benefits per R&D dollar spent -i.e. $B_i/(R_i/\delta_i)$ - by the average duration of an R&D project which equals λ_i in our case. These averages require information on many R&D projects in the same sector.

5.3. Partial-equilibrium Bias

Even if one were to calculate the expected ROR of R&D investments correctly using formulas (42) and (43), there is still bias in their magnitudes. This bias is systematic and it is related to the fact that partial-equilibrium-based calculations abstract from the relation between aggregate consumption and R&D services. Figure 1 shows that aggregate consumption expenditure expressed in units of skilled labor is a decreasing function of agricultural R&D, R_1, and an increasing function of industrial R&D, R_2. The economic intuition for this relationship is related to equations (23) and (24). An increase in C increases the profitability of industrial R&D and consequently it increases the demand for industrial researchers, R_2. An increase in R_2 reduces the number of agricultural researchers, R_1, through the full employment of labor condition (24). By assumption, agricultural R&D is not linked directly to aggregate expenditure based on profitability considerations; it is related inversely to aggregate expenditure through the labor market constraint.

Figures 3a and 3b show the expected social ROR as functions of R&D services in each sector. The solid downward sloping lines are the partial-equilibrium expected RORs which take C as given. The dashed downward sloping lines are the general-equilibrium expected RORs in each sector. Equation (37) implies that an increase in R_1, which reduces C, diminishes the instantaneous benefits to agricultural R&D. Similarly, a reduction in R_1 increases R_2 and C, and thus augments the instantaneous benefits of industrial research. Partial-equilibrium calculations holding C constant miss these effects. Figures 3a and 3b also show the growth-maximizing expected ROR for the case $\Gamma > 1$ with agriculture being the growth-intensive sector. Projects that have social expected ROR higher than $\hat{ROR}_1$ or $\hat{ROR}_2$ should be undertaken. It should be emphasized that since there is no systematic relationship between $\hat{R}_1$ and $\hat{R}_2$, it is impossible to tell which growth-maximizing ROR is higher. Of course, in the case of $\alpha_1 = \alpha_2$, $\theta = ½$ and $\delta_1 = \delta_2$, then $\hat{R}_1 = \hat{R}_2$ and $\hat{ROR}_1 = \hat{ROR}_2$. Consequently, although social sectoral RORs might be useful to the ranking of R&D projects within a sector, they cannot be used to provide policy recommendations for aggregate growth performance.

The economic intuition for the upward bias in the expected ROR of agricultural R&D that the partial-equilibrium calculations generate is very simple. Because industrial R&D is based on profitability considerations, there is a direct relationship between the reward to R&D (which increases in C) and R&D services R_2. Agricultural R&D is not related directly to income because it is financed by the government. As a result, an increase in R_2 raises C and reduces R_1 because of the skilled labor employment constraint. Thus, there is a general-equilibrium inverse relationship between income C and agricultural R&D. This general-equilibrium bias increases with the size of the R&D project undertaken.

The magnitude of the bias in developing-country agriculture is probably small. Pardey and Roseboom (1989) show that for most developing countries, expenditure on agricultural research is less than 1% of agricultural product value. However, the effect of hiring additional agricultural scientists (even at below-market rates) on skilled wages and industrial R&D remains an interesting empirical question.

Figure 3a. Agricultural Expected ROR

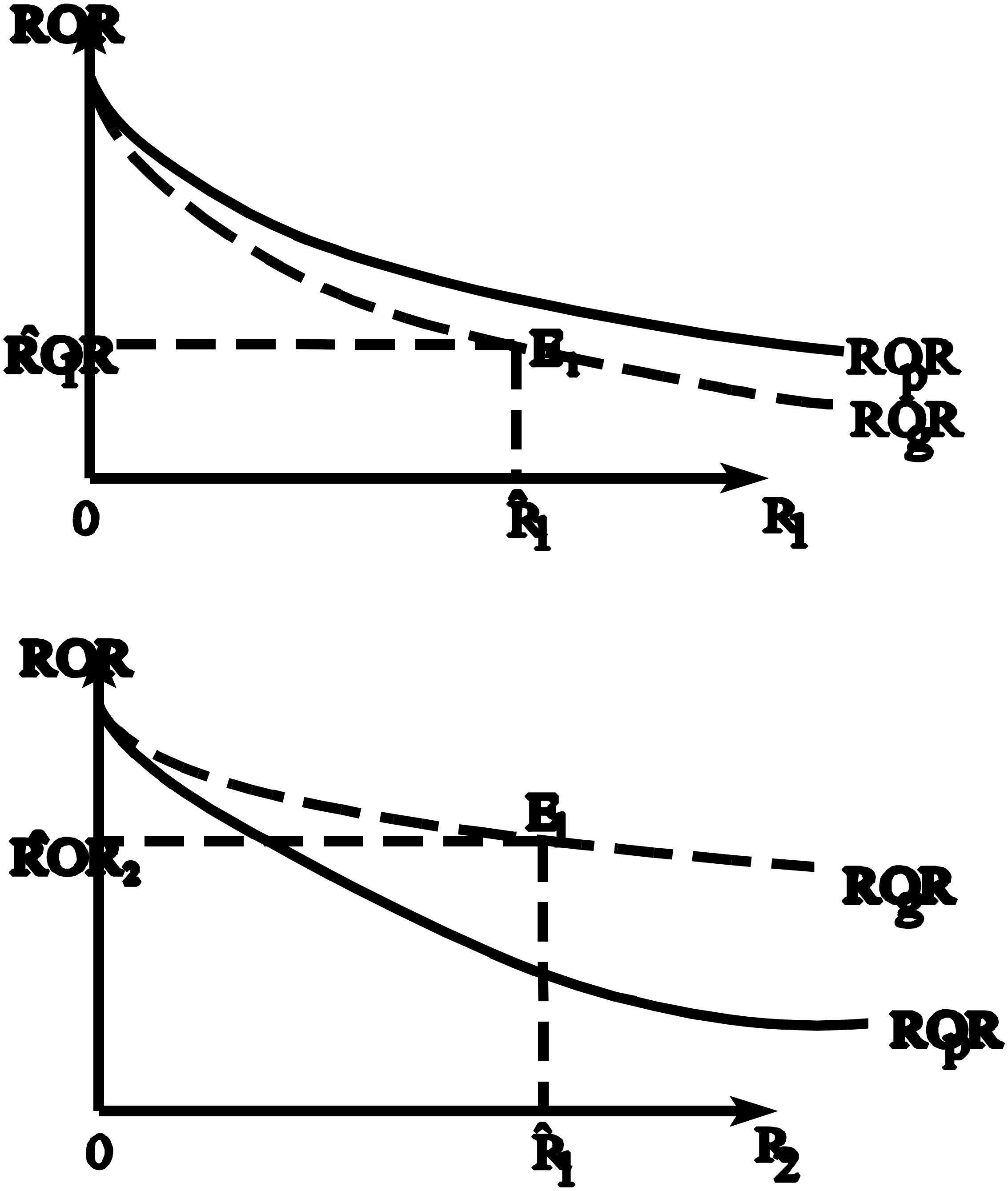

Figure 3b. Industrial Expected ROR

6. CONCLUSIONS

The present paper developed a dynamic general-equilibrium model of Schumpeterian growth with industrial and agricultural R&D investments. Agricultural R&D is government-financed and generates better production techniques. Industrial R&D is fueled by temporary monopoly profits and results in better production techniques. The properties of growth-maximizing sectoral R&D investments were analyzed. The relative growth-intensity of the two sectors determines the optimal allocation of R&D investments across the two sectors, and economies with higher levels of skilled labor (required for R&D investments) experience higher long-run growth rates.

A second application of the model was the analysis of partial-equilibrium based social rates of return of industrial and agricultural R&D. A distinction was made between historical and expected social RORs, the latter being the correct measures in the presence of uncertainty in the timing of innovations. It was also found that the partial-equilibrium framework introduces an upward bias to agricultural social ROR and a downward bias to industrial social ROR. The extent of this bias increases with the magnitude of R&D projects and depends on the private vs public nature of R&D investment in each sector. As a result of this bias, the optimal allocation of R&D resources across sectors cannot be determined from partial-equilibrium ROR measures.

The functional forms of production and taste structures of the model can be generalized at the expense of more complicated algebra and the loss of some economic intuition. Different policy objectives can be readily introduced into the basic model. For example, following Dinopoulos (1994), welfare maximization can be handled easily. More realistic distortions could also be introduced in the form of unemployment, agricultural price support schemes, or financial and product market imperfections. Finally, following Dinopoulos and Syropoulos (1994) and Dinopoulos, Oehmke, and Segerstrom. (1993), the role of trade and trade policies could be analyzed as well. The above mentioned important extensions await further research.

REFERENCES

Aghion, P. and P. Howitt. 1992. A Model of Growth Through Creative Destruction. *Econometrica* 60.2: 323-352.

Arroyo, C., E. Dinopoulos, and S. Donald. 1994. Schumpeterian Growth and Capital Accumulation: Theory and Evidence. University of Florida. mimeo.

Dinopoulos, E. 1994. Schumpeterian Growth Theory: An Overview. Osaka City University *Economic Review* 29. 1: 1-21.

Dinopoulos, E., J. Oehmke, and P. Segerstrom. 1993. High-Technology-Industry Trade and Investment: The Role of Factor Endowments. *Journal of International Economics* 34: 49-71.

Dinopoulos, E. and M. Kreinin. 1994. Schumpeterian Growth and International Transmission of Technology. University of Florida. mimeo.

Dinopoulos, E. and C. Syropoulos. 1994. Trade Liberalization and Schumpeterian Growth. Pennsylvania State University. mimeo.

Echeverria, R. 1990. Assessing the Impact of Agricultural Research. In *Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research*, ed. R. Echeverria. ISNAR. New Jersey: Rutgers University.

Grossman, G. and E. Helpman. 1991. *Innovation and Growth in the Global Economy*. MIT Press.

Jones, C. and M. Kiguel. 1994. Africa's Quest for Prosperity: Has Adjustment Helped? *Finance and Development* 31.2: 2-5.

Nadiri, I. 1993. *Innovations and Technological Spillovers*. NBER Working Paper No. 4423.

Oehmke, J. 1995. Achievements of African Agricultural Research. Staff Paper. East Lansing: Michigan State University, Department of Agricultural Economics.

Oehmke, J. and E. Crawford. 1993. The Impact of Agricultural Technology in Sub-Saharan Africa: *A Synthesis of Symposium Findings*. MSU International Development Paper No. 14. East Lansing: Michigan State University, Department of Agricultural Economics.

Pardey, P. and J. Roseboom. 1989. ISNAR. Agricultural Research Indicators Series.

Cambridge: Cambridge University Press.

Romer, P. 1989. Are Nonconvexities Important For Understanding Growth? *American Economic Review* 80.2: 97-103.

Romer, P. 1990. Endogenous Technological Change. *Journal of Political Economy* 98: S71-S102.

Schumpeter, J. 1942. Capitalism, Socialism and Democracy. Harper. New York.

Schwartz, L., J. Sterns, and J. Oehmke. 1993. Economic Returns to Cowpea Research, Extension and Input Distribution in Senegal. *Agricultural Economics* 8: 161-171.

Segerstrom, P. 1995. A Quality Ladders Growth Model with Decreasing Returns to R&D. East Lansing: Michigan State University. mimeo.

Segerstrom, P., T. C .A. Anant, and E. Dinopoulos. 1990. A Schumpeterian Model of the Product Life Cycle. *American Economic Review* 80: 1077-1091.

Thompson, Peter. 1994. Technological Opportunity and the Growth of Knowledge: *A Schumpeterian Approach to Measurement. Journal of Evolutionary Economics.* forthcoming.

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