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Abstract

In endogenous growth theory the long-run economic expansion is determined by intertemporal preferences for consumption, population growth and other factors, like for instance certain taxes. Here we focus on more subtle and strategic factors, like the willingness of firms to internalize learning externalities, managerial discretion based on the separation between ownership and control, risk aversion and the trade-off between uncertainty and growth. Following seminal work by Scott (1989) a theory of endogenous growth is developed starting from a fundamental growth equation. Learning by doing and learning by watching are the main elements behind this equation. It is shown that firms may internalize the learning externality even under perfect competition. Moreover, firms may maximize the growth rate subject to a financial constraint. However, in a macroeconomic context the result will depend on the way firms set labour demand. Uncertainty has a positive impact on growth, because of precautionary savings. The effect is amplified if projects with higher growth rates are more risky.

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1 Introduction

The theory of economic growth is meant to explain long-run developments. As is well-known, the neoclassical version of the theory is not fully satisfactory as it attributes long-term growth to exogenous factors like technological change and population growth. Over the past seven years a new theory was developed to overcome this deficiency of the standard growth theory. In endogenous growth theories, the long-run growth rate of the economy depends upon preferences for consumption over time and parameters which relate to some "engine of growth". Although theories differ a great deal with respect to the specification of the "engine of growth", the savings rate holds a central position in all of them. Population growth is taken into account in some theories but not in others. Moreover, population growth may induce accelerating growth rates in theories where the "engine of growth" depends among other things on the non-reproducible factor of production, e.g. labour.

From an intellectual point of view the new growth theory may be considered as an improvement vis-a-vis its predecessor as it explains more. However, a final assessment should be based on empirical tests of both theories. For the time being there seems to be no clear indication which theory is to be preferred. The problem with the empirical implementation of both theories is that in the neoclassical theory savings matter also during the process of transition towards a steady state. And such transition processes may take substantial time.

Growth theories are set up to explore trends, but there may be shifts in long-run developments that mark different episodes in stories about growth. The developments of rich economies from 1950 to roughly 1970 seem to be different from the more recent pattern of economic growth. The productivity slow-down envisaged after 1970 is not well explained by neoclassical growth theory, but the same verdict holds for the new growth theory as well (Scott, 1989). If so, there is need for extensions of the theory. Endogenous growth theory may be a promising start, but at the same time not fully satisfactory as the theory ignores institutional and organizational factors, which may prove important explanatory factors (e.g. Stern, 1991). The relevance of these factors for understanding economic growth is most clearly revealed in publications based on careful analysis of case studies. For instance, in Detouzos, Lester and Solow (1989) the problem is stated in the following terms:

> "If organizational and attitudinal deficiencies do indeed have an important bearing on American industrial performance as our findings indicate, then a purely macroeconomic approach is insufficient. This is because there is no efficient market in which organizational forms and attitudinal complexes compete with one another" (pp. 38-39).

However, macroeconomic analysis is well-suited to deal with market imperfections. And a number of issues discussed in the quoted study may fall under this heading. The authors emphasize factors as the application of outdated strategies, short time horizons and technological weaknesses in development and production in the US economy. To get a clear picture of what is meant by these factors a descriptive approach is essential. Outdated strategies relate to a focus on mass-production, which is superseded by developments in the market. A reorientation of strategy is not easy because individual parts of the traditional pattern cannot be replaced piecemal. Short time horizons are closely connected to the organizational structure of capital markets and the way executives' motives are linked to the financial result of the firm. Technological weaknesses may emerge if lower-risk investments dominate alternatives based on the integration of product and process engineering, for example. Similar observations on corporate strategies, and managerial attitudes in the US economy over the recent period are made in Porter (1990, Ch. 9).

Although theory inevitable implies abstraction, endogenous growth theory can be improved by taking account of some of the factors just mentioned. The present paper aims at a start in that direction by extending a theory of endogenous growth along the lines set by Scott (1989,1991) in several directions. Scott's theory based on learning by doing is discussed in Section 2. What distinguishes this theory from other contributions in the field is its true dynamic character. The traditional static production function is substituted for an investment programme contour, which makes the model very flexible and powerful. Learning externalities, which are the topic of Section 3, fit easily into the framework. Internalization of the learning externalities proves to be a feasible alternative for a market economy. In Section 4 it is assumed that managers have some discretion with respect to the goals set for the firm. Growth maximization subject to constraints is considered as an alternative for maximization of the value of the firm. At this point the analysis bears some resemblance with the theory of managerial economics (Marris, 1964, 1971), which did not receive the attention it deserved. This may be due to the fact that it is a set up as a theory of the firm rather than as a theory of economic growth. Uncertainty and growth is the subject of Section 5. Investment programmes have to cope with uncertainty. A theory of growth can therefore not ignore the uncertainty connected with the returns on investment. However, from an analytical point of view it is difficult to incorporate this aspect in a satisfactory manner, but that may be no excuse to eliminate uncertainty as is standard practise in growth theory. Section 6 contains some conclusions and suggestions for further research.

2 A theory of endogenous growth

The new theory of economic growth of Scott (1989, 1991) is based on a simple but powerful view on the world. Ongoing production processes are seen as a heritage from the past. Increases in production can be brought about by changing production processes and by changing existing economic arrangements, which requires investment outlays to be made. At the same time, every transformation implies problem solving from which people learn. Therefore, as in Arrow (1962) investment leads to learning by doing and the level of knowledge depends on accumulated gross investment. Investment programmes build upon their predecessors. But this also implies that investments have an "option value", which is defined in Myers (1984) as the present value of future opportunities that will be opened up if the investment is made. Diminishing returns to capital accumulation may be absent as investment opportunities are recreated by undertaking investment and over time their average quality does not change very much for the whole economy.

Investment leads to growth in output and change in employment. However, there may be different options with respect to the labour saving character of investment programmes. Cost consideration may induce firms to opt for investment programmes with more or less growth or a decline of employment. Moreover there are diminishing returns with respect to the rate of investment. At any moment in time, firms have to choose from a set of investment projects which are not equally profitable. The most profitable projects are chosen first and the larger the rate of investment the lower the average quality of the selected projects. However, the average quality of the entire set of available investment opportunities does not diminish over time because of learning by doing. Past investments then generate a set of possibilities which are captured by the fundamental growth function:

$$g = g(\sigma, g_\ell), \quad with \quad \begin{array}{ll} \frac{\partial g}{\partial \sigma} > 0, & \frac{\partial^2 g}{\partial \sigma^2} < 0 \\ \frac{\partial g}{\partial g_\ell} > 0, & \frac{\partial^2 g}{\partial g_\ell^2} < 0 \end{array} \tag{1}$$

where g, g_ℓ and σ denote the growth rate of output, the rate of change of employment and the (gross) investment ratio. Equation (1) may be called a primitive (as in Romer, 1991), but the same verdict applies to the neoclassical production function for which there is no strict need in a theory of economic growth. To some extent, this modeling of (dynamic) production opportunities resembles that of Romer (1986) where learning by doing keeps growth going and where diminishing returns to the rate of investment are present due to convex adjustment costs. However, the introduction of a dynamic growth equation makes it possible to analyse some issues that can not be dealt with using the static production function, like the internalizing of dynamic learning externalities in competitive markets (see Section 3 below).

The preference of households are given by an intertemporal utility function

$$U = \int_0^\infty u(c_i)e^{-\theta t}dt$$

where c_i denotes per capita consumption and θ denotes the pure rate of time preference. It is convenient to assume a constant coefficient of relative risk aversion, ρ, so that the instantaneous CRRA utility function can be written as

$$u(c_i) = \frac{c_i^{1-\rho}}{1-\rho}$$

Market equilibrium implies that (aggregate) output (y) equals aggregate consumption (c) and investment expenditure (i).

$$c = y - i = (1 - \sigma)y \tag{2}$$

where σ denotes the (macroeconomic) investment ratio. To concentrate on issues of strategic interaction only paths of balanced growth are taken into consideration. The more general case where growth rates change over time is analysed in Van de Klundert and Meijdam (1991). It is shown there that the model has no transition dynamics in its standard setting, so that it is fully justified to concentrate on steady state solutions.

Denoting the growth rate of output by g and that of per capita consumption by g_c we have

$$y = y(0)e^{gt} \tag{3}$$

$$c_i = c_i(0)e^{g_c t} \tag{4}$$

Assuming that the population grows at the exogenous rate g_n we may write $g = g_c + g_n$. The model may be solved in a centralized or a decentralized version as in other theories of economic growth (e.g. Sala-i-Martin, 1990).

The centralized economy
In a planning approach the authorities choose σ and g optimally so that per capita intertemporal utility is maximized. Moreover they equate the growth of employment with the growth rate of population ($g_\ell = g_n$). Consequently, the following problem can be formulated

$$Max\ U = \int_0^\infty \frac{(c/\ell)^{1-\rho}}{1-\rho} e^{-\theta t} dt$$

$$\text{s.t.}\quad \begin{aligned} c &= (1-\sigma)y \\ y &= y(0)e^{gt} \\ \ell &= \ell(0)e^{g_n t} \\ g &= g(\sigma, g_n) \end{aligned}$$

Substituting the constraints, the integral can be solved to yield

$$U = \left(\frac{[y(0)/\ell(0)]^{1-\rho}}{1-\rho}\right) \frac{(1-\sigma)^{1-\rho}}{\theta + (\rho-1)[g(\sigma, g_n) - g_n]}$$

provided that $(1-\rho)(g-g_n)-\theta < 0$ which is a familiar condition (e.g. Koopmans, 1967). The first-order condition $\partial U/\partial\sigma = 0$ implies

$$(1-\sigma)\frac{\partial g}{\partial \sigma} = [\theta + g_n + \rho(g - g_n)] - g \tag{5}$$

Equation (5) implies that the proportionate marginal product of investment should be equal to the difference between the rate of time preference in the steady state (term in square brackets) and the macroeconomic growth rate (g).

The optimal values of g and σ follow from solving equations (1) and (5) assuming $g_\ell = g_n$.

The decentralized economy
In a market economy the saving and investment decisions are taken by consumers and producers respectively. The capital market coordinates these decisions by equating supply and demand at the equilibrium real rate of interest.

It will be assumed that managers maximize the present value of the representative firm. Denoting the real wage by w, the cash flow of the firm is $y - \ell w - i = (1-\sigma)y - \ell w$. In a situation of balanced growth employment changes at rate g_ℓ and real wages increase at rate g_w. Denoting the constant real rate of interest by r, the present value (V) of the firm at $t = 0$ can then be written as

$$V = \int_0^\infty [(1-\sigma)y(0)e^{gt} - \ell(0)e^{g_\ell t}w(0)e^{g_w t}]e^{-rt} dt$$

Integration of this equation for a constant σ yields

$$V = y(0)\left[\frac{1-\sigma}{r-g} - \frac{\lambda}{r-(g_\ell + g_w)}\right], \tag{6}$$

where $\lambda \equiv \ell(0)w(0)/y(0)$ denotes the share of output accruing to labour in the initial situation. It should be noticed that the steady state value of λ is an endogenous variable. As there is no transition dynamics the steady state value of λ is attained by a suitable adjustment in the real wage rate, w. Firms maximize V with respect to the investment ratio (σ) and the rate of change of employment (g_ℓ). Maximization of V is constrained by the growth equation (1) so we can replace g by $g(\sigma, g_\ell)$. Moreover, initial output has to be taken as given because levels cannot be changed without investing. To simplify $y(0)$ is set at unity.

The first order conditions are

$$\frac{\partial V}{\partial \sigma} = -\frac{1}{r-g} + \frac{1-\sigma}{(r-g)^2}\frac{\partial g}{\partial \sigma} = 0$$

$$\frac{\partial V}{\partial g_\ell} = \frac{1-\sigma}{(r-g)^2}\frac{\partial g}{\partial g_\ell} - \frac{\lambda}{[r-(g_\ell+g_w)]^2} = 0$$

Assuming that the economy exhibits balanced growth with $g - g_\ell = g_w$, so that λ is constant, results in:

$$(1-\sigma)\frac{\partial g}{\partial \sigma} = r - g \tag{7}$$

$$(1-\sigma)\frac{\partial g}{\partial g_\ell} = \lambda \tag{8}$$

The optimum conditions (7) and (8) are easily interpretable. According to equation (7) the proportionate marginal product of investment corrected for growth costs (measured by σ) should be equal to the growth corrected real rate of interest. Equation (8) implies that the proportionate marginal product of labour again corrected for growth costs should be equal to the share of labour in output. Equation (7) determines the optimal amount of investment, whereas the labour saving bias follows from equation (8).

Scott (1989) gives the fundamental growth equation (1) more structure by postulating that the function is linear homogenous in $q(\sigma)$ and g_ℓ, so that it can be written as

$$g = q(\sigma) f\left[\frac{g_\ell}{q(\sigma)}\right] \quad \text{with} \quad \begin{array}{lll} f' > 0 & f'' < 0 & \\ q' > 0 & q'' < 0 & q(0) = 0 \end{array} \tag{9}$$

Equation (5), which is shown in Figure 1, is called the investment programme contour ('IPC').

Insert Figure 1 here.

Maximization of equation (6) subject to equation (9) yields as first order conditions for an optimum:

$$(1-\sigma)\omega\left(\frac{g}{\sigma} - f'\frac{g_\ell}{\sigma}\right) = r - g \tag{10}$$

$$(1-\sigma)f' = \lambda \tag{11}$$

where $\omega \equiv \sigma q'/q$ $(0 < \omega < 1)$ is a measure of diminishing returns with respect to the investment ratio. The lower ω the more severe diminishing returns to investment are. Constant returns to investment imply $\omega = 1$, but for a maximum of V one must have $\omega < 1$. Conditions (10) and (11) are equivalent to equations (7) and (8). The specification preferred by Scott makes it somewhat easier to derive comparative static results, showing the impact of exogenous variables and parameters on long-run growth rates. However, before these results can be discussed the model has to be closed by specifying consumers' behaviour and postulating equilibrium in markets.

In a market economy, the representative and infinitely lived household maximizes the intertemporal utility function of the CRRA-form as given above subject to the intertemporal budget constraint by choosing the level of per capita consumption. The dynamic budget constraint can be written as

$$\dot{a}_i = \omega + (r - g_n)a_i - c_i$$

where a_i denotes per capita nonhuman wealth. The non-consumed part of interest and labour income adds to the stock of family wealth. A rise in the size of the household has a negative effect on individual wealth because total household wealth must be shared by more persons. The first order condition for the optimal consumption plan boils down to the well-known Keynes-Ramsey rule

$$g_c = \dot{c}_i/c_i = (r - \theta - g_n)/\rho$$

Aggregation over individual consumers, whose number increases at rate g_n, gives the growth rate of aggregate consumption $\dot{c}/c = g_c + g_n$. Equilibrium in the output market relates aggregate consumption to output according to $c = (1-\sigma)y$ (equation (2) above). In a situation of balanced growth σ and $\dot{y}/y = g$ are constant so that $\dot{c}/c = g$ and the Ramsey-rule can be rewritten as

$$r = \theta + g_n + \rho(g - g_n) \tag{12}$$

The rate of interest equals the rate of time preference in the situation of steady growth. Concerning the labour market, labour supply is exogenous and increases at rate g_n, assuming a constant participation rate of the population. Labour market equilibrium requires:

$$g_\ell = g_n \tag{13}$$

As discussed in Van de Klundert and Meijdam (1991), this steady-state result obtains in case of labour market clearing (zero unemployment) as well as in the case with some form of equilibrium unemployment and hysteresis in the labour market. It should be noticed that market equilibrium is defined in terms of flows and not necessarily in terms of stocks. All that is needed is that the increase in output is sold and that the change in labour supply is absorbed in the production process to the extent that the capacity utilization ratio and the unemployment rate remain constant. From this point of view, it is obvious that the model may exhibit hysteresis in levels as do many other endogenous growth models.

The complete market model comprises equations (9)-(13), solving for the endogenous variables $g, g_\ell, \sigma, \lambda$ and r. Comparing equations (7) and (12) with equation (5) for the centralized economy points out that the decentralized and centralized outcomes are equivalent, although in the command economy there is no need to distinguish between labour income and capital income so that r and λ are not determined explicitly.

A closed-form solution of the model is difficult to obtain, even after suitable specification of the IPC. In Table 1 (first column) a numerical solution is presented. The specification of the IPC and the numerical value of the parameters chosen are presented in the Appendix. Comparative static results can easily be derived as shown in Van de Klundert and Meijdam (1991). For $\omega < 1$ and $f' < 1$ the following results hold:

$$\frac{dg}{dg_n} > 0 \quad \frac{dg}{d\theta} < 0$$

$$\frac{d\sigma}{dg_n} > 0 \quad \frac{d\sigma}{d\theta} < 0$$

Moreover, if the slope of the IPC is sufficiently flat one has:

$$\frac{d\lambda}{dg_n} < 0 \qquad \frac{d\lambda}{d\theta} > 0$$

The mild conditions that have to be imposed on the IPC are discussed in Scott (1989) and are legitimate from an empirical point of view. A rise in the growth rate of labour supply leads to a higher growth rate of the economy and a fall in the share of output accruing to labour. An increase in the subjective rate of discount has just the opposite effects: the growth rate (and the investment ratio) decline and the share of labour in output rises. A numerical illustration of the latter case is given in Table 1 (second column). If consumers have less patience the rate of savings declines, which leads to lower investment and growth. The share of labour rises, because growth costs fall, so that the net proportionate marginal product of labour increases on balance despite a shift towards less labour saving projects as illustrated in Figure 1 by a movement along the IPC from A to B.

Higher cost of capital pushes US firms in the direction of a shorter time horizon as Detouzos, Lester and Solow (1989) argue in comparing the performance of the US economy with that of its competitors. But there may be additional factors which exert a downward pressure on growth rates in general. In the sections below the model will be extended to allow for further perspectives in explaining economic growth.

Table 1*

	Benchmark	Increased time preference	Learning by watching	Internalizing the learning externality
g	2.92%	2.71%	3.66%	4.18%
σ	0.1652	0.1333	0.1739	0.2275
λ	0.7608	0.7854	0.7626	0.7170
r	7.81%	9.27%	9.64%	10.96%

* See Appendix for parameter choices.

3 The coordination perspective

To a large extent a firm's investment opportunities are affected by its ability to learn from investments undertaken by other firms. Learning by doing has to be supplemented with learning by watching (e.g. King and Robson, 1989). There is clearly an externality involved. The individual investor will not capture all the benefits resulting from his own investment, as they accrue in part to other firms. However, if firms realize that they are in the same position they may internalize the learning externality. As a result profits for all firms will be higher than without internalization. If all firms maximize in this way there is no advantage in staying behind. If no firm internalizes it is impossible to benefit from the externality. There is a coordination problem, which can only be solved by some outside factor. For instance, macroeconomic stability may induce firms to take chances and go for the maximum.

The learning externality arising from learning by watching can be built into the model by assuming that it reduces the degree of diminishing returns of investment for the individual company. Denoting the individual firm's investment ratio by σ and the investment ratio for the economy by σ_s the IPC may now be written as

$$g = q(\sigma)z(\sigma_s)f\left[\frac{g_\ell}{q(\sigma)z(\sigma_s)}\right], \quad \text{with} \quad \begin{array}{l} z' > 0, \quad z'' < 0 \\ z > 1 \end{array} \tag{14}$$

The multiplier z captures the effect of learning by watching.

Let us first consider the case that learning by watching is seen as an external effect. Firms take the factor z for granted and from the firms' point of view, the marginal contributions of investment and employment growth to the maximization of the value of the firm are not influenced by the benefits from learning by watching. This implies that the optimum conditions are the same as in the model with only learning by doing as presented in Section 2. Since all firms are alike, one has $\sigma = \sigma_s$ and equations (9) and (10) apply. However, the solution will be different for $z > 1$. Learning-by-watching raises the average return on investment. A higher rate of interest makes households more thrifty, the investment ratio and growth rise along with a decline in the share of labour in income.

Next, we consider the case of internalization of the learning externality. Firms identify σ_s with σ and take into account the effects of investment through learning by watching. As can easily be checked the first order conditions for value maximization read in this case:

$$(1-\sigma)(\omega+\zeta)(\frac{g}{\sigma} - f'\frac{g_\ell}{\sigma}) = r - g, \quad \text{with} \quad \zeta \equiv \frac{z'\sigma}{z} \tag{15}$$

$$(1-\sigma)f' = \lambda \tag{11}$$

Diminishing returns with respect to investment by firms are corrected by the elasticity ζ. For a proper solution one must have: $\omega + \zeta < 1$. With diminishing returns less severe, the investment ratio and the growth rate of the economy will be higher. The condition for the bias in labour saving is identical to the one in Section 2. This is a result of the specification of the IPC: the function is linear homogenous in the learning externality and the growth rate of employment. However, as the growth costs rise the share of labour has to go down in the present model.

The solution of the model for different cases is illustrated in Figure 2. The upward sloping line represents the Keynes-Ramsey formula for intertemporal trade-off, equation (12). A higher rate of growth must be bought at a higher rate of return on investment. The downward sloping line gives the rate of return as a function of the growth rate. Such a "technology" line can be obtained by combining the IPC equations (9) resp. (14) and the FOC condition for optimal investment, equations (6) resp. (11) assuming that the labour market is in equilibrium ($g_\ell = g_n$). A rise in the investment ratio leads to a higher growth rate but the price to be paid is a lower profit rate as a result of diminishing returns with respect to both σ and g_ℓ. The line T^1 relates to the learning-by-doing model. Learning by watching without internalization gives rise to T^2, with internalization of the learning externality one gets the line T^3. The more possibilities for investment are exploited, the higher the rate of growth and the rate of interest. Numerical examples corresponding to Figure 2 are given in Table 1. As appears from the third column in this table "learning by watching" increases all variables, although the rise in λ is small. The economy is more productive, which raises income but the higher growth costs reduce *ceteris paribus* the share of labour in output. Internalization of the learning externality has a substantial effect on investment and growth, but at the expense of the share of labour as growth costs increase significantly.

Insert Figure 2.

Learning by watching is not an automatism as the theory almost inevitably suggests. In fact, it depends on the organization of industry and trade and the way firms take advantage of these opportunities. Porter (1990) describes the world in the following manner:

> "Competitive advantage emerges from close working relationships between world-class suppliers and the industry. Suppliers help firms perceive new methods and opportunities to apply new technology. Firms gain quick access to information, to new ideas and insights, and to supplier innovations. They have the opportunity to influence suppliers' technical efforts as well as serve as test sites for development work. The exchange of R&D and joint problem solving lead to faster and more efficient solutions. Suppliers also tend to be a conduit for transmitting information and innovations from firm to firm. Through this process, the pace of innovation *within the entire national industry is accelerated*" (p. 103, italics added)

The analysis of the learning externality emphasizes that economic growth cannot be explained adequately in mechanical terms. On the contrary, as Metcalfe (1991) observes in reviewing Scott's book: "maximization is trivial compared to the task of constructing the choice set on which a maximization problem can be defined".

4 The managerial perspective

Managerial controlled firms have discretionary power to pursue other goals than present value maximization. As hypothesised by Marris (1964, 1971) such firms would seek to maximize growth subject to constraints set by the capital market. In Marris (1964, Ch. 2) managerial motivation is discussed extensively taking account of psychological, sociological and economic motives. However, the view is not undisputed. First, it may be questioned whether there is a separation of ownership from control to the extent that managers have significant discretionary power. Second, even if there is such power certain incentives may favour present-value maximization over alternatives as for instance maximization of the growth rate of the firm. It is well-known that in the US management is rewarded through stock options and other profit-related schemes, so that the incentive to maximize profits is strenghtened (e.g. Myers, 1984). Despite empirical research on this issue, the questions raised are not yet settled [1]. There is a

[1] See for a discussion of some empirical studies Scott (1989, Ch. 9).

feeling among a number of authors that managerial control and deviations from present-value maximization may be relevant for Europe or Japan, but less so for the US (e.g. Scott, 1989; Detouzos et al., 1989).

It therefore makes sense to discuss the implications of growth maximization in the framework of the model of endogenous growth of Section 2. Solow (1971) criticizes the managerial approach and related growth-oriented theories for failing to establish the initial size of the firm as part of the optimization problem. This critique does not apply to our model as the level of output is path-dependent. In the theory of endogenous growth this is not an uncommon and perfectly acceptable result (e.g. Lucas, 1988). To concentrate on the issue of managerial discretion as such, learning externalities will now be ignored. Financial markets are ready to support the management of a firm unless the present value of future cash flows will deviate too much from the maximum attainable value. The gap $(V_{max}-\bar{V})$ between the maximum attainable value and the minimum required value is an indication for the discretionary power of the management. Managers maximize the growth rate of output (g) subject to the constraint on the value of the firm ($V \geq \bar{V}$). As a first step, $\bar{V}$ can be taken exogenous (with $\bar{V} < V_{max}$) [2].

As it is easy to show that the constraint is always binding, the problem can be stated as maximize

$$g = q(\sigma) f\left[\frac{g_\ell}{q(\sigma)}\right] \quad \text{subject to} \tag{9}$$

$$V = y(0)\left[\frac{1-\sigma}{r-g} - \frac{\lambda}{r-(g_w+g_\ell)}\right] = \bar{V} \tag{16}$$

Setting $y(0) = 1$, the Lagrangian expression can be written as

$$\mathcal{L} = q(\sigma) f\left[\frac{g_\ell}{q(\sigma)}\right] + \xi\left[\frac{1-\sigma}{r-g} - \frac{\lambda}{r-(g_w+g_\ell)} - \bar{V}\right]$$

The first order conditions with respect to σ and g_ℓ are then

$$\omega\left[\frac{g}{\sigma} - f'\frac{g_\ell}{\sigma}\right] + \frac{\xi}{(r-g)^2}\left[(g-r) + (1-\sigma)\omega\left(\frac{g}{\sigma} - f'\frac{g_\ell}{\sigma}\right)\right] = 0$$

$$\frac{\xi}{(r-g)^2} = \frac{f'}{\lambda-(1-\sigma)f'}$$

Elimination of the Lagrangian multiplier (ξ) and rearranging yields

$$\frac{\lambda}{f'}\,\omega\,\left(\frac{g}{\sigma} - f'\frac{g_\ell}{\sigma}\right) = r - g \tag{17}$$

The result can be interpreted by comparing the value of the firm in case of value maximization with the constrained value in case of growth maximization. Substitution of equation (11) in equation (6), assuming steady state growth and $y(0) = 1$ gives

$$V_{max} = \frac{(1-\sigma)(1-f')}{r-g}$$

[2] To endogenize $\bar{V}$ a utility function for managers with arguments V and g can be introduced (cf. Marris, 1964)

From (16) and balanced growth ($g = g_\ell + g_w$) follows

$$\bar{V} = \frac{1-\sigma-\lambda}{r-g}$$

The existence of discretionary managerial power implies $\bar{V} < V_{max}$ or

$$\frac{\lambda}{f'} > (1-\sigma)$$

Let α denote the difference between both sides of the inequality above. We then may write

$$(1-\sigma+\alpha)\ \omega\ (\frac{g}{\sigma} - f'\frac{g_\ell}{\sigma}) = r - g \tag{18}$$

$$f' = \frac{\lambda}{1-\sigma+\alpha} \tag{19}$$

As appears from these conditions in comparison with equation (10) and (11) the managerial model leads to a higher rate of growth and a higher share of output accruing to labour than in the model with present-value maximization. The premium on marginal products, α, corresponds to what Scott (1989) calls "animal spirits".

The managerial model can be completed by assuming that the supply of financial funds is given by equation (12). There is no good reason to suppose that consumers behave in a different manner if there is a separation between ownership and control of firms. Further, it is again assumed that the labour market is in equilibrium conform the definition given in Section 2. The complete managerial model then comprises equations (9), (12), (13), (16) and (17), which solve for $g, g_\ell, \lambda, \sigma$ and r. A numerical example is presented in Table 2, column 2. The results should be placed next to the outcomes of a benchmark case with present value maximization given in column 1.

Table 2*

	Value maximization	Managerial economy	
		with premium on labour demand	without premium on labour demand
g	3.40%	3.43%	3.96%
σ	0.1913	0.1941	0.3008
λ	0.7439	0.7608	0.6476
r	9.02%	9.06%	10.41%
V	1.155	0.8	0.8
α	0	0.0210	0.3021

* See Appendix for parameter choices.

Comparison of the results in columns 1 and 2 reveals that the managerial alternative to maximization of the value of the firm has a very small impact on the growth rate of output even if the constraint of the value of the firm is not very restrictive. The reason for this perhaps unexpected result is the macroeconomic constraint of labour market equilibrium. A higher rate of growth leads *ceteris paribus* to a rising demand for labour, but the increase in labour supply is exogenous in the model. Increased tension in the labour market induces a rise in the share of income accruing to labour, so that firms are under pressure to change towards relatively more labour-saving investment projects. This contrasts with the outcomes of managerial theory, which are based on a microeconomic setting.

However, the managerial approach may be introduced into the macro model in a different way. It may be assumed that firms maximize the growth rate of output, but pay labour their proportionate marginal product as in equation (11). This model variant implies that firms attract labour to maximize the value of the firm, so that there are ample financial means to invest and maximize growth. Under these assumptions the model comprises equations (9), (11), (12), (13), (16) and (18) and solves for $g, g_\ell, \sigma, \lambda, r$ and α. The numerical outcomes of this exercise are presented in column 3 of Table 2. As may be expected the growth rate is now substantial higher than in a managerial model with a premium on the proportionate marginal product of labour subject to the same financial constraint, as shown in the fifth line of the table. The problem rises which of the two variants of the managerial economics is the most realistic. Again there is a strategic element involved. It is in the common interest of all firms to pay labour its proportionate marginal product, because in that case the growth rate is the highest. But individual firms may want to offer high wages and attract additional labour to grow faster. However, from a macroeconomic perspective this behaviour is self defeating. In other words, individual firms do not internalize the effects of their own wage offer on the macroeconomic wage level. Like in the case of learning externalities, coordination among firms or something like 'animal spirits' may lead to internalizing.

5 Growth under uncertainty

Usually firms operate in an uncertain outside world. These uncertainties relate to numerous relevant aspects of business conditions and prospective changes in the economy as well as to their consequences for the firm. As emphasized by Lintner (1971) in such a typical dynamic and uncertain environment firms develop policies and strategies for growth. Firms tend to operate in terms of expectations or targets of average growth rates for the considerable future together with some assessment of the intensity of fluctuations around long-run averages. Formulating a strategic posture in these terms is of course a composite summary of the assessment of the more detailed environmental and competitive factors and the prospective success of firms in coping with these factors. Nevertheless, it seems worthwhile to envisage the strategic posture of the firm in terms of both a time path of expected growth and also a measure of risk or random variability about the expected trend. The basic policy decisions of firms can then be regarded as choosing among alternative pairs of expected growth rates and levels of risk on the one hand and fixing the desired intensity of labour-savings on the other hand. To simplify matters these two basic decisions will be treated as unrelated.

As shown by Kormendi and Meguire (1985) and Grier and Tullock (1989) there is a positive relation between growth rates and the variability of growth rates, which can be considered as a measure of risk. Expected growth can be increased at a given rate of investment and employment change only at the cost of a higher risk. The fundamental growth equation may therefore be written as

$$\bar{g} = \bar{g}(\sigma, g_\ell, var) \tag{20}$$

where $\bar{g}$ denotes the expected rate of growth of output and var denotes the variance of the growth rate. In addition to the conditions imposed in equation (1), we require $\partial\bar{g}/\partial var > 0$ and $\partial^2\bar{g}/\partial var^2 < 0$ (cf. Figure 3). The associated actual growth rate $\tilde{g}$ is a normally distributed random variable with mean $\bar{g}$ and variance var.

Firms have to choose from a set of investment projects which are not equally risky. From the projects with given growth and employment characteristics the least risky ones are chosen first. Hence at a larger rate of investment the firm has to accept *ceteris paribus* a higher risk on the average project. Following Lintner (1971), a direct dependence between the average riskiness (var) and the rate of investment (σ) is postulated

$$var = \nu_0 + \nu(\sigma) \qquad v' \geq 0 \quad v'' \leq 0 \tag{21}$$

A larger investment ratio leads to a greater variability in growth rates. The constant ν_0 is a basic risk variable which can be chosen in an optimal way.

In this section we return to the case that shareholders, in their capacity as owners, determine company policy and that managers have no incentives or possibilities to deviate from this policy. Efficiency of stock and bonds markets will guarantee that in a market economy the value of the firm, materialized in stock and bond prices and interest rates, reflects the preferences of the investor, who is to be identified with our representative consumer. Managers are risk-neutral and maximize the value of the firm. But, as the investor is risk averse, the cost of capital for the firm is influenced by the risk-growth mix choosen. Hence, the growth strategy of the firm has to take into account how consumers regard the trade-off between growth, risk and the rate of return. To avoid lengthy derivations for stock prices, etc. we treat the consumers' and firms' decisions as one single decision. This allows us to define an implicit real rate of return that would prevail in an efficient capital market.

The familiar intertemporal utility function of the CRRA-type is maximized. As the outcomes of the growth process are uncertain, it is the expected value of discounted utility that matters. The objection function can then be stated as:

$$\begin{aligned} E(U) &= E\left[\int_0^\infty \frac{c_i^{1-\rho}}{1-\rho} e^{-\theta t} dt\right], \qquad \rho > 1 \\ &= \frac{c_i(0)^{1-\rho}}{1-\rho} \int_0^\infty E\{e^{[(1-\rho)\tilde{g}_c - \theta]t}\} dt \end{aligned}$$

Applying the standard formula for the expected value between accolades in the expression for $E(U)$ and substituting $c_i = (1-\sigma)y/\ell$ yields

$$E(U) = \left(\frac{[y(0)/\ell(0)]^{1-\rho}}{1-\rho}\right) \frac{(1-\sigma)^{1-\rho}}{\theta + (\rho - 1)(\hat{g} - g_n)} \tag{22}$$

with

$$\hat{g} = \bar{g} - \frac{(\rho - 1)}{2} var \tag{23}$$

denoting the *certainty-equivalent* of the growth rate of per capita consumption. It should be noticed that in deriving equation (22) account is taken of the aggregation relation $\tilde{g}_c = \tilde{g} - g_n$.

Maximization of equation (22) with respect to σ and ν_0 and setting $y(0)/\ell(0) = 1$ for convenience gives after some manipulations

$$(1-\sigma)\frac{\partial \hat{g}}{\partial \sigma} = [\theta + g_n + \rho(\hat{g} - g_n)] - \hat{g} \tag{24}$$

$$\frac{\partial \hat{g}}{\partial \nu_0} = 0 \tag{25}$$

Equation (24) corresponds to equation (5). Under uncertainty the proportionate marginal product of investment should be equal to the rate of time preference minus the growth rate both evaluated in terms of the certainty equivalent of the growth rate. Equation (25) implies an optimal level of 'basic' risk that maximizes the certainty equivalent of the prospective growth rate. Differentiation of equation (23) with respect to respectively σ and ν_0 taking equation (21) into account results in

$$\frac{\partial \hat{g}}{\partial \sigma} = \frac{\partial \bar{g}}{\partial \sigma} + \left(\frac{\partial \bar{g}}{\partial\, var} - \frac{\rho - 1}{2}\right)\nu' \tag{26}$$

$$\frac{\partial \hat{g}}{\partial \nu_0} = \frac{\partial \bar{g}}{\partial\, var} - \frac{\rho - 1}{2} \tag{27}$$

Combination of equations (23)-(27) leads to the following first order conditions for maximization of the expected value of intertemporal utility

$$(1-\sigma)\frac{\partial \bar{g}}{\partial \sigma} = \theta + (\rho - 1)(\bar{g} - g_n - \frac{\rho - 1}{2} var) \tag{28}$$

$$\frac{\partial \bar{g}}{\partial\, var} = \frac{\rho - 1}{2} \tag{29}$$

Equation (29) reflects the trade-off between the benefits and costs of a higher variance. In the optimum, the marginal gain in the form of a higher growth rate should be equal to the marginal cost in the form of more risk which is disliked by the investor. This condition is illustrated in Figure 3 where the fundamental growth equation (20) with σ and g_ℓ fixed is tangent to the indifference curve I^2 (derived from equations (22)-(23)).

Insert Figure 3 here.

The model can be closed by assuming labour market equilibrium.

$$g_\ell = g_n \tag{30}$$

Equilibrium in the labour market requires competitive wage setting. The growth rate of labour supply is exogenous, but employment growth can be derived from the familiar condition

$$(1-\sigma)\frac{\partial \bar{g}}{\partial g_\ell} = \lambda \tag{31}$$

Shareholders value the contribution of employment growth on output growth in terms of the certainty-equivalent $\hat{g}$. However, because $\frac{\partial \hat{g}}{\partial g_\ell} = \frac{\partial \bar{g}}{\partial g_\ell}$ condition (25) determines the optimal labour-saving content of investment projects. The complete model comprises equations (20), (28), (29), (30) and (31), which solve for g, g_ℓ, σ, var and λ. The real rate of interest is implicit and can be set equal to

$$r = \theta + g_n + \rho(\bar{g} - g_n - \frac{\rho - 1}{2} var) \tag{32}$$

It is interesting to compare the outcomes under uncertainty with the results obtained in case of certainty. Comparison of equation (32) with equation (12) shows that the real rate of interest is lower under under certainty, *ceteris paribus*. As a consequence the investment ratio and the growth rate will be higher than under certainty. More savings are generated because uncertainty creates an additional precautionary motive (see also Blanchard and Fischer, 1989, Ch. 6). Consumers are risk averse and they opt for extra consumption in the future to compensate for the possibility of bad luck with respect to investment programmes. It should be noticed that the optimal rate of growth will also be higher under uncertainty, because shareholders exploit the trade-off between growth and risk in an optimal way. The level of risk selected maximizes the certainty equivalent of the growth rate conditional on any investment ratio as appears from equations (25) and (29) and from Figure 3. The equilibrium rate of interest may therefore be higher than under certainty. Uncertainty pays off in the form of higher rates of return. This will of course not be the case if the expected rate of growth in equation (20) is independent of the variance.

The two possibilities are illustrated numerically in Table 3. The benchmark case is identical to that in Table 2, and is not shown. The first column of Table 3 relates to the complete model with uncertainty, whereas the second column gives simulation results assuming $\frac{\partial \bar{g}}{\partial var} = 0$ and ν_0 being exogenous. In the latter case there are no direct effects of uncertainty on the average rate of growth. As appears from Table 3 uncertainty as such has only a small positive impact on growth. The precautionary motive is rather weak. What makes a substantial difference is the possibility to opt for higher growth rates at the expense of increased uncertainty (e.g. Black, 1987, Ch. 10). To facilitate a comparison between uncertainty with and without direct growth effects the basic risk level ν_0 in the latter case is set at the endogenous level obtained in the former case. As a consequence, savings rates and variances do not differ very much although growth rates do across those variants. However, the models refer to different underlying realities, which hampers a comparison.

Table 3*

	Uncertainty		
	with direct growth effects	without direct growth effects	direct growth effects increased risk aversion
g	4.15%	3.41%	3.82%
σ	0.2008	0.1918	0.1619
λ	0.7358	0.7434	0.7680
r	10.69%	8.86%	12.65%
var	0.0009	0.0009	0.0005

* See Appendix for parameter choices.

Alternatively, it is instructive to test the sensitivity of the results for the degree of risk aversion in the model with direct growth effects of uncertainty. A less tolerant attitude towards risk leads to a slower rate of growth as shown in the third column of Table 3. The effect on the growth rate is much stronger than in models without uncertainty, because shareholders trade-off growth for more certainty. In terms of Figure 3, increased risk aversion causes the slope of the indifference curves to rise and a point like B is chosen. The variance declines substantially as shown in the table. The (implicit) rate of interest rises as households reduce savings, so that diminishing returns to investment bite less.

6 Conclusions

The analysis presented is based on two main ideas. First, long-run economic growth is endogenous. Our theory therefore fits into the new growth theory as developed recently. It deviates from this theory by introducing a fundamental growth equation as substitute for the traditional production function. Second, economic growth is strongly influenced by institutional and strategic factors. To deal with these factors it is necessary to have a flexible theory of economic growth, which is precisely what the approach chosen here aimes at.

Learning externalities, managerial discretion and uncertainty of returns to investment are incorporated in a model of economic growth, which builds upon the seminal work of Scott (1989). At some instances there is room for strategic behaviour of entrepreneurs in the traditional sense. The outcomes of the activities of the individual entrepeneur depend in that case on the activities of all others. There is strategic interaction (e.g. Cooper and John, 1988), so that waves of optimism or pessimism may make a large difference in outcomes. The concept of strategies for growth may however be given a broader meaning. The institutional set-up of the economy is man-made and may fasten or hamper growth. This idea is documented extensively in Detouzos et al. (1989) with application to the United States. It is against this background that we summarise our main results in the form of a relatively pessimistic growth scenario, which shows how the combination of certain institutional features can impede the potential for growth in a serious manner.

Communication between firms is bad, so that the possibilities for learning by watching are not fully exploited. Moreover, firms do not internalize the externalities that remain, because there is insufficient trust that others will do the same. The organization of the capital market leaves not much room for managerial discretion and maximization of growth rates. Even when there is some separation of ownership from control the effects on growth rates are modest as managers compete excessively for workers on a tight labour market. The capital market is organized in such a way that risk discourages investment. The precautionary motive for savings, which may lead to higher growth rates under uncertainty, is cut out. Moreover, risk aversion is relatively strong.

Taken together these factors may have a substitutional impact on the long-run rate of economic growth given the fundamentals of the models. The message of the paper is therefore that the theory of economic growth can and should gain by incorporating institutional and organizational aspects of existing economies. Topics for further research in this area are easily traced. Capital markets are often complex and we have only scratched the surface. Labour market issues may be of importance too. Rent-seeking and rent-sharing activities need to be given proper attention. The new growth theory may deal with these and related issues by postulating a fundamental growth equation as a point of departure.

Appendix

The specification of the IPC (equation (9) or (14)) used in the tables is as follows:

$$g = q(\sigma), z(\sigma_s) \cdot f\left(\frac{g_\ell}{qz}\right) + \varphi(var)$$

with

$$q(\sigma) = 2\frac{1 - e^{-\gamma\sigma}}{\gamma}$$

$$z(\sigma_s) = \frac{\gamma}{\gamma_s} \cdot \frac{1 - e^{-\gamma_s\sigma_s}}{1 - e^{-\gamma\sigma_s}}$$

$$f\left(\frac{g_\ell}{qz}\right) = 0.1085 + 0.955\frac{g_\ell}{qz} - 0.4\left(\frac{g_\ell}{qz}\right)^2$$

$$\varphi(var) = \varphi_1(var)^{0.1}$$

The functional forms of $q(\sigma)$ and $z(\sigma_s)$ imply

$$\omega = \frac{\sigma\gamma}{e^{\gamma\sigma} - 1},$$

$$\zeta = \left(\frac{\gamma_s}{e^{\gamma_s\sigma} - 1} - \frac{\gamma}{e^{\gamma\sigma} - 1}\right)\sigma$$

Equation (21) is specified as

$$var = v_0 + \nu_1\sqrt{\sigma}$$

The specification of $q(\sigma)$ and $f(.)$ are taken from Scott (1989, pp. 214 and 179). The specification of $z(\sigma_s)$ is chosen in such a way that there is no externality (or full internalizing) if $\gamma_s = \gamma$ and there is a positive learning externality if $\gamma_s < \gamma$. The parameters in the $f(.)$-function are based on Scott's data set for the postwar growth experience of ten OECD countries. The choice of the other parameters is shown below. The variance in Table 3 is calibrated to 0.0009. This means a standard deviation of 0.03 which corresponds roughtly to empirical findings from the Summers and Heston (1991) data set for the 80 richest countries. [3]

	Table 1	Table 2	Table 3
γ	8,8,8,4	6	6
γ_s	8,8,4,4	6	6
ρ	2.5	2.5	2.5, 2.5, 3.5
φ_1	0	0	0.1361, 0, 0.1361
v_0	0	0	*, 0.00045,*
ν_1	0	0	0.001
θ	0.02, 0.04, 0.02, 0.02	0.02	0.02
g_n	0.01	0.01	0.01

* endogenous

[3] We thank Ton van Schaik for providing us with the variances of growth rates.

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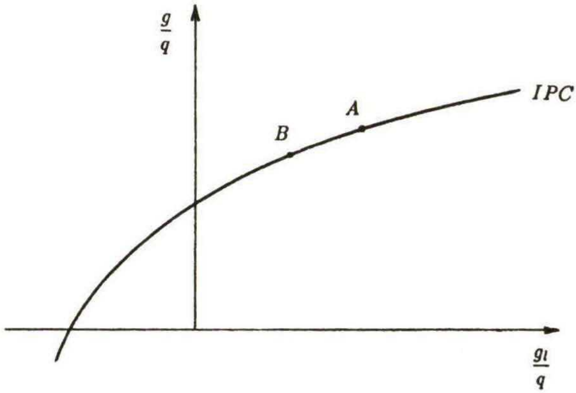

Figure 1: The Investment Programme Contour (IPC)

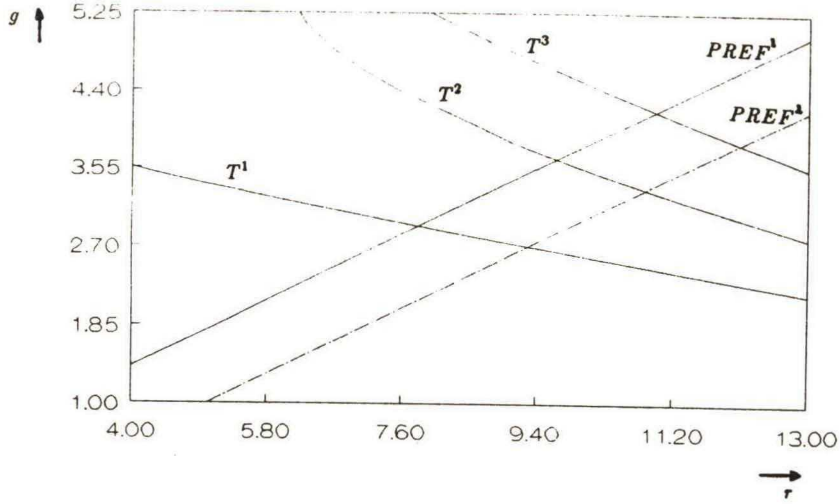

Figure 2: Learning by doing, learning by watching and internalizing the learning externality

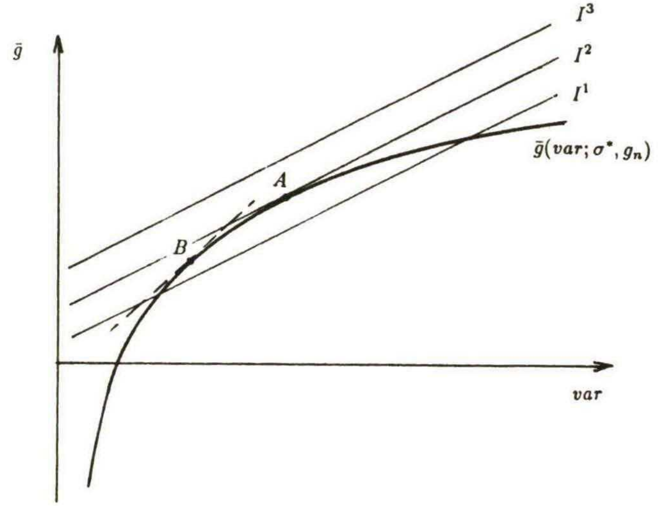

Figure 3: The optimal trade-off between growth and risk

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