# What Does Modern Growth Analysis Say About Government Policy toward Growth?

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Modern endogenous growth analysis puts the determinants of technical change at the heart of the economics of growth. By making technical change dependent on economic forces, it provides a framework in which government policies can affect the long-term growth of an economy, whereas standard neoclassical growth analysis does not allow for a policy impact. But since the long term can be a quarter century or more, policies that bring growth closer to the long term growth rate are difficult to distinguish from policies that affect the long term rate, blurring in practice the endogenous growth and neoclassical growth frameworks.

In this essay I compare modern endogenous growth analysis and neo-classical growth analysis; summarise the extent to which empirical studies support or reject their main tenets; and consider the implications for government policies toward growth. Before getting down to the substantive issues, however, I want to clarify two things.

First, the term endogenous growth theory emerged in the late 1980s when Paul Romer (1986) and Robert Lucas sought to make the "residual" which dominates empirical growth calculations an economically determined factor. Among others who put technology at the heart of growth analysis are Schumpeter, Kuznets, Nelson and Winters, and analysts of the return to R&D, such as Griliches, Schmookler, and Mansfield.

Second, the alternative to an endogenous growth explanation is the standard neo-classical growth and business cycle models. Because we can not easily differentiate medium frequency changes in growth around a constant long-term rate from changes in long run growth, it is hard to test endogenous growth stories against neo-classical growth stories in the policy relevant time period. The growing importance of IT and the knowledge economy makes the endogenous growth analysis more appealing to some economists, including me, but others prefer to see the world through the neoclassical lenses.

## 1. Endogenous vs Neo-classical growth theory

Neoclassical growth analysis uses the aggregate production function to relate ln changes in output to ln changes in inputs, with the impact of the changes in inputs dependent on their share in output. Changes in labour depend on population growth, while changes in capital depend on the savings rate. The analysis predicts that output per worker will stabilise once the economy has attained a steady-state capital-labour ratio, save for exogenous technological change that lies beyond the scope of economics. It gives government no scope for affecting the economic growth over the long run.

Endogenous growth analysis diverges from neoclassical analysis by making technological change a function of economic incentives and behaviour. It predicts that growth will be faster or slower depending on the costs and benefits of knowledge-creating and innovative activity, which policy can influence in various ways. The impetus for endogenous growth theory is that the simplest version of neoclassical analysis contradicts basic facts about growth and trivialises the contribution of economics to understanding and influencing long term growth.

## Problems of neoclassical growth analysis

Neoclassical growth analysis produces a growth accounting equation that relates growth of output per worker to growth of inputs per worker, with the effect of inputs dependent on their share of output:

(1) $(g/l)' = (1-b)(k/l)' + R$, where g is output; l is the number of workers; k is capital; the ' reflects the ln rate of growth; b is the share of labour in output; and R is the residual.

Recognising that labour is not simply bodies but bodies augmented by education, analysts add the growth of education, measured by absolute changes in years of schooling (De), to the equation as part of the labour input:

(2) $(g/l)' = b(D\,e) + (1-b)(k/l)' + R$,

Models of this form have four empirical problems.

1) The residual problem. In advanced countries labour's share of output tends to be 2/3rds or more and capital's share 1/3rd. With a 1/3rd coefficient, increases in capital have modest effects on the rate of growth of output. Since e changes slowly, the analysis predicts smaller growth than we observe, which makes the residual the key term.

2) The end of growth/declining impact of capital problem. As the capital-labour ratio rises, the return to capital should fall because of diminishing marginal productivity. This reduces the growth of capital until k/l reaches some constant ratio, at which point output per worker stagnates save for the exogenous residual. This does not fit well with continued growth in advanced economies and continued high returns to capital.

3) The convergence problem. The neoclassical model predicts that output per worker will converge around the world. Areas with low k/l ratios will have high rates of return to capital and attract capital and lose labour until eventually they catch-up with more advanced areas. The facts contravene this prediction. There has been little or no convergence in output per head around the world. Capital has gone to the most highly advanced country, the US, rather than to poorer countries.

4) The balanced sector problem. The multi-sector version of the neo-classical model is a von Neumann balanced growth model, where all sectors expand at the same rate, and where no sector has any more importance than any other sector in the growth process. In fact, growth is unbalanced across sectors over time, with some sectors such as IT in the 1990s seeming to spark the entire growth process.

Underlying these problems is the fact that neo-classical analysis punts on explaining the driving force of long term growth, technological advance. For economics to illuminate the process of long term growth rather than to leave the field to engineers or futurologists or whomever, it must show that economic forces or incentives affect technological change in important ways.

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## The endogenous growth fix

**"Knowledge is the only instrument of production not subject to diminishing returns" (JM Clark).**

Endogenous growth analysis tries to bring long term growth into the domain of economics by analysing the distinct features of knowledge as a factor of production. Unlike capital or labour, knowledge can be used and reused by the same economic agent over time or by many agents at once, so that gains in knowledge spillover from one agent to another. In addition, one person's investment in knowledge may provide the insight or tool for others to develop a new idea or product, raising the productivity of their investment in knowledge, creating more spillovers. How might these spillovers show up?

Romer (1990) assumed that investment in physical capital creates knowledge as well as goods, so that technological progress t' would depend on the growth of k/l:

(3) $t' = c(k/l)'$

Adding this to the basic growth equation yields:
(4) $(g/l)' = (1 - b + c)(k/l)' + R$

In (4) investments in capital raise growth directly by (1-b) and indirectly by c, giving them a higher impact on growth than in the neoclassical model. Because of the spillover effect, the social return to investment should exceed the private return.

Lucas stressed the externalities associated with investment in human capital, including externalities across countries. Thus, the growth of human capital should have an impact that exceeds labour's share of output; and the social return to investment in schooling or other forms of human capital should exceed the private return.

Several theorists beginning with Romer (1986) (Aghion and Howitt, Grossman and Helpman) make investments in R&D the key factor in creating externalities in the growth process. If R&D has externalities, it too should have an impact on growth of output that exceeds its modest share of output; and its social return should exceed its private return.

By making investments in knowledge central to economic growth, endogenous growth analysis directs attention at topics previously viewed as peripheral to the economic theory of growth: most notably, the intellectual property rights that govern knowledge. It brings to the fore the conflict between economic growth and efficiency that any treatment of such rights creates. People need property rights over new knowledge to motivate investing in knowledge creation. But such rights necessarily restrict or reduce use of the knowledge, lowering efficiency. Because temporary monopolies encourage investment in knowledge, endogenous growth theory is more at home with imperfect competition than with perfect competition. Schumpeter redux.

## Neo-classical growth fixes

**"One of the lasting contributions of endogenous growth theory is that it stimulated empirical work that demonstrated the explanatory power of the neoclassical growth model" – R. Barro.**

There is nothing in economics that limits the inputs in growth equations to capital and labour (augmented by human capital), as conventionally measured. A wide variety of factors, ranging from government regulations to incentive pay to investments in infrastructure could affect aggregate production and short term growth in the neoclassical model. The natural way to deal with the residual problem is to add additional inputs to the growth equation, as Denison did in his analysis of the sources of growth for the US. Since capital and labour remain central in the equation, these factors either reflect additional inputs or institutional factors that presumably alter the productivity of capital and labour. Another way to deal with the residual problem is to try to better measure the quality or effectiveness of capital and labour (Fraumeni, Gollup, and Jorgenson). This moves the residual from the production function to "inside" the inputs, and changes the question about technical change from why production improved to why the inputs improved.

To deal with the failure of output per worker to converge around the world, neo-classical analysts modify the convergence proposition to conditional convergence – that is, convergence conditional on similar institutional structure or policies. As long as these other factors differ, output per worker need not converge to a common level.

In short, the neoclassical response to endogenous growth theory is to add numerous additional variables to growth equations, which necessarily raises its explanatory power, per the Barro quote above. The list of additional variables is a kitchen sink of economic and political factors: tax rates, inequality, democracy, openness to trade, economic regulations, geographic conditions that make up 36 broad categories of explanatory variables according to Durlauf and Quah. By opening the door to such a range of variables, growth theorists have ceded the terrain to empiricists and to the weight of evidence, providing only a modicum of guidance as to what factors might be more or less important.

## Cross Country Evidence

Cross-country growth regressions seek to explain differences in growth rates among countries using either an endogenous growth or neo-classical growth framework (see Durlauf and Quah for an extensive review). Most studies are cross-sectional, examining the variation in growth rates in a given period of time among countries. Some studies, however, are longitudinal, examining the variation in growth rates within countries between specified time periods. Some studies limit comparisons of growth rates to advanced countries, but the majority take all countries as their universe of observation.

All analyses show that growth of capital per worker – the key variable in neo-classical analysis – has a strong robust relation to growth (Levine and Revelt, Sala-I-Martin) while many other posited factors, including even investment in human capital, have links to growth that vary with specification, measurement, or period covered. But the fact that the country that invests a lot grows a lot does not mean that an exogenous increase in investment will induce greater growth. Some omitted factor – a good business climate – may explain both growth and investment in physical capital. To deal with this problem, some studies supplement their analysis of growth rates with separate equations for investment in physical capital.

But few studies find coefficients on capital that exceed its share of output by a statistically significant amount, though there are exceptions. De Long and Summers found that investment in equipment had a substantially larger impact on output than predicted by its share of output, but this result was non-robust to changes in specification (Blomstrom, Lipsey, and Zejan).

Measurement problems have plagued estimates of the growth of human capital across countries, with the result that some studies find substantial effects while others do not (see Durlauf and Quah, table 2 education). Krueger and Lindahl show that classical measurement error and inappropriate use of proxy variables (enrollments rather than the stock of human capital) or functional form (using percentage changes in years of education when theory favour absolute changes) explains many inconsistencies. Still, there is no convincing cross-country evidence that human capital has a

substantially larger impact on output than the share of labour in production.

There is a wide range of results on the impact of the multitude of additional variables that analysts have added to growth equations. Some studies find that trade variables or trade policy variables affect growth. Others do not (see Durlauf and Qhah, table 2, trade, trade policy). Several studies find that inequality reduces growth (Benabou) but others find a complex relation dependent on political structure (Persson and Tabellini) and some analysts (Barro, 1999) find no overall relation, with a positive link for richer countries and a negative one for less developed countries. Some studies show that democratic governance favours growth; others do not (see the review by Przeworski and Limongi)

What explains the inconclusive nature of much of the cross-country growth analysis?

One important fact, stressed by Easterly, Kremer, Pritchett, and Summers, is that aside from the newly industrialised countries in Asia, there is relatively little persistence of growth rates across developing countries. A country may have rapid growth in one five or ten year period and become the "poster economy" of the World Bank or IMF and then have a poor growth record in the next five or ten years. This makes it hard to argue that long-term structural characteristics of economies have major impacts on growth unless one can explain the changed performance in some other way. Even among OECD countries, where growth rates are less variable, the variation over time is enough to blur interpretation. In the 1970s and 1980s other advanced countries grew more rapidly than the US, providing some support for the thesis of convergence in per capita income among advanced countries and for arguments that Japanese or German institutions were more suitable for economic growth. In the late 1990s, the US did better, which made convergence seem less plausible, and which supported arguments that more competitive market institutions are better suited for growth.

Another problem is that economists have developed too many variables or hypotheses for the available cross section or longitudinal evidence to yield statistically reliable results. There are 87 different explanatory variables in the Durlauf and Quah review, compared to about 100 countries, many of which will be omitted from particular calculations due to lack of data. Limiting analysis to advanced OECD countries gives just 22 or so observations in cross-sectional analysis. If, moreover, growth depends on a configuration of factors so that some factor – say an open economy – adds to growth only in the presence of other factors – say a deregulated product market and a strong education system and low taxes – the number of cases that require investigation grows rapidly.[1] A similar problem arises if there is some lexicographic ordering of variables. If stable property rights are necessary for free trade to have a large impact on growth, and if free trade is necessary for collective bargaining to have positive effect on growth, one must split samples along the appropriate lines (Durlauf and Johnson), reducing the numbers of observations in each classification.

Longitudinal analyses of cross-country data offer no panacea to the data problem because removing country-specific factors can produce low signal to noise ratios in poorly measured variables. The result can be insignificant results even on factors that may truly affect growth. More important, perhaps, longitudinal analysis necessarily treats short term (high frequency) data, rather than the (low frequency) differences in long-term growth rates across countries that are of interest. Compounding these problems, the econometrics for analysing short panel data on countries can be tricky when lagged variables such as the initial level of income per head are important, since one cannot apply asymptotic statistical theory.

To sum up, it is difficult to draw firm conclusions about the effect of most proposed explanatory factors on economic growth from cross country regressions, or to determine whether endogenous growth theory or neoclassical growth theory are better representations of the world. For most variables you can find at least one study that shows that the variable matters and a comparable study that shows that it does not matter. Most parameter estimates are too imprecise to rule out the neoclassical model or the endogenous growth model. For more reliable evidence, we turn to studies of firms or sectors within countries.

## Company-based empirics

Cross-company growth regressions seek to explain differences in growth rates among companies in terms of R&D investments, incentive pay, or the organization of the firm. These studies use more refined and accurate measures of policy relevant variables than cross country analyses and offer more observations for analysis as a group, though some studies cover relatively few firms.[2] To the extent that we can generalise from relationships among companies to a country as a whole, these studies offer the best guide to which policies might raise the rate of growth within a country.

The cross-company studies find that investment in knowledge through R&D has a significant impact on growth; that incentive pay has a significant impact; and that the organisation of the firm and market also affects performance. These results fit well into the endogenous growth framework, although they cover too short a period and are too disaggregated to rule out a neo-classical growth interpretation.

Analysts of the effect of R&D on company performance usually regress growth of sales or sales per worker on investment in physical capital/sales and R&D/sales, appropriately lagged. Most studies find that R&D raises productivity with a coefficient that implies considerable spillover effects. Estimates of the rate of return to R&D show higher social than private returns as well (Jones and Williams). The implication is that the endogenous growth story fits the investments in knowledge that are its major concern and thus that encouraging such investments should be a major goal of policy.

Analysts that look at the effect of forms of variable pay on productivity also find positive relationships, though with greater variability in results. The Weitzman and Kruse meta-analysis found strong statistically significant impacts of profit-sharing on productivity, on the order of 5-6%. Studies relating productivity to employee ownership give weaker positive results, with worker participation in the firm apparently a key intervening factor: participation plus incentives seems to improve productivity. Conyon and Freeman have found that various forms of shared compensation schemes in the UK, ranging from profit-sharing to share ownership to options are positively related to productivity growth in the 1990s in both longitudinal and cross section comparisons.

None of these studies, however, examines if incentive pay has a one-off effect on the level of productivity or if it raises the rate of productivity growth.[3] In addition, no one has compared private vs social rates of return in this area. Given that tax policy favours incentive pay and that changing from a hierarchical to a more shared decision-making enterprise can be expensive, it is not clear how such a benefit-cost calculation would come out.

Finally, diverse evidence from the behaviour of IT and knowledge

1 With four explanatory variables, as in the text, coded for simplicity as 0/1 there are 24 =16 possible configurations. Many of these configurations will not be observed, so that one cannot empirically rule out the possibility that they might yield better or worse outcomes.

2 Some company studies treat only a small number of firms, but there are many independent samples, so that company studies cover more observations in total than cross country studies.

3 Evidence that firms that are employee owned/relate pay to company performance have better than average stock market performance supports the productivity finding, but does not cast light on the one-off vs permanent question.

intensive firms in the new Internet economy – the formation of networks of firms to advance certain technologies; clustering of firms around universities, in Silicon Valley, etc; argues for important spillovers in production that fit well in the endogenous growth framework.

## Implications for policy

In the endogenous growth framework pure market allocation of resources produces growth below what can be achieved through government encouragement of investments in knowledge that have spillovers from one economic agent to another. In the neo-classical framework policies can affect growth over policy relevant periods, though not over the truly long run. In both frameworks, incentive structures that encourage participation and risk-taking can also improve growth.

There are a wide variety of policies that could in principle affect the rate of growth of knowledge and innovation. They range from subsidies for R&D spending in the private sector, public spending on particular areas of science, scholarship support to students in areas likely to produce knowledge spillovers, funding for university based research. Some of these policies affect the supply of knowledge-creating activities. Others affect the demand for such activities. Their impacts on the overall level of knowledge-creating activity will accordingly differ. For example, a policy of supporting students to increase the supply will lower pay/employment opportunities in the future, which will reduce future supply and possibly lead to emigration of specialists. By contrast, a policy of subsidisation of R&D or increased spending on science could simply raise pay in short-run, producing little additional output. These considerations suggest that it is best to think of a coordinated policy that operates on both sides of the market.

In 2000 the UK expanded its national investment in scientific activities, following the analysis and review in the DTI White Paper 'Excellence and Opportunity'. The additional investment in science infrastructure, boost to research in key areas, and support of higher wage positions for top scientists fits well within the endogenous growth framework. These initiatives offer an excellent opportunity for a policy assessment of what government can do to enhance knowledge creation and the economic consequences thereof. In particular, it will be valuable to see whether these expenditures and policies will stop the flow of young qualified researchers to the US and other countries.

There are other policies that also fit into the growth framework, albeit less directly. Immigration policy can increase the supply of highly skilled workers, particularly in the short run. The US grants H1(B) visas for persons in occupations that firms deem in short supply. Germany is introducing a programme to bring Indian software engineers to the country. Canada has long had a policy that makes occupation a key element in immigration. Policies toward foreign students can also affect the supply of highly skilled workers, either by encouraging or discouraging them to remain in a country when their education is done. To the extent that schools motivate young students toward science, elementary and secondary school policies toward the recruitment and retention of specialist science teachers also could be considered as part of a growth policy strategy. With the seeming success of the literacy and numeracy hours in schools, perhaps the next step should be science hours.

If the spillovers that underlie endogenous growth theory are important, for instance in the form of network economies in IT, there may scope for something that smacks of industrial policy, albeit limited to research initiatives. This is sectoral or technology targeting of R&D support based on potential economic outcomes as well as on potential scientific outcomes. In this vein the US has made sizable commitment to nano-technology, in large part out of a belief that this will bring sizable economic benefits (www.nano.gov). Governments have to make choices in funding research. Potential scientific progress and defense benefits will always weigh heavily in these decisions, but so too should the potential for spillovers to the economy.

On the incentive side, the UK has developed tax policies to encourage firms to grant options or shares to workers and for workers to hold those shares for extended periods of time. The UK policy differs markedly from the US policy, which encourages ESOPs or collective ownership of shares through pension fund trusts. All economic analyses, endogenous or neoclassical growth, stress the importance of incentives, but no one knows that particular formula that would work best. Here too, there is potential value in careful monitoring of the impact of programmes.

Incentives cover the possibility of losses as well as gains. Innovative activity of the type stressed by modern growth theory runs serious risks of failure, as the fall 2000 collapse of many dot.com companies has made patently clear. The way a country deals with business failure can affect innovation and risk-taking. This makes bankruptcy laws another policy area which could affect the growth rate.

In sum, the latest economic thinking provides a distinct perspective on the policies that can affect growth. It suggests that growth policy might benefit from policy-makers consulting with the science and technology community in addition to the usual financial and industrial suspects. But extant studies say little about which specific policies can affect outcomes, much less whether those policies would meet benefit/cost tests. What modern growth analyses do say is that the framework to think about issues diverges from the traditional Treasury domain of thinking: science and technology rather than financial markets and government borrowing requirements. Endogenous growth theory, Mr. Chancellor, says you need not just economic advisors but science and technology advisors as well; or some weird fusion of the two.

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