The Forces of Economic Growth
A Time Series Perspective

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2. Methodology: Cross-Country or Time Series Studies
3. Externalities of Investment
4. Education and Economic Growth
5. Knowledge Accumulation and Economic Growth
6. Public Infrastructure Investment
7. Evaluation and Conclusion
Questions:

Walt Rostow (1990), ”Theorists of Economic Growth...” and (1960) ”The Stages of Economic Growth”

- Are we in the second, third, fourth, of fifth Industrial Revolution?
- Does the massive reallocation of resources from agriculture into manufacturing and services enhance growth?
- Will the gap between the rich and the poor nations widen?
- Will that old devil Diminishing Returns get us in the end?
1. Introduction

- Many generations of growth theories have studied the issue of the forces of economic growth (Classical economists, Harrod-Domar, Solow). Kaldor (1961) has proposed a stylized fact: constant aggregate ratios, constant per capita growth rate, different growth rates across countries, reallocation of resources. Modern modern growth theory, building on micro foundations and dynamic optimization of agents (Uzawa, Lucas, Romer...), has attempted to replicate some of those facts. In particular it has pursued the question of what forces produce persistent growth rates.

- Empirically, in the spirit of the above, cross-country regressions have explored a large number of forces of growth
  - population growth, investment rates, human capital, openness and competition, well functioning financial sector, rule of law, economic and political stability, fiscal policy, attitude toward work, climate and religion, etc...
  - but there are methodological perils with this approach, see below

- We take a time series perspective and focus our attention on some major forces of economic growth: Learning from others (externalities), human capital, knowledge accumulation, infrastructure investment
  - linear models have the problem of scale effects: There may be diminishing returns to forces of growth
  - we thus need models with nonlinearities and estimations of those
  - this allows us to study stages of economic growth characterized by different forces
  - we undertake, with newly constructed times series data, empirical studies for a few countries

- The important questions are: can a time series approach serve as a better guidance for growth policy? Can this approach better integrate public economics and economic growth? Does such an approach aid to identify country specific policies to improve growth and reduce poverty for specific stages of growth?
2. Methodology: Cross-Country or Time Series Studies

Cross-Country Regressions

\[ \ln Y_{t+1} - \ln Y_t = \alpha + \beta_1 \ln(Y_{60}) + \beta_2 \ln(n) + \beta_3 \ln(I/Y) + \beta_4 \ln(school) + \ldots + \beta_i x_i \ldots \]

- Disadvantages: countries may be at different stages of growth, there may be thresholds in development, there may not be the same preferences and technologies across countries, there is uncertainty and heterogeneity with respect to the underlying model and parameters, there is doubt on robust econometric results (see Brock and Durlauf), policy based on non-robust results

- Advantages: the studies have generated useful knowledge on factors of growth (at least for similar countries), this approach has data advantage (averaging data)

Time-Series Perspective

- Micro behavior is important, can be allowed to change over time (though embedded in a macro environment)

- For growth models, with preferences for households, first order conditions derived: one obtains a system of FOC and state variables

- Nonstationarity requires the model to be transformed into a stationary model

- Scale effects require nonlinearities

- The model needs to be transformed into an estimable form (by substituting out unobservable variables)

- Empirical estimates of the parameters and test of matching the data (using ML or GMM estimation with Simulating Annealing).

- Data requirements: high quality data

- Our results appear to support the view that there are stages of growth
3. Externalities of Investment

Growth models with positive externalities of investment implying that investment not only raises production possibilities of the investor but has also positive effects on the aggregate economy. This type of growth model goes back to Scitovsky (1954), Myrdal (1957), Romer (1986) and may characterize the first stage of growth.

The Estimable Model with Externalities

\[
\max_C \int_0^\infty e^{-(\rho-n)t}U(C)dt.
\]

\[
\dot{K} = A^\alpha K^{1-\alpha} - C(\delta_K + n)K, \quad \dot{\lambda} = \varphi I - \delta_A A.
\]

Dynamics: FOC and the state variables

\[
\frac{\dot{C}}{C} = -\frac{\rho + \delta_K}{\sigma} + \frac{(1-\alpha)K^{-\alpha}A^\alpha}{\sigma},
\]

\[
\frac{\dot{K}}{K} = - (\delta_K + n) - \frac{C}{K} + \left(\frac{A}{K}\right)^\alpha,
\]

\[
\frac{\dot{\lambda}}{\lambda} = -\delta_A + \varphi \left(\frac{I}{A}\right).
\]

In ratios: Presume, \( k = K/A \) and \( c = C/A \) are constant over time. This gives \( \dot{k}/k = \dot{K}/K - \dot{\lambda}/\lambda \) and \( \dot{c}/c = \dot{C}/C - \dot{\lambda}/\lambda \) or explicitly:

\[
\frac{\dot{k}}{k} = - (\delta_K + n) - \frac{c}{k} + \delta_A + \varphi c + (1-\varphi k)k^{-\alpha},
\]

\[
\frac{\dot{c}}{c} = -\frac{\rho + \delta_K}{\sigma} + \frac{1-\alpha}{\sigma} k^{-\alpha} + \delta_A + c\varphi - \varphi k^{1-\alpha}.
\]

which gives an estimable equation:

\[
D(\ln(C/K)) = (\delta_K + n) + \frac{\delta_K + \rho}{\sigma} + \frac{1-\alpha}{\sigma} \left(\frac{A}{K}\right)^\alpha - \frac{I}{K}.
\]
Empirical Results

Table 1: Estimation of Equation (9) for Germany

<table>
<thead>
<tr>
<th>$\varphi = 0.3$</th>
<th>$\varphi = 0.4$</th>
<th>$\varphi = 0.5$</th>
<th>$\varphi = 0.6$</th>
<th>$\varphi = 0.7$</th>
<th>$\varphi = 0.8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_1$</td>
<td>-0.106</td>
<td>0.044</td>
<td>-2.417</td>
<td>$c_1$</td>
<td>-0.08</td>
</tr>
<tr>
<td>$c_2$</td>
<td>0.405</td>
<td>0.065</td>
<td>6.214</td>
<td>$c_2$</td>
<td>0.327</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.38</td>
<td></td>
<td></td>
<td></td>
<td>$R^2$</td>
</tr>
</tbody>
</table>

In Sum:

For Germany, Table 3.1 gives the outcome for different values of $\varphi$. Overall, the model matches the growth performance for Germany, France and Japan, but less for the US and the UK.
4. Education and Economic Growth

Growth models in which individuals spend time on the formation of human capital. A prototype example is the Uzawa-Lucas model (based primarily on Uzawa 1965 and Lucas 1988) which may characterize an important force in the second stage of growth.

The Uzawa-Lucas Model

$$\max_{c,u} \int_0^\infty L(t) \frac{c(t)^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt$$ (10)

subject to

$$\dot{K}(t) = AK(t)^{1-\alpha}(u(t)h(t)L(t))^{\alpha}h_\alpha - L(t)c(t) - \delta_kK$$ (11)

$$\dot{h}(t) = h(t)p_1\kappa(1 - u(t)) + \delta_h h(t)$$ (12)

In Lucas (1988:) $$\dot{h}(t) = h(t)\kappa(1 - u(t))$"

The Estimable Model

$$\frac{\dot{k}}{k} = Ak^{-\alpha}h^{\alpha+\zeta}u^\alpha - \frac{c}{k}$$ (13)

$$\frac{\dot{h}}{h} = \kappa(1 - u)$$ (14)

$$\frac{\dot{c}}{c} = \frac{A(1 - \alpha)}{\sigma}h^{\alpha+\zeta}u^\alpha - \frac{\rho}{\sigma}$$ (15)

$$\frac{\dot{u}}{u} = \frac{\kappa(1 - \alpha - \zeta)}{1 - \alpha}u + \frac{\kappa(\alpha + \zeta)}{1 - \alpha} - \frac{c}{k}$$ (16)

The model with the direct scale effects does not fit, therefore, we consider two variants. First, we suppose that the equation $$\dot{h}/h$$ is given by

$$\frac{\dot{h}(t)}{h(t)} = h(t)p_1^{-1}\kappa(1 - u(t)) + \delta_h,$$ (17)

Second, it is written as

$$\frac{\dot{h}(t)}{h(t)} = h(t)p_1^{-1}\kappa(t)(1 - u(t)) + \delta_h.$$ (18)

With those modifications of (12) a modified system of (13)-(17) – including depreciation rates, population growth and nonlinearity in human capital creation—using ratio formulation is estimated. This is called Lucas II (Lucas I is a simpler system, with u a historical variable)
Empirical Results for Lucas II

Table 2: Estimation of the Uzawa-Lucas II Model.

<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters for Matching ((k_t - k_{t-1})/k_{t-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\alpha)</td>
<td>0.4560 (0.1289)</td>
<td>0.5192 (0.3569)</td>
</tr>
<tr>
<td>(A)</td>
<td>0.0637 (0.0062)</td>
<td>0.0539 (0.0010)</td>
</tr>
<tr>
<td>(\zeta)</td>
<td>-0.0066 (0.0681)</td>
<td>0.0081 (0.2850)</td>
</tr>
<tr>
<td>(\rho_k)</td>
<td>0.7123 (0.0582)</td>
<td>0.8518 (0.0516)</td>
</tr>
<tr>
<td>Parameters for Matching ((c_t - c_{t-1})/c_{t-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\rho)</td>
<td>0.0337 (0.0042)</td>
<td>0.0134 (0.0008)</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>1.5465 (1.1702)</td>
<td>0.4032 (0.1029)</td>
</tr>
<tr>
<td>(\rho_c)</td>
<td>0.7385 (0.0566)</td>
<td>0.5265 (0.0839)</td>
</tr>
<tr>
<td>Parameters for Matching ((h_t - h_{t-1})/h_{t-1}) and ((u_t - u_{t-1})/u_{t-1})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\kappa)</td>
<td>0.0738 (0.0030)</td>
<td>0.0608 (0.0070)</td>
</tr>
<tr>
<td>(p_1)</td>
<td>0.3295 (0.0729)</td>
<td>0.4300 (0.1060)</td>
</tr>
<tr>
<td>(p_2)</td>
<td>0.1341 (0.0119)</td>
<td>0.0155 (0.0032)</td>
</tr>
<tr>
<td>(\rho_h)</td>
<td>0.9517 (0.4975)</td>
<td>0.9936 (0.0655)</td>
</tr>
<tr>
<td>(\rho_u)</td>
<td>0.9369 (0.0175)</td>
<td>0.9712 (0.0037)</td>
</tr>
</tbody>
</table>

In Sum:
The Uzawa-Lucas model fits the data only, if nonlinearities – as shown in (12) – are allowed for: This means at low level of education the growth effects are stronger than for higher level education and human capital (see also Krueger and Lindahl 2001).
5. Knowledge Accumulation and Economic Growth

Models in which economic agents spend resources for the creation of new knowledge (measured by R&D, scientist and engineers, patents etc). This type is often called an R&D model of economic growth (see Romer 1990, Grossman and Helpman 1991) and may be characteristic for a third stage of growth.

The Model:

\[
\int_0^\infty \frac{C^{1-\sigma} - 1}{1 - \sigma} e^{-\rho t} dt, \quad (19)
\]

s.t.

\[
\dot{K} = \bar{\eta} \alpha (H - H_A) L^\beta K^{1-\alpha - \beta} - C - \delta K, \quad (20)
\]

\[
\dot{\bar{A}} = \mu H_A^\gamma A^\theta - \delta_A \bar{A}, \quad (21)
\]

Romer (1990):

\[
\dot{\bar{A}} = \mu H_A \bar{A}
\]

Estimated Model and Results:

\[
\frac{\dot{K}}{K} = \bar{\eta} K^{-\alpha} (A(H - H_A)L)^\alpha - \frac{C}{K} - \delta_K \quad (22)
\]

\[
\frac{\dot{C}}{C} = \frac{\bar{\eta}}{\sigma} (1 - \alpha)^2 (A(H - H_A)L)^\alpha K^{-\alpha} - \frac{\rho + \delta_K}{\sigma} \quad (23)
\]

\[
\frac{\dot{\bar{A}}}{\bar{A}} = \mu H_A^\gamma A^{\theta - 1} - \delta_A \quad (24)
\]

\[
\frac{\dot{H}_A}{H_A} = \ldots \quad (25)
\]
Table 3: Estimation of the Modified Romer Model

<table>
<thead>
<tr>
<th>Parameters for Matching ((K_t - K_{t-1})/K_{t-1})</th>
<th>U.S. Economy</th>
<th>German Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\alpha)</td>
<td>0.5564 (0.1114)</td>
<td>0.6171 (0.1360)</td>
</tr>
<tr>
<td>(\eta)</td>
<td>0.1179 (0.0065)</td>
<td>1.6094 (0.9742)</td>
</tr>
<tr>
<td>(\rho_k)</td>
<td>0.9686 (0.0039)</td>
<td>0.9904 (0.0002)</td>
</tr>
</tbody>
</table>

Parameters for Matching \((C_t - C_{t-1})/C_{t-1}\)

| \(\rho\)                                         | 0.0034 (0.0036) | 0.0071 (0.0065) |
| \(\sigma\)                                       | 0.5358 (0.4404) | 0.6953 (0.7506) |
| \(\rho_c\)                                       | 0.8234 (0.0480) | 0.7494 (0.0668) |

Parameters for Matching \((A_t - A_{t-1})/A_{t-1}\)

| \(\mu\)                                         | 6.8065 (2.8171) | 1.5806 (0.3598) |
| \(\gamma\)                                       | 0.3506 (0.049)  | 0.0010 (0.0681) |
| \(\phi\)                                         | 9.43e-005 (0.0044) | 0.4936 (0.0323) |
| \(\rho_a\)                                       | 0.9785 (0.0110) | 0.9675 (0.0133) |

In Sum:

The knowledge accumulation model fits the data better, as shown in (21), if nonlinearities are allowed for: This means at low level of the accumulation knowledge the growth effects may be stronger.
6. Public Infrastructure Investment

Public Infrastructure investment is important for all stages of growth. The above forces of economic growth need the support by public policy and thus fiscal policy, and its sustainability, is central. It is thus useful to connect public economics with growth theory. We need to study the composition effect of public expenditure is important.

- We pursue an approach that originates in Barro (1990) and Futagami, Morita, and Shibata (1993), and others. In their model the government undertakes productive investment that raises the marginal product of capital and stimulates economic growth (or as social service it enters households' welfare).

- Yet they assume a balanced budget, we allow for borrowing and debt, but we have to define certain fiscal regimes (fiscal rules).

- We consider a broad class of public expenditure (public consumption, public investment, transfers) and consider the composition effect of public spending (social investment could be included as well),
The Model with Infrastructure

\[
\max_{C(t)} \int_0^{\infty} e^{-(\rho-n)t} L_0 u(C(t)) dt,
\]

subject to

\[
\dot{K} + \dot{B} = (w + r_1 K + r_2 B)(1 - \tau) - C + T_p - (\delta_K + n)K - nB
\]
\[
\dot{G} = \varphi_3(1 - \varphi_0)T - (\delta_G + n)G,
\]
\[
\dot{B} = r_2 B + C_p + T_p + I_p - T - nB
\]

with per capita production function of the form

\[
f(K, G) = K^\beta (\bar{G}/L)^\alpha,
\]

Budgetary Regimes (Blinder and Solow, Domar, Barro)

Table 4: Budgetary Regimes

<table>
<thead>
<tr>
<th>Target</th>
<th>Deficit due to</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 (C_p + T_p + r_2 B &lt; T)</td>
<td>public investment</td>
</tr>
<tr>
<td>A2 (C_p + T_p + \varphi_4 r_2 B &lt; T)</td>
<td>public investment + ((1 - \varphi_4) r_2 B)</td>
</tr>
<tr>
<td>B1 (C_p + T_p + I_p &lt; T)</td>
<td>interest payment on national debt</td>
</tr>
<tr>
<td>B2 (C_p + T_p + I_p &gt; T), (C_p + T_p &lt; T)</td>
<td>(C_p + T_p + I_p) + interest payment</td>
</tr>
</tbody>
</table>

Remark:

The regimes starting from A1 and declining to B2 represent budgetary regimes with softer and softer budget constraints: Regime A1, allows public investment to be financed by deficit, regime A1, permits in addition some interest on debt to be paid by the deficit, B1 allows all interest to be paid by the deficit and B2 allows to shift any component of the public budget to be paid by deficit.
Solution for Fiscal Regimes

Solving the above optimization problem and taking into account the marginal productivity rules and the budgetary regimes, we obtain:

\[
\frac{\dot{K}}{K} = -\frac{C}{K} - (\delta_K + n) + K^{\beta-1}G^\alpha - \tau (\varphi_2 + \varphi_3(1 - \varphi_0)) \times \\
\left( K^{\beta-1}G^\alpha + \frac{B}{K} \left( \beta K^{\beta-1}G^\alpha - \frac{\delta_K}{1 - \tau} \right) \right) \\
\frac{\dot{B}}{B} = (\varphi_0 - 1)(1 - \varphi_3)\tau \left( \beta K^{\beta-1}G^\alpha - \frac{\delta_K}{1 - \tau} + \frac{K^\beta G^\alpha}{B} \right) - n + \\
(1 - \varphi_4) \left( \beta K^{\beta-1}G^\alpha - \frac{\delta_K}{1 - \tau} \right) \\
\frac{\dot{C}}{C} = -\frac{\rho + \delta_K}{\sigma} + (1 - \tau)\beta K^{\beta-1}G^\alpha \\
\frac{\dot{G}}{G} = \varphi_3(1 - \varphi_0)\tau \left( G^{\alpha-1}K^\beta + \beta K^{\beta-1}G^\alpha \frac{B}{G} - \frac{B}{G} \frac{\delta_K}{G(1 - \tau)} \right) - \delta_G - n
\]

Estimated Model and Results:

\[
c \equiv \frac{C}{K}, \quad b \equiv \frac{B}{K}, \quad x \equiv \frac{G}{K}.
\]

The new variables with respect to time gives

\[
\frac{\dot{c}}{c} = \frac{\dot{C}}{C} - \frac{\dot{K}}{K}, \quad \frac{\dot{b}}{b} = \frac{\dot{B}}{B} - \frac{\dot{K}}{K}, \quad \frac{\dot{x}}{x} = \frac{\dot{G}}{G} - \frac{\dot{K}}{K}
\]

Using GMM-estimation, the set of orthogonal conditions for our GMM estimation is:

\[
E \left[ \tilde{c} - f_1 (c, x, b) \right] = 0 \quad (33) \\
E \left[ \tilde{b} - f_2 (c, x, b) \right] = 0 \quad (34) \\
E \left[ \tilde{x} - f_3 (c, x, b) \right] = 0 \quad (35)
\]
Table 5: Results of the GMM Estimation for U.S. Time Series, 1960.4-1992.1, with \((\tau, \varphi_0, \varphi_1, \varphi_2, \varphi_3, \varphi_4) = (0.32, 0.815, 0.4, 0.35, 1.3, 0.9)\) from empirical data, Regime A2.

<table>
<thead>
<tr>
<th></th>
<th>(\rho)</th>
<th>(\sigma)</th>
<th>(1 - \alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Parameters</td>
<td>0.061</td>
<td>0.053</td>
<td>0.244</td>
</tr>
<tr>
<td>(standard errors)</td>
<td>(75096)</td>
<td>(614621)</td>
<td>(0.0179)</td>
</tr>
</tbody>
</table>

Table 6: Results of the GMM estimation for German Time Series, 1966.1-1995.1, with \((\tau, \varphi_0, \varphi_1, \varphi_2, \varphi_3, \varphi_4) = (0.4, 0.945, 0.4, 0.42, 1.5, 1)\) from empirical data.

<table>
<thead>
<tr>
<th></th>
<th>(\rho)</th>
<th>(\sigma)</th>
<th>(1 - \alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Parameters</td>
<td>0.004</td>
<td>0.224</td>
<td>0.135</td>
</tr>
<tr>
<td>(standard errors)</td>
<td>(230566)</td>
<td>(8425716)</td>
<td>(0.0287)</td>
</tr>
</tbody>
</table>

In Sum:

- The outcome on growth rates (welfare) and growth maximizing tax rates depend on the fiscal regimes (A1 and A2 are the superior ones)
- The empirical estimates indicate an overestimation of the contribution of public capital (since other forces of growth are left aside)
- Sustainability tests of fiscal policy: Using the above estimated parameters one can make inference concerning the sustainability of fiscal policy (the model allows to assess solvency; recently we explored other tests, i.e. time varying coefficient models)
7. Evaluation and Challenging Issues

- through the construction of time series for externalities, human capital (cumulative educational expenditure), knowledge capital (cumulative R&D), and public infrastructure, we have estimated the model for countries with high quality data.

- dynamic models with nonlinearities estimated: the results suggest ”stages of economic growth”

- we undertake an empirical study for a few countries, further modifications can be considered (structural shifts, more complex preferences, etc.)

- the study was mostly undertaken for countries with higher per capita income (with high quality data), new studies are on the way for less developed countries, the construction of data such as human capital, i.e. through cohorts

- our study suggests policies to improve growth prospects for specific stages (this surely needs to be more work)
  
  - are for each stage of economic growth particular policies needed (public goods and services, growth enhancing policies)
  
  - we here have explicitly modelled the effects of components of public spending but have not much considered social expenditure improving welfare (there may be trade-offs as well as complementarities),
  
  - can the model be extended to include basic social services (health, disease control) where the impact has long lags
  
  - efficiency of governments: we are aware that publicly induced investment may crowd out private investment, and as there are market failures there are also government failures (accountability and transparency needed, i.e. public accounting office)