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Modeling Growth: Exogenous, endogenous and Schumpeterian growth models

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Abstract

In this lecture, I review the theoretical origins of the empirical growth models. I begin with the Solow and AK models informed by neoclassical theory. I demonstrate that both models do not make an explicit distinction between capital accumulation and technological progress. They just lump together the physical and human capital. Then I discuss the Schumpeterian growth models with creative destruction and institutions (particularly democracy as a meta-institution). I demonstrate that the Schumpeterian models can address a wider range of questions – particularly those that cannot be addressed satisfactorily by neoclassical models. I conclude by arguing for innovations in growth modeling – particularly for innovations that involve explicit incorporation of product-market competition and non-linearities in the relationship between innovation and growth.

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Modeling Growth:
Exogenous, endogenous and Schumpeterian growth models

1. Exogenous neoclassical growth model: Solow (1956)

The Solow (1956) growth model is a model of capital accumulation in a pure production economy. No prices are involved as we are interested in output as a measure of real income. Also there is no choice in terms work/leisure (all workers work) or savings (everybody saves a fixed portion of income). Saving is always invested. Output (real income) is shared between capital and labour in accordance with their marginal products. Finally, there is no government (and hence no taxes or subsidies) and no international trade or financial markets. As such, the Solow model captures the pure impact that savings have on the long run standard of living, captured by per-capita income.

Main predictions of the Solow growth model can be summarised as follows:

- A 'steady-state growth path' is reached when output, capital and labour are all growing at the same rate. At the steady state, output per worker and capital per worker are constant.
- Shifting the trend rate of growth upward requires an increase in the labour supply and also a higher level of productivity of labour and capital.
- Cross-country differences in the rate of technological change explain much of the variation in growth rates that we see.
- Catching-up and convergence: less developed countries catch up with their developed counterparts due to higher marginal rates of return on invested capital; and per-capita income in less developed countries converges to the level in their developed counterparts.

The Solow model aims to address an essential problem in growth models without technology. The latter implies that per-capita output and per-capita capital do not grow at the steady-state. This is inconsistent with empirical evidence, which indicates that most advanced economies exhibit growth in per-capita variables in the long run. To address this issue, Solow has added a technology variable *A* into the model as follows:

$$Y(t) = f\,[K(t), A(t)L(t)] = K(t)^{\alpha}\,[A(t)L(t)]^{1-\alpha} \qquad (1)$$

Here: *Y* is real output, *K* is capital stock, *A* is technology, *L* is labour, *AL* is effective labour and α is elasticity of output with respect to capital stock. The term *AL* implies that labour is more productive when the level of technology is higher (i.e., technology is labour-augmenting or Harrod-neutral).

Solow assumes that **technological progress** and **population growth** are **exogenous**.

This implies the following levels of technology, labour and effective labour at year (t):

$A(t) = A(0)e^{gt}$; $L(t) = L(0)e^{nt}$ and $[A(t)L(t)] = [A(0)L(0)]e^{(n+g)t}$

Where A(0), L(0) and [A(0)L(0)] are initial levels of technology, labour and effective labour.

Let:

$$s = \frac{S}{Y} = saving\ rate;$$

$$k = \frac{K}{AL} = capital\ stock\ per\ effective\ labour$$

$$y = \frac{Y}{AL} = output\ per\ effective\ labour$$

Then (1) can be written as:

$$y(t) = \frac{K(t)^{\alpha}}{AL(t)^{\alpha}} = k(t)^{\alpha} \qquad (2)$$

According to (2), output per effective labour in year (t) is a positive function of capital stock per effective labour k(t) in that year.

Define the evolution of *k(t)* as the difference between: (a) investment (which is equal to savings as a fraction of output) in year (t); and (b) the ratio of capital stock to effective labour adjusted for population growth, technology growth and depreciation rate. This can be stated as follows:

$$\dot{k}(t) = sy(t) - (n + g + \delta)k(t) = sk(t)^{\alpha} - (n + g + \delta)k(t)$$

Then the ratio of capital stock to effective labour (*k*) converges to its steady-state value (*k**) when $\dot{k}(t) = 0$. This yields a steady-state value of capital-to-effective-labour ratio given in (3).

$$sk^{*\alpha} - (n + g + \delta)k^{*} = 0$$

$$\rightarrow\ sk^{*\alpha} = (n + g + \delta)k^{*}$$

$$\rightarrow\ k^{*} = [s/(n + g + \delta)]^{1/(1-\alpha)} \qquad (3)$$

Now substitute the steady-state value of capital (K* = k*[A(t)L(t)] into the Cobb-Douglas production function in (1).

$$Y(t) = \left[s/(n+g+\delta)^{1/(1-\alpha)}A(t)L(t)\right]^{\alpha}[A(t)L(t)]^{(1-\alpha)}$$ or
$$Y(t) = \left[s/(n+g+\delta)^{\alpha/(1-\alpha)}\right][A(t)L(t)] \quad (4)$$

Take logs of both sides of (4):
$$lnY(t) = \frac{\alpha}{1-\alpha}lns - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + lnA(t) + lnL(t) \quad (5)$$

Express (5) in terms of output per worker:
$$lnY(t) - lnL(t) = \frac{\alpha}{1-\alpha}lns - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + lnA(t) \quad (6)$$

Recall that *A(t) = A(0)e*^{gt}, then:
$$lnY(t) - lnL(t) = \frac{\alpha}{1-\alpha}lns - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + lnA(0) + gt$$

Let $lnA(0) = \theta + \varepsilon$, then:
$$lnY(t) - lnL(t) = lny(t) = \theta + gt + \frac{\alpha}{1-\alpha}lns - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) + \varepsilon \quad (7)$$

Assuming that the error term (ε) is not correlated with the regressors *s, n, g* and δ; equation (8) can be estimated with:

- OLS if data is averaged over the whole period. In this case, the term *gt* disappears.

  OR

- Static panel data methods (FE) if data has a panel structure, with averaging over shorter time periods.

Equation (7) is in levels – but can be converted into a growth equation by taking the log difference between income in year t and income T years ago, giving:

$$\ln y_t - \ln y_{t-T} = \theta + gt - \gamma_0 \ln y_{t-T} + \alpha/(1-\alpha)\, lns - \alpha/(1-\alpha)\, ln(n+g+\delta) + v \quad (8)$$

In (8), the convergence rate is β_0/T.

Assuming that the error term (v) is not correlated with the regressors *s, n, g* and δ; equation (8) can be estimated with:

- OLS if data is averaged over the whole period. In this case, the term *gt* disappears.

  OR

- Dynamic panel data methods (e.g., GMM) if data has a panel structure, with averaging over shorter time periods.

2. Precursor to endogenous growth models: Augmented Solow (or AK) model

Omission of human capital in the original Solow model may be problematic from theoretical and/or empirical perspectives. Kendrick (1976) argued that more than 50% of the US capital stock in 1969 was human capital. Also, Lucas (1988) argued that there may be decreasing returns to physical capital accumulation, but increasing returns to human capital accumulation. As a result, returns to total capital (physical + human capital) may be constant. Then, empirically, absence of human capital in (7) or (8) causes omitted variable bias (OVB).

Therefore, endogenous growth models augment the Solow model with human capital (*H*) - as indicated in (9) below.

$$Y(t) = f\,[K(t), A(t)L(t)] = K(t)^{\alpha}H(t)^{\beta}\,[A(t)L(t)]^{1-\alpha-\beta} \qquad (9)$$

Following the routine above, we can write the augmented model as follows:

$$\ln y_t - \ln y_{t-T} = \theta + gt - \beta_0 \ln y_{t-T} - \left(\frac{\alpha+\beta}{1-\alpha-\beta}\right)\ln(n+g+\delta) + \left(\frac{\alpha}{1-\alpha-\beta}\right)\ln s_k + \left(\frac{\beta}{1-\alpha-\beta}\right)\ln s_h + v \qquad (9a)$$

Where s_h and s_k are ratios of physical and human capital to effective labour, respectively.

Implications of the augmented Solow model is similar to the original Solow model. A larger saving rate implies a higher level of output per capita; and a larger rate of population growth implies a smaller level of output per capita. The novelty is that a larger ratio of human capital to effective labour is associated with higher level of output per capita.

As it is the case in the Solow model, the coefficients are functions of factor shares. The difference is that the coefficient on physical capital is larger. This is explained as follows: higher saving leads to higher income and this leads to a higher steady-state level of human capital - even if the percentage of income devoted to human-capital accumulation is unchanged. Hence, the presence of human-capital accumulation increases the impact of physical-capital accumulation on income. Secondly, the coefficient on $\ln(n + g + \delta)$ is larger in absolute value. The implication is that population growth is associated with a more adverse effect on per-capita income. This is because not only capital but also human capital will be spread more thinly over the larger population. In a nutshell, omitting the human-capital term biases the coefficients on saving and population growth.

Both neoclassical growth models are criticised for lacking policy implications. In these models, growth is purely a function of inputs and technology is exogenous. Stated differently, there is no room for 'growth policy' (Aghion and Hovitt, 2006).

Further criticisms include the following:

From a heterodox perspective, the neoclassical models are criticised on the grounds that:

- They assume full employment of labour and full capacity utilization
- They assume no effective demand failures
- They do not have an 'investment function' in addition to and independently of the savings function (they overlook the scope for investment-led growth)
- They overlook the reverse causality between output growth and labour productivity (Verdoorn's Law)

From a Schumpeterian perspective (Aghion and Hovitt, 2006), the neo-classical models are criticised for:

- Failing to explain why the US has been growing faster than Europe since the mid-1990s - even though the average European saving rate has been higher than the

US rate. Also, the average European capital-labor ratio has remained higher than the US ratio and has not decreased.
- Failing to explain why the growth gap between Europe and the US has persisted despite the fact that the institutions of property rights (which affect technology adoption) have been similar.

In fact, according to Aghion and Hovitt (2006) the 'first version of endogenous growth theory' (or the so-called AK models) did not make an explicit distinction between capital accumulation and technological progress. It just lumped together the physical and human capital. The accumulation of the latter is studied as intellectual capital accumulation that occurs when technological progress is made. This is evident in Lucas's (1988) influential contribution, which followed Uzawa (1965) by assuming that human capital and technological knowledge were one and the same.

3. Endogenous growth models mark 2: Schumpeterian models

The augmented Solow model was followed by a second wave of endogenous growth theory, generally known as 'innovation-based' growth theory. The latter recognizes that intellectual capital, the source of technological progress, is distinct from physical and human capital. Physical and human capital are accumulated through saving and schooling, but intellectual capital grows through innovation.

One version of innovation-based theory was initiated by Romer (1990), who assumed that aggregate productivity is an increasing function of the degree of product variety. In this theory, innovation causes productivity growth by creating new, but not necessarily improved, varieties of products.

It makes use of the Dixit–Stiglitz–Ethier production function, in which final output is produced by labour and a continuum of intermediate products:

$$Y = L^{1-\alpha} \int_0^A x(i)^\alpha di, \qquad 0 < \alpha < 1 \tag{10}$$

where L is the aggregate supply of labour (assumed to be constant), x(i) is the flow input of intermediate products, and A is the measure of different intermediate products that are available for use.

Intuitively, an increase in product variety, as measured by A, raises productivity by allowing society to spread its intermediate production more thinly across a larger number of activities, each of which is subject to diminishing returns and hence exhibits a higher average product when operated at a lower intensity.

The other version of innovation-based growth theory is the 'Schumpeterian' theory developed by Aghion and Howitt (1992) and Grossman and Helpman (1991). (Early models were produced by Segerstrom, Anant and Dinopoulos, 1990, and Corriveau, 1991). Schumpeterian theory focuses on quality-improving innovations that render old products obsolete, through the process of 'creative destruction' (Schumpeter, 1942).

In Schumpeterian theory aggregate output is again produced by a continuum of intermediate products, this time according to:

$$Y = L^{1-\alpha} \int_0^1 A(i)^{1-\alpha} x(i)^\alpha di, \qquad (11)$$

Compared to In (10), there is a fixed measure of product variety, normalized to unity, and each intermediate product i has a separate productivity parameter A(i).

Each sector is monopolized and produces its intermediate product with a constant marginal cost of unity. The monopolist in sector i faces a demand curve given by the marginal product:

$$\alpha.(A(i)L/x(i)^{1-\alpha}$$

of that intermediate input in the final sector. Equating marginal revenue (α times this marginal product) to the marginal cost of unity yields the monopolist's profit-maximizing intermediate output:

$$x(i) = \varphi LA(i), \quad \text{where } \varphi = \alpha^{2/(1-\alpha)}$$

Using this to substitute for each x(i) in the production function (11) yields the aggregate production function:

$$Y = \theta AL \tag{12}$$

where $\theta = \varphi^{\alpha}$ and A is the average productivity parameter: $A \equiv \int_0^1 A(i)\,di$

Innovations in Schumpeterian theory create improved versions of old products. An innovation in sector i consists of a new version whose productivity parameter A(i) exceeds that of the previous version by the fixed factor $\gamma > 1$. (We can call γ as the productivity premium on innovation)

Suppose that the probability of an innovation arriving in sector i over any short interval of length dt is $\mu.dt$.

Then the growth rate of A(i) is

$$\frac{d(A(i))}{A(i)}.\frac{1}{dt} = \begin{cases} (\gamma - 1).dt \text{ with probability of } \mu.dt \\ 0 \quad\quad \text{with probability of } 1 - \mu.dt \end{cases}$$

Therefore the expected growth rate of A(i) is:

$$E(g) = \mu(\gamma - 1) \tag{13}$$

We can call μ as the flow probability of innovation. In any sector, it is proportional to the current flow of productivity-adjusted R&D expenditures:

$$\mu = \lambda R/A \tag{14}$$

where R is the amount of final output spent on R&D. Dividing it by A takes into account the force of increasing complexity. That is, as technology advances it becomes more complex, and hence society must make an ever-increasing expenditure on research and development just to keep innovating at the same rate as before.

The law of large numbers guarantees that the growth rate g equals the expected growth rate in (13). Thus, from (13) and (14) we have:

$$g = (\gamma - 1)\lambda R/A \qquad (15)$$

Let's define the fraction of GDP spent on research and development as:

$$n = R/Y \qquad (16)$$

Combining (12), (15) and (16), we obtain:

$$g = (\gamma - 1)\lambda\theta nL \qquad (17)$$

Thus, innovation-based theory implies that the way to grow rapidly is not to save a large fraction of output but to devote a large fraction (n) of output to research and development.

The theory is explicit about how R&D activities are influenced by various policies, who gains from technological progress, who loses, how the gains and losses depend on social arrangements, and how such arrangements affect society's willingness and ability to create and cope with technological change, which is the ultimate source of economic growth.

Empirical challenges

The endogenous growth theory (including its Schumpeterian version) has been challenged on empirical grounds.

Critique 1: For example, Mankiw, Romer and Weil (1992), Barro and Sala-i-Martin (1992) and Evans (1996) showed, using data from the second half of the 20th century, that most countries seem to be converging to roughly similar long-run growth rates.

Yet, Schumpeterian growth theory seems to imply that, because many countries have different policies and institutions, they should have different long-run growth rates.

Proponents of Schumpeterian growth theory have responded with modifications that make the theory consistent with the critics' evidence.

For example, the Schumpeterian model of Howitt (2000) incorporates the force of technology transfer. Here, the productivity of R&D in one country is enhanced by innovations in other countries (diffusion). This implies that all countries that perform R&D at a positive level should converge to parallel long-run growth paths.

The key to this convergence is what Gerschenkron (1952) called the 'advantage of backwardness'; that is, the further a country falls behind the technology frontier, the larger is the average size of innovations, because the larger is the gap between the frontier ideas incorporated in the country's innovations and the ideas incorporated in the old technologies being replaced by innovations. This increase in the size of innovations keeps raising the laggard country's growth rate until the gap separating it from the frontier finally stabilizes.

Critique 2: Jones (1995) has argued that the evidence of the United States and other OECD countries since 1950 refutes the 'scale effect' of Schumpeterian endogenous growth theory. That is, according to the growth equation (12) an increase in the size of population should raise long-run growth by increasing the size of the workforce L, thus providing a larger market for a successful innovator and inducing a higher rate of innovation.

But in fact productivity growth has remained stationary during a period when population, and in particular the number of people engaged in R&D, has risen dramatically.

The models of Dinopoulos and Thompson (1998), Peretto (1998) and Howitt (1999) counter this criticism by incorporating Young's (1998) insight that, as an economy grows, proliferation of product varieties reduces the effectiveness of R&D aimed at quality improvement by causing it to be spread more thinly over a larger number of different sectors.

When modified this way the theory is consistent with the observed coexistence of stationary TFP growth and rising population, because in a steady state the growth-enhancing scale effect is just offset by the growth-reducing effect of product proliferation.

Critique 3: Early versions of innovation-based growth theory implied that growth would be adversely affected by stronger competition laws. This is because competition reduces the profits that imperfectly competitive firms can earn reduce the incentive to innovate. This was found to be refuted by evidence

However, Aghion and Howitt (1998, ch. 7) describe a variety of channels through which competition might in fact spur economic growth. One such channel is provided by the work of Aghion et al. (2001). The latter show that an increase in the intensity of competition will tend to reduce the absolute level of profits realized by a successful innovator, but it will also tend to reduce the profits of an unsuccessful innovator by even more. In this variant of Schumpeterian theory, more intense competition can have a positive effect on the rate of innovation because firms will want to escape the competition that they would face if they lost whatever technological advantage they have over their rivals.

Aghion et all (2013) demonstrate that the relationship between competition and productivity has an inverted-U shape.

4. Combining Schumpeterian growth models with institutional models of growth: the case of democracy

This variant of growth models combine the insights from the Schumpeterian innovation and institutional economics. In a seminal paper, Acemoglu, Aghion and Zilibotti (2006) propose a model that differentiates between economic growth in developed and developing countries. In the model, the driver of growth in developing countries consists of adoption and imitation of existing technologies and investment in existing lines of business. Growth in advanced (frontier) economies is driven by innovation.

The paper offers a number of insights about the relationship between institutions/organizations, economic growth and economic development. One of these insights relates to the notion of “appropriate institutions/organizations”. Stated simply, the equilibrium organization of production and the broader institutions of the society may differ countries depending on: (a) the level of development; and (b) the distance of the country's technology to the frontier technology. The other insight is that attempts to impose such "appropriate institutions" from the outside can turn them into "inappropriate institutions," i.e., into barriers to further convergence of a developing economy. This is just the opposite of what the Washington Consensus has been prescribing for developing countries.

The model in Acemoglu, Aghion, and Zilibotti (2006) allows for a number of predictions:

Prediction 1: Average growth should decrease more rapidly as a country approaches the world frontier when openness is low.

Prediction 2: High entry barriers become increasingly detrimental to growth as the country approaches the frontier.

These two empirical exercises point to the importance **of interacting institutions or policies with technological variables** in growth regressions: openness is particularly growth-enhancing in countries that are closer to the technological frontier; entry is more growth-enhancing in countries or sectors that are closer to the technological frontier.

Below we will see that higher (in particular, graduate) education tends to be more growth-enhancing in countries or in US states that are closer to the technological frontier, whereas primary-secondary (possibly undergraduate) education tends to be more growth enhancing in countries or in US states that are farther below the frontier.

These findings are supported in Aghion, Boustan, Hoxby and Vandenbussche (2009). This study uses cross-US-states panel data to look at how spending on various levels of education matter differently for growth across US states with different levels of frontierness as measured by their average productivity compared to frontier-state (Californian) productivity.

Prediction 3: The more frontier an economy is, the more growth in this economy relies on research education.

Innovation, democracy and growth

Does democracy enhance or hamper economic growth? One may think of various channels whereby democracy should affect per-capita GDP growth.

A first channel is that democracy pushes for more redistribution from rich to poor, and that redistribution in turn affects growth.

Along this line, Persson and Tabellini (1994) and Alesina and Rodrik (1994) analyze the relationship between inequality, democratic voting, and growth. They develop models in which redistribution from rich to poor is detrimental to growth as it discourages capital accumulation. More inequality is then also detrimental to growth because it results in the median voter becoming poorer and therefore demanding more redistribution.

A second channel, which we explore in this section, is Schumpeterian. In this perspective, democracy reduces the scope for expropriating successful innovators or for incumbents to prevent new entry by using political pressure or bribes. **In other words, democracy facilitates creative destruction and thereby encourages innovation.**

To the extent that innovation matters more for growth in more frontier economies, the prediction is:

Prediction 4: The correlation between democracy and innovation/growth is more positive and significant in more frontier economies.

Aghion et al (2013) provides a comprehensive assessment of what we can learn from Schumpeterian growth theory. In what follows, I draw liberally on that paper to highlight the relationship between innovation, democracy and growth.

Consider the following Schumpeterian model in discrete time. All agents and firms live for one period. In each period t a final good (henceforth the numeraire) is produced in each state by a competitive sector using a continuum one of intermediate inputs, according to the technology:

$$lnY_t = \int_0^1 lny_{jt} d_j \qquad (18)$$

where the intermediate products are produced again by labour according to:

$$y_{jt} = A_{jt} l_{jt} \tag{19}$$

There is a competitive fringe of firms in each sector that are capable of producing a product with technology level: A_{jt}/γ

So, each incumbent's profit flow is

$$\pi = \frac{\gamma - 1}{\gamma} \tag{20}$$

Note that each incumbent will produce using the same amount of labour (*l*)

$$l_{jt} = \frac{Y_t}{\gamma w_t} \equiv l \tag{21}$$

where *l* is the economy's total use of manufacturing labour.

We assume that there is 1 unit of labour that is used only for production. Therefore l = 1, and this implies that:

$$w_t = \frac{Y_t}{\gamma} \tag{22}$$

Finally, (9) ; (10) and (11) deliver the final output as a function of the aggregate productivity At in this economy:

$$Y_t = A_t \tag{23}$$

With $A_t = \int_0^1 lnA_{jt} d_j$ as the **end-of-period-t aggregate productivity** index:

Technology and entry

Let A_t denote the world productivity frontier at date t and assume that

$$\bar{A}_t = \gamma \bar{A}_{t-1} \tag{24}$$

with $\gamma > 1$ and exogenously given.

In Schumpeterian models, the sectors differ with respect to the type of technological competition. There are sectors where the incumbent producer is "neck-and neck" with the frontier; and those in which the incumbent firm is below the frontier.

At the beginning of date t a sector j can either be at the current frontier, with productivity level

$$A_{jt}^{b} = \bar{A}_{t-1} \tag{25}$$

or one step below the frontier, with productivity level

$$A_{jt}^{b} = \bar{A}_{t-2} \tag{26}$$

Thus, imitation -or knowledge spillovers- in this model means that whenever the frontier moves up one step from $\bar{A}_{t-1}$ to $\bar{A}_{t}$, then backward sectors also automatically move up one step from $\bar{A}_{t-2}$ to $\bar{A}_{t-1}$.

In each intermediate sector *j* only one incumbent firm I_j and one potential entrant E_j are active in each period.

In this model, innovation in a sector is made only by a potential entrant E_j since innovation does not change the incumbent's profit rate.

Before production takes place, potential entrant E_j invests in R&D in order to replace the incumbent I_j.

If successful, it increases the current productivity of sector j to

$$A_{jt} = \gamma A_{jt}^{b} \tag{27}$$

and becomes the new monopolist and produces. Otherwise, the current incumbent preserves its monopoly right and produces with the beginning-of-period productivity $A_{jt} = A_{jt}^{b}$ and the period ends.

Finally, the innovation technology is as follows: if a potential entrant E_j spends $\frac{A_t \lambda z_{jt}^2}{2}$ on R&D in terms of the final good, then it innovates with probability z_{jt} (innovation effort)

Democracy

Entry into a sector is subject to the democratic environment in the domestic country. Similar to Acemoglu and Robinson (2006), Aghion et al (2013) model democracy as freedom to entry. In a country with democracy level $\beta \epsilon [0,1]$, a successful innovation leads to successful entry only with probability β, and it is blocked with probability (1 - β).

As a result, the probability of an unblocked entry is βz_j

An unblocked entrant raises productivity from $A_{jt}^b \; to \; \gamma A_{jt}^b$ and becomes the new monopoly producer.

Equilibrium investment in innovation

The innovation decision of the potential entrant *Ej* is given by:

$$\max_{z_{jt}} \{ z_{jt} \beta \pi Y_t - A_t \lambda \frac{z_{jt}^2}{2} \tag{28}$$

In equilibrium:

$$z_{jt} = \bar{z} = \frac{\beta \pi}{\lambda} \tag{29}$$

The aggregate equilibrium innovation effort is increasing in profits and decreasing in R&D cost.

Most important for us, the innovation rate is increasing in the democracy level:

$$\frac{\delta \bar{z}}{\delta \beta} > 0 \tag{30}$$

Growth

Now we can turn to the equilibrium growth rate of average productivity. The average productivity of a country at the beginning of date t is

$$A_{t-1} = \int_0^1 A_{jt} d_j = \mu \bar{A}_{t-1} + (1-\mu)\bar{A}_{t-2} \tag{31}$$

Average productivity at the end of the same period is:

$$A_t = \mu[\beta \bar{z} \gamma \bar{A}_{t-1} + (1-\beta \bar{z})\bar{A}_{t-1}] + (1-\mu)\bar{A}_{t-1} \tag{32}$$

Then the growth rate of average productivity is simply equal to:

$$g_t = \frac{A_t - A_{t-1}}{A_{t-1}} = \gamma \frac{\mu \beta \bar{z}(\gamma-1)+1}{\mu(\gamma-1)+1} \tag{33}$$

Taking partial differential with respect to democracy (β), we can see that democracy is always growth enhancing:

$$\frac{\delta g_t}{\delta \beta} = (\bar{z} + \frac{\delta \bar{z}}{\delta \beta}\beta)(\frac{\gamma \mu(\gamma-1)}{\mu(\gamma-1)+1} > 0 \tag{34}$$

Moreover, democracy is more growth enhancing the closer the domestic country is to the world technology frontier:

$$\frac{\delta^2 g_t}{\delta\beta\delta\mu} = (\bar{z} + \frac{\delta\bar{z}}{\delta\beta}\beta)(\frac{\gamma(\gamma-1)}{[\mu(\gamma-1)+1]^2} > 0 \qquad (35)$$

This result is quite intuitive. Democratization allows for more turnover (entry and exit) that, in turn, encourages outsiders to innovate and replace the incumbents. Since frontier countries rely more on innovation and benefit less from imitation or spillovers, the result follows.

Conclusions

Neoclassical theory has informed growth models with and without human capital. These models have been shown to perform well in estimating the effects of human and physical capital on growth towards the steady state. They have also been shown to estimate convergence rates (Mankiw et al., 1992). However, they have also been criticised for failing to explain the difference in growth rates of Europe and the US despite similar institutional characteristics and similar or even higher saving rates or capital-labour ratio in Europe. Furthermore, convergence rates estimated with neoclassical growth models vary significantly between samples/studies – with a mean of 4.3% and minimum and maximum values of 1.43% and 8.34% respectively (Abreu et al., 2005).

In Schumpeterian models, growth results from quality-improving innovations. Unlike endogenous growth models informed by neoclassical theory (Romer, 1990), they highlight the importance of key economic variables such as the country's distance to the technological frontier, its institutional quality or its degree of financial development. This feature enables Schumpeterian models to address policy-relevant questions.
Nevertheless, both neoclassical and Schumpeterian models share the common characteristic of being supply-side models. The challenge is to explore the extent to which growth may be affected by effective demand failures – or more interestingly, it may generate such failures.

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