

## Section Chapter 9: Endogenous Growth Models

The growth models discussed studied in Chapter 8 identify technology as a major determinant of growth, but these models are incomplete since they don't explain where technology is coming from or how it improves. Advances in theory have aimed to endogenize (explain) technological change, explain selective convergence and differences in availability and use of technology across countries, and show a role for the state in promoting growth.

### 1 Selective/Conditional Convergence

Remember that the Solow model predicts that GDPpc will converge across countries because of (1) decreasing returns to capital and (2) technology as a free international public good allowing all countries to achieve the same TFP (total factor productivity or "the unexplained residual"). If this were true, we would expect to find a negative coefficient  $\beta$  in the cross-country growth regression

$$\dot{y}_{i,(t,t+T)} = \alpha + \beta y_{it} + \varepsilon_{it}$$

where a negative  $\beta$  on initial GDPpc  $y_{it}$  means that growth  $\dot{y}_{i,(t,t+T)}$  between times  $t$  and  $T$  is lower for countries that start out with higher GDPpc in time  $t$ . This isn't what has been found empirically, however, and when a range of poorer and richer countries are included,  $\beta$  isn't significantly different from zero, against the idea of *strong* (universal) *convergence*.

However, by including ("controlling for") supposedly exogenous (not affected by growth) investment, population growth, and rate of secondary school - denoted together as  $X_{it}$ -

$$\dot{y}_{i,(t,t+T)} = \alpha + \beta y_{it} + X_{it} + \varepsilon_{it},$$

$\beta$  is negative, indicating convergence once we have accounted for  $X_{it}$  - *conditional* (or *selective*) *convergence*. With positive coefficients on investment and secondary school (investment in human capital!) and a negative coefficient on population growth, we can interpret this to mean that if poorer countries matched richer ones in these characteristics, we would expect the poorer ones to be growing more quickly.

If we assume these  $X$ 's are exogenous to growth (meaning that the more favorable  $X$ 's of the richer countries are not a result of their growth), then a policy implication would be that poorer countries should be able to improve their growth rates (and achieve convergence) by increasing investment or schooling, and/or lowering population growth. Similarly, other studies have found selective convergence - convergence only among countries open to trade.

Still, what can firmly be said from these kinds of regressions is that countries with good growth have good policies, and a simple regression like the one above isn't enough to establish causality. And so we develop more theory on how choices and policies can lead to growth....

## 2 Coordination and Multiple Equilibria

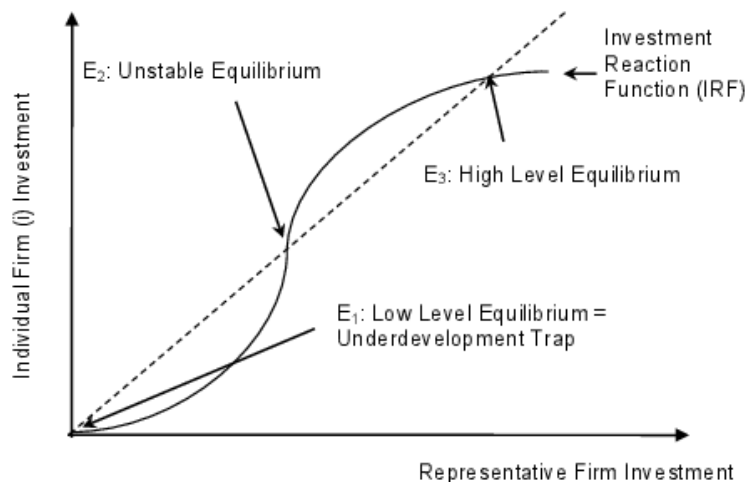
In some cases, investment in one sector may only lead to growth if complementary sectors are well developed. If a pair or more sectors each depends on the other (say, for inputs or demand for outputs), these sectors face a coordination game. In the simple version, Coal and Steel, if both sectors invest, both gain. If a sector invests alone, it loses, and the other breaks even. If neither invests, the status quo is maintained.

		Steel	
		invest	don't invest
Coal	invest	gain,gain	loss,0
	don't invest	0,loss	0,0

We can see that both sides prefer that both invest, and at minimum, both want to do the same thing. With two sectors (and a limited number of players within), perhaps the two could simply communicate their intentions and both invest. Of course, in a larger game with more necessary players, coordination could be much more complicated, and simultaneous development can be a gamble when one is unsure of the others' final action.

See that this also leads us to multiple potential equilibria - low (neither invests) and high (all invest). If we think of it in a setting with many players, we can look at the following Investment Reaction Function (IRF) from Chapter 9. In the figure, we can see two equilibrium points - high and low - that correspond to "all invest" and "none invest" in the coordination game. Everyone is best off when everyone invests at the same level, but everyone has to get past the turning point E2 into order for all the firms to want to continue pushing investment up to the high equilibrium. Short of this, one can see how countries could remain trapped at the lower equilibrium. As a result, we see a potential role for the state in helping coordination of investment across sectors.

**Figure 9.3. Multiple equilibria: The investment coordination problem**



### 3 Endogenous Growth Theory

The theory of endogenous growth proposed by Romer (1990) extends the Solow model by making the  $A$  factor an endogenous outcome and thereby explaining the origin of technological change. Technology is not an international public good (as assumed by Solow) but instead, because knowledge is protected by intellectual property rights, firms need to employ labor to engage in research. Let  $L$  be the total labor force and  $L_y$  the part of labor employed in generating output  $Y$ , and  $L_A$  the part of labor engaged in research activities, with  $L = L_y + L_A$ . The production function is

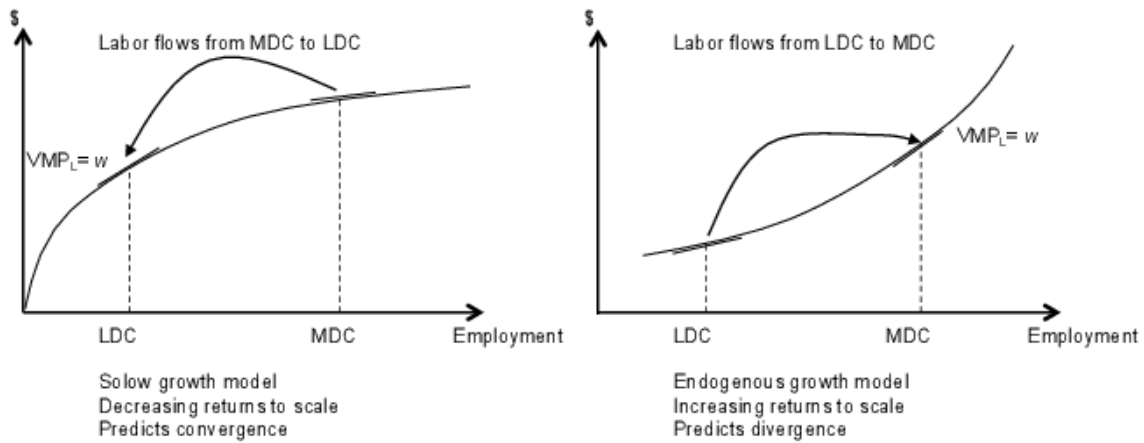
$$Y = f(K, A(L_A)L_Y)$$

$A$  can grow inside the productivity function when  $L_A$  is applied generating  $A$ . Furthermore, the model assumes that growth of knowledge is proportional to the existing stock of knowledge:

$$\Delta A = A * \delta L_A$$

where  $\delta$  is a technical coefficient that relates employment in research and the research outcome, and as a result,  $f$  displays increasing returns to scale (imagine having computers used by workers to design better computers). With increasing returns to scale, this rules out convergence.

Note that since labor should try to flow from locations with a low marginal product of labor (and low wage) to locations with a high marginal product of labor (and high wage), leading to opposite predictions between the Solow and endogenous growth models, as can be seen in Ch. 9.



The table gives summarizes differences between the Solow and endogenous growth model.

	Solow model	Endogenous growth model
Production function	$Y = Af(K, L)$	$Y = f(K, A(L_A)L_Y)$
Returns to scale	Constant; decreasing each factor	Increasing due to $\Delta A = A * \delta L_A$
Technological change $\Delta A$	Exogenous	Endogenous
Origin of technological change	International public good	Firm investment in R&D
Income differences across countries	Convergence	Divergence
Predicted international labor flows	From MDC to LDC (not observed)	From LDC to MDC (observed)

## 4 Clusters

An interesting implication in endogenous growth is a tendency toward geographic clusters. Geographic proximity facilitates spillovers across firms from benefits through the coordination described above, incomplete intellectual property rights, and specialization of labor, and formation of skilled labor markets. This can lead to imitation, and strong incentive for firms to innovate to stay ahead. This surge in innovation can further aggravate divergence.

## 5 Behavioral Determinants of Growth

Don't forget, behavior ultimately drives technological change and growth, leaving roles for

- entrepreneurship: individual, social, and contextual characteristics
- expectations about others' behavior
- learning - "learning by doing" and "learning from others"