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An Empirical Work on Catch up by The Diffusion of Technology

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Abstract: The main idea of catch up hypothesis is how rapidly follower economies tend to catch the leader since imitation and implementation of discoveries are cheaper than innovation. Therefore imitation and implementation of discoveries tends to generate convergence even though diminishing returns to capital or to R&D do not apply. If the diffusion of technology occurs gradually, then we get another reason to predict a pattern of convergence across economies, which we estimate in this study. The estimation indicates that follower economies tend to catch up the leader. Hence, we could say imitation and implementation of discoveries generate convergence in an empirically.

Key Words: Convergence, Diffusion, Human Capital and Physical Capital

Introduction

A vast and increasing number of papers have examined the pattern of convergence across countries, regions and states or provinces. Researhers' considerations have been focused on the question of whether richer economies tend to grow slower than poorer ones, possibly after controlling for other variables. If we understand the driving forces of income dynamics, then we can distinguish the main convergence (divergence) factors identified in the extant literature and develop some models to illustrate their implication for income dynamics.

The key assumption determining the convergence/divergence implication of a model has to do with the returns-to-scale properties of production technology and determinants of technical progress. Therefore, convergence arises from two channels; decreasing returns-to-scale, and technological diffusion (catch-up).

In the fashion of studying convergence, vast majority of findings is based on diminishing returns to inputs. That is the aggregate production function displays decreasing returns to inputs such as physical and human capital. Shortly, if output increases less than proportionately with these inputs, making the return to these factors is higher in economies where it is relatively scarce.

The higher rate of return on these inputs in poor economies or at least in economies that have been further below their own steady-state positions- could lead to the faster rate of per capita growth. Speed of convergence rate in this case depends upon whether poor economies have tended to save a higher or lower fraction of their incomes. Most empirical studies on convergence show that economies do convergence conditionally for less homogenous countries and absolutely for most homogenous countries such as states in USA or OECD countries.

Second channels of the convergence/divergence is that there is a process of technological diffusion allowing countries to invest relatively little in technology so not to fall too far behind in technical efficiency. The key issue in this subject is how fast discoveries of leading economies diffuse to follower economies. The main idea of catch up hypothesis is how rapidly follower economies tend to catch the leader since imitation and implementation of discoveries are cheaper than innovation. Therefore imitation and implementation of discoveries tends to generate convergence even though diminishing returns to capital or to R&D do not apply. If the diffusion of technology occurs gradually, then we get another reason to predict a pattern of convergence across economies which we will try to estimate in this study.

If decreasing returns to capital and imitation and implementation of discoveries assumptions fail to hold, as in some recent models of endogenous growth, inequalities grow without bound over time as the rich grow faster than the poor. If these two assumptions do hold, on the other hand, the distribution of income per capita across economies tends to gradually stabilize over time, although substantial income disparities may persist indefinitely if countries differ in their broad sense of investment and other characteristics.

Even if this argument has been discussed in the literature, catch up type of convergence has empirically received little attention. One good example for the catch up type study is conducted by Benhabib and Spiegel (1994) who investigated the human capital effects on the economic growth. In this study, human capital directly influences productivity by fixing the capacity of nations to innovate new technologies studied to the domestic production and also the assumption in this study is that the nation's ability to adapt and implement the new technology from abroad

is a function of its domestic human capital stocks which refers catch up type convergence.
In the first section of this study introduces the model, while the second section provides empirical implementation, and the third section presents estimation and the last conclusion.

Materials and Methods

Starting from production function of leading economy

$$Y_1 = A_1 L_1^{(1-\alpha)} \sum_{j=1}^{N_1} (x_{ij})^{\alpha} \quad (1)$$

and following economy

$$Y_2 = A_2 L_2 \sum_{j=1}^{N_2} (x_{ij})^{(1-\alpha)} \quad (2)$$

as following Barro and Sala-i-Martin (1995) in chapter 8 will leads us the model

$$\gamma_2 = \gamma_1 - \mu \log\left[(y_2 \div y_1) \div (y_2 \div y_1)^*\right] \quad (3)$$

where γ_2 and γ_1 are per capita growth rate of follower and leader countries, respectively. From now on, indices 1 and 2 refer leader and follower economies, respectively. y_2 and y_1 show the per capita income level and also these two variables with star indicate the steady state point of per capita income level. A_1 and A_2 are the productivity parameters which can represent various aspects of government policy -such as taxation, provision of public services, and maintenance of property rights- as well as the level of technology. x_{1j} and x_{2j} are quantity of nondurable input of type j. L_1 and L_2 are the aggregate labor input which are constant. N_1 and N_2 are the numbers of products are available for both economies.
The differences between A_2 and A_1 could, as already mentioned, reflect differences in government policies. The total labor input represents the scale over which an intermediate good can be utilized in production. Thus the gap between L_2 and L_1 reflects the differences in scale of the two economies. For these two economies, it is set that $N_2 \leq N_1$ and N_2 is a subset of N_1. Also any new discoveries in country 2 and any imitation in country 1 are not allowed in these model. Therefore, the model focuses on the adaptation to country 2 of product that were discovered by innovators in country 1.
This equation implies a form of conditional convergence: the growth rate of country 2, γ_2, declines with y_2/y_1 for given value of $(y_2/y_1)^*$ and γ_1. Since $(y_2/y_1)^*$ is an increasing function of A_2/A_1 and L_2/L_1 in the model, and therefore, for given value of y_2/y_1 and γ_1, a follower economy grows faster if A_2/A_1 and L_2/L_1 are higher, which means, if follower's level of technology and government policies are more favorable relative to those in the leading economy and if the follower has a relatively larger scale. These effects consider the positive effects of A_2 and L_2 on the incentive to introduce new product into economy 2.

Considering a group of follower countries, i=2,3,... with associated levels of per capita product y_i, absolute convergence need hold, if the values of A_i and L_i are the same, the poorer places may grow faster. I order to isolate the predicted inverse relation between the growth rate and the initial level of per capita product, we must condition the observed values of y_i and A_i and L_i (or observable proxies for these variables).
This type of conditional convergence do not depend on diminishing returns to capital or innovation, but does require a form of diminishing returns in imitation which is strongly depends on the assumption, for a given stock of invention. The cost of imitation rises as the number of goods already copied increases.
Empirical Implication for Convergence: One of the main issues to consider is whether the type of conditional convergence that arises in this model of technological diffusion can be distinguished empirically from the Solow-Swan and Ramsey models. If a panel data set contains variation in the variable y_1 over time, we may be able to discriminate this type of convergence empirically. Third equation implies that growth effect from log (y_i) is conditioned on the leader's value, log (y_1) which is the key to distinction. If the steady-state ratio $(y_i/y_1)^*$ is hold fixed, then an increase in $\log(y_1)$ slows down economy i's growth rate for a given value of $\log(y_i)$.
Third equation, from the diffusion model, implies that the growth rate for follower country i is determined by

$$\gamma_i = \gamma_1 - \mu \log(y_i) + \mu \log(y_1) + \mu \log(y_i \div y_1)^* \quad (4)$$

where economy 1 represents the world technological leader. More generally, country 2 would refer to an array of lagging economies that can imitate in various sectors from leading economies. In a cross section of lagging countries for given time period, γ_1 and y_1 are constants. If we have observable variables that proxy for variations in $(y_i/y_1)^*$;operationally, these variables would be the same as those that we mentioned before as proxies for variation in y_i^*. Then we can run a regression in the form of equation (4) to get an estimate of the coefficient μ.
Estimation: In this study panel data set of 48 contiguous states are used for the period from 1971 to 1986. Two way fixed effect model is applied. The state of California has been chosen as the leader state. The estimated model is as follows
$\gamma_i = c + \gamma_1 - \mu_1 \log(y_i) + \mu_2 \log(y_1) + \mu_3 \log(y_i)^* - \mu_4 \log(y_1)^*$
where $\log(y_i)^* = c_i + \log k_i + \log n_i + \log t_i$
and $\log(y_1)^* = c_1 + \log k_1 + \log n_1 + \log t_1$
y_i^* and y_1^* stand for the steady state output level for the followers and leader, respectively, while y_i and y_1 stand for the current output level for the followers and leader, respectively. k stands for physical capital to human capital ratio and n population growth rate besides t is proxy for exogenous technological proxy.
After eliminating the first and fourth autoregressive parameters which are statistically very significant in both regressions, the results are without constant terms,

1-$\log(y_i)^* = -.643941\log k_i + 0.012640\log n_i + 0.068872\log t_i$
(-27.314) (1.442) (13.769)
R-Square is 0.9454
2-$\log(y_1)^* = -0.00071\log k_1 - .046816\log n_1 + 0.020747\log t_1$
(-0.468) (-9.308) (83.782)
R-Square is 0.9229
After eliminating the first autoregressive parameters this estimated results are used in the first regression model and the result is as follows.
3-$\gamma_i = 0.850668\gamma_1 - 4.826608\log(y_i) + 1.899182\log(y_1) +$
(7.146) (-24.745) (6.193)
$4.814260\log(y_i)^* - 34.254981\log(y_1)^*$
(25.178) (-6.720)
R-square is 0.7968
after eliminating the first order autoregressive parameter. Sign of the each coefficient are just the expected. In regression (3) each of the variable (x refers any variable) is calculated by as follows in order to normalize the variables. For the sake of convenient, constant terms are not reported.

$$x = \left(x_{it} - \bar{x}\right) \div (\text{standart error})$$

This result shows us that there is a strong tendency to converge income per capita level for states. μ_1 is greater than μ_2. This shows us that convergence strongly occurs because of technological diffusion. I also estimated whether the parameters μ_1 μ_2 μ_3 and μ_4 are statistically different from each other. Estimation shows that they are statistically very different from each other. This may mean that states with different factor endowments cause these differences.

Conclusion

In addition to many finding of convergence with decreasing returns to inputs, technological diffusion would cause convergence. The main idea of catch up hypothesis is how rapidly follower economies tend to catch the leader since imitation and implementation of discoveries are cheaper than innovation. Therefore imitation and implementation of discoveries tends to generate convergence even though diminishing returns to capital or to R&D do not apply. If the diffusion of technology occurs gradually, then we get another reason to predict a pattern of convergence across economies, which we estimate in this study. The estimation indicates that follower economies tend to catch up the leader. Therefore, we could say imitation and implementation of discoveries generate convergence in an empirically.

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