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Regional Income Convergence: Evidence from a Rapidly Growing Economy*

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This paper investigates whether Korea, a rapidly growing economy, has experienced convergence of regional incomes. For the sample period 1967-1992, we found an evidence of convergence of regional incomes, which is consistent with the neoclassical growth model. The convergence rate is estimated to be four to six percent per year, much higher than that found by Barro and Sala-i-Martin (1992). However, the convergence rate in Korea has widely fluctuated from period to period. In particular, interregional income disparities in the 1970's increased due to aggregate shocks which differently affected the country's regions.

I. Introduction

The standard neoclassical growth model predicts that incomes across economies converge toward the steady-state level over time, and poor economies grow faster than rich economies. Baumol (1986), Dowrick and Nguyen (1989), Mankiw, Romer and Weil (1992), and Barro and Sala-i-Martin (1991, 1992, 1995), among others, supported the hypothesis of income convergence across developed countries. Barro and Sala-i-Martin (1991), in their comprehensive study, provided further evidence of regional income convergence in the United States, seven European countries, and Japan. They estimated a two percent annual rate of β-convergence in most of the developed countries examined. It is noteworthy that a similar rate of convergence was found for other countries over various sample periods. However, a large capital share is required to justify such a low rate of convergence. Mankiw, Romer and Weil (1992) suggested that an incorporation of human capital along with physical capital into production functions can reconcile the low rate of convergence with the model's prediction. Barro and Sala-i-Martin (1992) also conjectured that slower convergence of regional incomes in the U.S. than predicted stems from a large capital share, including human capital.

The purpose of this paper is to examine the convergence property of regional incomes in Korea. Although empirical findings for developed countries are well documented, those for developing countries are quite rare.[1] A natural question arises as to whether regional incomes

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1. The only available evidence from developing countries found by the authors, is Cardenas and Ponton (1995). They claim that the rate of convergence is close to 4 percent per year in Colombia during the period 1950-1990.

for fast growing countries would also exhibit convergence and how high the convergence rate would be. Korea should be an ideal place to address this question since Korea has been one of the fast growing economies in the world.[2] From 1967 through 1992, it was found that regional incomes converged at a rate of four to six percent per year.[3] However, the 1970's produced non-convergence of regional incomes due to the aggregate shocks (e.g., oil shock) which seemed to affect the regions in a different manner. The overall rate of four to six percent is much higher than that found in developed countries. The rapid progress of technology and the openness of regional economies are among the factors responsible for the relatively high rate of convergence in Korea.

In Section II, we will review the model of convergence and its properties. In Section III, we will present empirical results and Section IV is reserved for summary and conclusions.

II. Convergence Hypothesis

1. β-convergence

It is assumed in Solow's growth model that the saving rate, technological progress, and population growth rate are exogenous. The production function in the representative region is given by the following equation.

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha}, \tag{1}$$

where Y denotes output, K capital, L labor and A the level of technology. With the population growth rate n, saving rate s, depreciation rate δ, and the rate of technological progress g, the evolution of capital per effective labor, $k(=K/AL)$, is given by:

$$\begin{aligned} dk_t/dt &= sy_t - (n+\delta+g)k_t \\ &= sk_t^{\alpha} - (n+\delta+g)k_t, \end{aligned} \tag{2}$$

where y denotes income per effective labor $(=Y/AL)$.

Equation (2) implies that k converges to its steady-state level k^*. Thus the per capita income y also converges to its steady-state level, y^*, which is given by:

$$y^* = [s/(n+\delta+g)]^{\alpha/(1-\alpha)}. \tag{3}$$

The model predicts that the higher the s and the lower the n, the higher is the steady-state income level y^*.

2. The average annual growth rate of GDP in Korea was around 7.4 percent from 1967 to 1992.
3. This result is consistent with Byun (1998). Using various measures of rank-size distribution, he finds that interregional income disparities in Korea have decreased.

With the speed of convergence β, an approximation of y_t around the steady-state income level yields the following first-order differential equation.

$$d\ln(y_t)/dt = \beta[\ln(y^*) - \ln(y_t)], \tag{4}$$

where

$$\beta = (n+\delta+g)(1-\alpha). \tag{5}$$

Note that β gets larger as the capital share, α, becomes smaller, and technological progress is made more rapidly.

If, for example, $n = 0.014$, $\delta = 0.05$, $g = 0.03$ and $\alpha = 0.36$, then $\beta = 0.06$.[4] This implies that the economy moves halfway to steady-state in about 12 years.

The solution of Equation (4) is:

$$\ln(y_t) = (1-e^{-\beta t})\ln(y^*) + e^{-\beta t}\ln(y_0). \tag{6}$$

Equation (6) can be rewritten as follows:

$$\ln(y_t) - \ln(y_0) = (1-e^{-\beta t})\ln(y^*) - (1-e^{-\beta t})\ln(y_0). \tag{7}$$

Equation (7) implies that an economy having low initial income grows rapidly with the coefficient of initial income (y_0) being negative.

If diminishing marginal returns to capital sets in, a poor region having a low capital-labor ratio grows faster than a rich region having a high capital-labor ratio. Thus the incomes for all regions converge to the same steady-state level over time if all regions have the same steady-state income level with the identical tastes, technology, and so on. This is referred to as absolute convergence. On the other hand, conditional convergence will occur if we allow for heterogeneity across regions. If the steady-state level differs, each region's income will converge to its own steady-state, and the further a region is from its own steady state, the faster the region will grow.

2. σ-convergence

Barro and Sala-i-Martin (1991) introduce another concept of convergence, σ-convergence, which means the reduction of the standard deviation in the log of income per capita across regions. It is noted that β-convergence does not necessarily imply σ-convergence. Equation (7) is reduced to the following equation once local shocks, $u_{i,t}$, are incorporated.

4. These values are generally accepted in the Korean economy.

$$\ln(y_{i,t}/y_{i,0}) = \alpha - (1-e^{-\beta t})\ln(y_{i,0}) + u_{i,t}. \quad (8)$$

Let the variance of $\ln(y_{i,t})$ be σ_t^2. Then

$$\sigma_t^2 = e^{-2\beta t}\sigma_0^2 + \sigma_{ut}^2. \quad (9)$$

In Equation (9), even if β is positive, σ_t^2 does not decline if σ_{ut}^2 increases over time sufficiently to offset the reduction in the first term. Because reducing the cross-sectional variance is not likely to make any sense, Sala-i-Martin (1994) claims that the most interesting question is the concept of β-convergence, not σ-convergence. However, most researchers investigate σ-convergence and present it as a supplementary evidence for convergence.

III. Empirical Analysis

1. Description of the Data

The data used are annual observations of per capita real regional products for ten Korean provinces over the period 1967-1992.[5] Since regional income data are not available, we constructed a regional product data from various sources. Hwang (1984) provided per capita regional products for the period 1963-1969. Kim *et al*. (1991) generated regional product data for the period 1970-1986. The observations for the period 1985-1992 were obtained from the Bureau of Statistics. We constructed a consistent series of real per capita gross regional products (GRP) for our sample period using the GDP deflator indexed to 1985=100.

Figure 1 plots the average growth rate of per capita GRP for each region against the corresponding per capita GRP of the initial year, 1967. A negative relationship clearly exists between the initial income level and the growth rate, suggesting that, on average, poor regions have grown faster than rich ones. The correlation coefficient is -0.960.

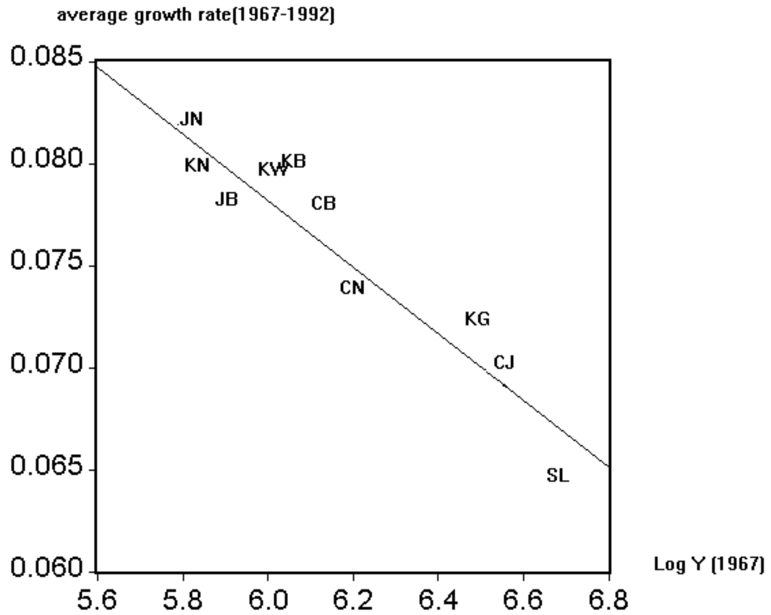
2. Convergence

Next we estimate β-convergence rate of regional incomes in Korea following Barro and Sala-i-Martin (1991, 1992). With y_{it} as the per capita income of region i in the period t, the average growth rate between the periods 0 and t is given by the following equation.

$$(1/t)\ln(y_{i,t}/y_{i,0}) = B-((1-e^{-\beta t})/t)\ln(y_{i,0}) + u_{i,t}, \quad (10)$$

where u represents random shocks to the production function and preferences. Equation (10) is obtained based on the assumption that all regions possess the identical steady-state level

5. The provinces include Seoul, Kyunggi, Kangwon, Chungbuk, Chungnam, Chonbuk, Chonnam, Kyungbuk, Kyungnam (including Pusan) and Cheju.



Note: SL (Seoul), KG (Kyunggi), KW (Kangwon), CB (Chungbuk), CN (Chungnam), JB (Chonbuk), JN (Chonnam), KB (Kyungbuk), KN (Kyungnam), CJ (Cheju)

Figure 1 Convergence of Per Capita GRP across Regions

of income. This assumption is not too restrictive since Korea is small enough for all regions to share the identical technology and preferences.

Next, we divide the whole period (1967-1992) into five-year sub-periods: 1967-1972, 1972-1977, 1977-1982, 1982-1987, 1987-1992. This grouping is consistent with 'Five-year Economic Development Plan' driven by the government.

Equation (10) is estimated by nonlinear least squares method. Table 1 summarizes the estimation results for the basic Equation (10) and the equation with a dummy variable. The dummy variable was added to capture possible difference in the steady-state of incomes between developed and underdeveloped regions.

In the regression of the basic Equation (10) for the entire sample period 1967-1992, the convergence rate was estimated to be 0.0456, which is significant at the 1% level. This rate of convergence is much higher than those found in the U.S. and some European countries and similar to that in Colombia.[6] The results for two sub-periods, however, show large fluctuations in the estimated β ranging from -0.0173 for 1972-1977 to 0.1041 for 1987-1992. The estimated β's are insignificant for the periods 1972-1977 and 1977-1982. It may be argued that the

6. See Barro and Sala-i-Martin (1992) and Cardenas and Ponton (1995).

Table 1 Basic Regressions

period	Basic Regression		Regression with Dummy	
	$\hat{\beta}$	R^2 [$\hat{\sigma}$]	$\hat{\beta}$	R^2 [$\hat{\sigma}$]
1967-1992	.0456*** (.0087)	.992 [.002]	.0614** (.0195)	.937 [.002]
1967-1972	.0995*** (.0193)	.847 [.001]	.1099** (.0338)	.850 [.011]
1972-1977	-.0173 (.0272)	.044 [.017]	.0543 (.0496)	.447 [.014]
1977-1982	.0087 (.0208)	.022 [.013]	.0514 (.0511)	.160 [.013]
1982-1987	.0545** (.0182)	.594 [.009]	.0920* (.0473)	.644 [.009]
1987-1992	.1041** (.0314)	.702 [.010]	.0870 (.0694)	.705 [.010]
joint, five sub-periods	.0528*** (.0053)		.1092*** (.0114)	
likelihood-ratio statistic	12.9250**		7.4973	

Notes: Numbers in parentheses, ( ) and [ ] are, respectively, standard errors of $\hat{\beta}$ and the standard errors of the regression equations. *(**, ***) denotes significance at 10% (5%, 1%) level. The likelihood ratio statistic is distributed as chi-square under the null hypothesis of the β's being the same for the sub-periods. The critical value with 4 degrees of freedom is 9.488 at 5% level.

aggregate shocks having different effects on regions would be responsible for the non-convergence in the 1970's. The oil shocks may have unfavorable effects on the regions whose main industries use a lot of imported oil.

When β was restricted to the same value over five year sub-periods, it was significantly estimated to be 0.0528. However, the likelihood ratio test rejects the restriction at the 5% level of significance. The critical value of χ^2 with 4 degrees of freedom at the 5% level is 9.488 while the calculated χ^2 statistic is 12.925.

The second column of Table 1 contains the results with a dummy variable which captures the difference in the steady-state level across developed and underdeveloped regions. The value of 1 was assigned to the industrialized regions and 0 elsewhere.[7] In general, the inclusion of the dummy variable tends to increase the rate of convergence in all sub-periods except for 1987-1992. The β is significantly estimated to be 0.0614 for the entire sample period, which is higher than that in the regression without the dummy variable. This suggests a much higher convergence rate of regional incomes within each sub-group. The coefficient on the dummy variable is estimated to be 0.003 (s.e. = 0.0015) for the entire sample period, implying that the steady-state of developed regions differs from that of underdeveloped regions. Also, the restriction of β being the same across the sub-periods is not rejected by the likelihood ratio test. The calculated χ^2 statistic is now 7.4973, which is not rejected at the 5% level.

7. The industrialized regions include Seoul, Kyunggi, Kyungbuk, and Kyungnam provinces.

The constrained estimate of β is 0.1092. Allowing for the difference in the steady-state level due to the difference in the development stage, regional incomes converge at the similar rate over the sub-periods.

If the effect of aggregate shocks is correlated with the initial income level, we may not obtain consistent estimates of the convergence rate. We need to eliminate unobservable shocks in the error term which have systematic relations with the initial income level. Following Barro and Sala-i-Martin (1992), we tried a few methods. First, we construct a variable for the sectoral composition, $S_{i,t}$, defined as follows:

$$S_{i,t} = \sum_{j=1}^{3} [w_{ijt} \log(y_{j,t+T}/y_{j,t})/T], \tag{11}$$

where w_{ijt} denotes the weight of the j-th sector in region i's per capita product at time t and $y_{j,t}$ is the national average per capita product from the j-th sector. Three sectors considered are agriculture, forestry and fishing; mining and manufacturing; and construction, electricity, gas and service.[8] The structural variable ($S_{i,t}$) indicates how much a region would grow if each sector grows at the national average rate. For example, suppose that region i specializes in the mining and manufacturing industries, and that sector does not grow over the period between t and $t+T$. Then the low value of $S_{i,t}$ for this region indicates that it cannot grow fast because that sector suffered from the shocks.

Table 2 shows that the structural variable is not statistically significant in all regressions. The inclusion of sectoral composition variable into the basic regression makes little change in the β estimates. It does not seem that sectoral shocks affect the convergence rate significantly. One possible reason for this poor result is that the classification of sectors we employed here may not capture the virtual sectoral shocks.

Table 2 Regressions with the Sectoral Composition

period	β	S	R^2 [$\hat{\sigma}$]
1967-1992	.0406** (.0129)	-.0194 (.0417)	.924 [.002]
1967-1972	.0681** (.0245)	-.2347 (.1549)	.884 [.010]
1972-1977	.0601 (.0895)	.3970 (.3376)	.201 [.017]
1977-1982	.0581 (.0478)	.1866 (.1354)	.231 [.013]
1982-1987	.0157 (.0276)	-.1564 (.1057)	.691 [.009]
1987-1992	.1155** (.0371)	.0443 (.0558)	.727 [.010]

8. A more detailed breakdown of industries is not possible due to the unavailability of the data.

Table 2 (Continued)

period	$\hat{\beta}$	S	R^2 [$\hat{\sigma}$]
joint, five sub-periods	.1249*** (.0139)	individual	--
likelihood ratio statistics	185.0738***		

Notes: Numbers in parentheses, ( ) and [ ] are, respectively, standard errors of $\hat{\beta}$ and the standard errors of the regression equations. * (**, ***) denotes significance at 5% (1%) level. The likelihood ratio statistic is distributed as chi-square under the null hypothesis of the β's being the same for the sub-periods. The critical value with 4 degrees of freedom is 13.277 at 1% level.

Second, we introduce into the regression the share of each region's heavy machinery and chemical industry (*HVY*), which is defined as the ratio of the product from the group of heavy machinery and chemicals industries (including chemicals and petroleum, basic metal, fabricated metal, machinery and equipment) to the gross regional product. A region with a high *HVY* generates relatively high per capita income since this sector has become the major source of income in Korea. If the effect of heavy-industry promotion policy is reflected on the error term, the correlation between errors and the initial income level should be non-zero.

Table 3 Regressions with the Share of Heavy Industry

period	$\hat{\beta}$	*HVY*	R^2 [$\hat{\sigma}$]
1967-1992	.0672*** (.0165)	.0161** (.0065)	.958 [.002]
1967-1972	.1247*** (.0298)	.0434 (.0341)	.875 [.010]
1972-1977	-.0082 (.0348)	.0209 (.0402)	.079 [.018]
1977-1982	.0668* (.0329)	.0727** (.0273)	.512 [.010]
1982-1987	.0731* (.0338)	.0187 (.0257)	.623 [.009]
1987-1992	.1553** (.0596)	.0263 (.0203)	.759 [.009]
joint, five sub-periods	.0825*** (.0027)	individual	--
likelihood ratio statistics	10.0903**		

Notes: Numbers in parentheses, ( ) and [ ] are, respectively, standard errors of $\hat{\beta}$ and the standard errors of the regression equations. * (**, ***) denotes significance at 10% (5%, 1%) level. The likelihood ratio statistic is distributed as chi-square under the null hypothesis of the β's being the same for the sub-periods. The critical value with 4 degrees of freedom is 9.488 at 5% level.

The estimated coefficient on *HVY* for the overall sample is 0.0161, which is statistically significant at the 5% level. The convergence rate is 0.0672, higher than that found in the basic regression. Holding constant the heavy industry ratio, the convergence rate increases significantly. Interestingly, the coefficient on *HVY* variable is significantly positive for the sub-period, 1977-1982. It is alleged that a strong promotion policy was implemented on the heavy machinery and chemical industries during this sub-period. Note that the inclusion of *HVY* renders the convergence rate significantly positive for 1977-1982. Since heavy machinery and chemical industries require a lot of oil, the oil shock affects unfavorably rich regions, thereby reducing the income disparities.

Third, the export-GRP ratio (*EXP*) was also tried as a control variable.[9] We hypothesized that the export ratio may be correlated with the income level since Korea has adopted an export-oriented growth policy. If that is the case, the $\hat{\beta}$ estimates may be inconsistent. Table 4 reports the estimation results. Contrary to our conjecture, the *EXP* variable does not obtain the same sign for each of the sub-periods and is not statistically significant for the entire period.

Table 4 Regressions with Export Ratio

period	$\hat{\beta}$	*EXP*	$\bar{R}^2$ [$\hat{\sigma}$]
1967 - 1992	.0456*** (.0093)	-.0042 (.0629)	.922 [.002]
1967 - 1972	.1030*** (.0152)	-.4883** (.1906)	.921 [.008]
1972 - 1977	-.0097 (.0178)	.1845*** (.0502)	.673 [.011]
1977 - 1982	.0067 (.0249)	-.0073 (.0427)	.026 [.014]
1988 - 1992	.1867* (.0806)	.0336 (.0532)	.765 [.013]
joint, four sub-periods	.0957*** (.0104)	individual	--
likelihood ratio statistics	15.744***		

Notes: Estimation cannot be done for the period 1983-1987 due to lack of the data. Numbers in parentheses, ( ) and [ ] are, respectively, standard errors of $\hat{\beta}$ and the standard errors of the regression equations. * (**, ***) denotes significance at 10% (5%, 1%) level. The likelihood ratio statistic is distributed as chi-square under the null hypothesis of the $\hat{\beta}$'s being the same for the sub-periods. The critical value with 3 degrees of freedom is 11.345 at 1% level.

The last variable we tried was the labor migration rate of each region (*MIG*), which is defined as the ratio of net number of people who migrated into the region during a sub-period to the population size of the initial period. Labor migration may have two opposite effects on the convergence of regional incomes. First, migration from poor to rich regions could help decrease the disparities of regional per capita incomes by increasing the capital-labor ratio for poor regions. The migration of workers possessing a high stock of human capital into rich regions, however, may reinforce the divergence of regional incomes. If migration is an important source of convergence and the migration rate can be treated as exogenous with

9. Fukuda and Toya (1995) claim that, given the export-GDP ratio, the cross-country evidence supports strong convergence in East Asian countries.

respect to the error term in the regression equation, the addition of the migration rate as a regressor will lower the estimated β coefficient. The estimation results are summarized in Table 5.

Table 5 Regressions with Migration Rate

period	$\hat{\beta}$	*MIG*	$\bar{R}^2$ [$\hat{\sigma}$]
1969 - 1992	.0385*** (.0080)	-.0017 (.0098)	.943 [.001]
1969 - 1972	.1349*** (.0324)	.0563 (.0639)	.851 [.012]
1972 - 1977	.0526 (.0538)	.1109* (.0561)	.386 [.015]
1977 - 1982	.0090 (.0412)	-.0006 (.0653)	.022 [.014]
1982 - 1987	.0756** (.0303)	.0357 (.0361)	.644 [.009]
1987 - 1992	.1004** (.0472)	-.0051 (.0478)	.703 [.010]
joint, five sub-periods	.0562*** (.0067)	individual	--
likelihood ratio statistics	9.6640**		

Notes: The starting year in this case is 1969. Numbers in parentheses, ( ) and [ ] are, respectively, standard errors of $\hat{\beta}$ and the standard errors of the regression equations. * (**, ***) denotes significance at 10% (5%, 1%) level. The likelihood ratio statistic is distributed as chi-square under the null hypothesis of the β's being the same for the sub-periods. The critical value with 4 degrees of freedom is 9.488 at 5% level.

When the migration rate is added to the basic regression equation, β is estimated 0.0385 (s.e. = 0.0080), slightly lower than 0.0395 (s.e. = 0.0055) for the entire period, and is statistically significant.[10] For all but the sub-period 1972-1977, the migration variable is not statistically significant.

If we restrict the coefficient on *MIG* to be the same for all sub-periods, the estimated coefficient on *MIG* is positive and significant (0.0607 (s.e. = 0.0103)). The joint estimate of β, 0.0562 (s.e. = 0.0055), is nearly the same as the value obtained when the migration rate is excluded from the regression. The joint estimate of β without *MIG* variable is 0.0556 (s.e. = 0.0039). That is, there is little change in the β estimate when the net migration is held constant. Thus, migration appears to have little effects on the convergence of regional incomes, though this may be due to the fact that the migration data are not well documented in Korea.

Since our income data were constructed from various sources, measurement errors may be large enough to introduce a bias in the estimate of β. To account for the measurement errors, we used lags of the log of income as instruments in the regressions. When we reestimated the basic equation with one period lagged income as an instrument, we obtained a joint estimate of β of 0.0309 (s.e. = 0.0035). This panel used four sub-periods starting from 1972 because

10. Since official migration data are available only from 1969, we reestimated the basic equation for 1969-1992.

the observations for 1967-1972 were lost. The OLS estimate of β for the four sub-periods is 0.0416 (s.e. = 0.0053), slightly higher than the instrumental variable estimate. Thus we conclude that measurement errors are unlikely to be critical for the convergence of Korean regional incomes.

We should mention that the convergence rate was not identical over sub-periods in most of the regressions we tried. We conjecture that a possible reason for unstable convergence rates is the too short length of sub-periods. Most literature investigating convergence of incomes uses a decade as a sub-period. When we reestimate Barro equation for decade-long data, the β estimate is 0.0363 (s.e. = 0.0123) for 1967-1977 and 0.0294 (s.e. = 0.0116) for 1977-1987. The likelihood ratio test fails to reject the null hypothesis of β being the same over the 3 sub-periods (1967-1977, 1977-1987, and 1987-1992), suggesting that the convergence rate is stable over time. This result reinforces our conclusion that regional incomes have a tendency toward convergence in Korea as in the developed countries.

Finally, we also examined σ-convergence. Figure 2 shows the cross-sectional standard deviation for the log of per capita income for all regions from 1967 to 1992. The dispersion declined from 0.31 in 1967 to 0.11 in 1992. The dispersion was relatively high in the 1970's due to the aggregate shocks having different effects on regions, but fell drastically in the late of 1980's and 1990's. This trend in the σ-convergence rate is consistent with changes in the β coefficient estimated above.

Figure 2 Dispersion of Per Capita GRPs, 1967-92

IV. Concluding Summary

Solow's growth model predicts convergence of incomes toward the steady-state level over time. Recently, the tests of the convergence hypothesis have attracted much research effort. While empirical results are mixed for convergence of incomes across countries, convergence of incomes across regions within a country is generally supported. All findings are, however, derived from developed countries. There have been few literature on developing countries.

The present study examined the regional income data in Korea, one of the most rapidly developing economies. Despite the rather short time horizon, we found an evidence of convergence in Korea. For the sample period 1967-1992, regional incomes seemed to converge at a rate of four to six percent per year. However, we observed non-convergence of regional incomes during the 1970's evidently due to the aggregate shocks (e.g., oil shock) having different effects on regions. Since Korea is considered a fast growing economy, the acceptance of the convergence hypothesis suggests that balanced growth can be achieved during a period of high rate of aggregate growth.

Interestingly, the convergence rates for various sub-periods show a lot of fluctuations. Our future research will attempt to discern the determinants of convergence rates in each sub-period. To pursue a balanced growth policy, we need to analyze factors responsible for the convergence rate of regional incomes.

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