Accounting for Two-Club Convergence

by

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Abstract

We decompose the growth of labor productivity of 52 countries into three components attributable to (1) technological change (the increase in total factor productivity), (2) capital deepening (the increase in the capital-labor ratio), and (3) the accumulation of human capital. We find that (a) two-club convergence (international polarization) is generated primarily by technological change, with help from capital deepening, whereas (b) the increased dispersion of the distribution in the 1965–1990 period is attributable primarily to capital deepening, with help from technological change and human capital accumulation.

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1. Introduction and Summary.

Much of the extensive empirical literature on economic growth focuses on (a) the convergence hypothesis (whether the poor economies are catching up with the rich) and (b) the sources of economic growth and of convergence or divergence. The early literature testing the convergence hypothesis (beginning with Baumol [1986]) relied on regressions of productivity growth rates on initial levels of productivity (and conditioning variables).[1] These studies tend to reject absolute convergence (which requires a significant negative coefficient on initial productivity levels without conditioning variables) but tend to confirm conditional convergence (a significant negative coefficient on initial productivity levels when conditioning variables are included) at a rate of about 2% per year.

But these results remain controversial. From our point of view, the most compelling criticism is that of Quah [1993, 1996a, 1997], who has argued that analyses based on first moments of the distribution cannot adequately address the issue of convergence.[2] These arguments are buttressed by the empirical analyses of Quah [1993, 1996b, 1997] and others (*e.g.*, Jones [1997]) posing robust stylized facts about the international growth pattern that beg for explanation. Figure 1 evinces three prominent characteristics of the change in the international distribution of labor productivity over time (in this case from 1965 to 1990): the mean and the dispersion increased substantially and the number of modes increased from one to two.[3] Both the enhanced dispersion and the shift to bimodality provide evidence against the convergence hypothesis.[4] The latter, in particular, means that the world is becoming divided, as a stylized fact, into two categories: the rich and the poor. This phenomenon has been referred to in the literature as "two-club," or "twin-peak," convergence (Quah [1993, 1996b, 1997] and Jones [1997]) and as "international polarization" (Henderson and Russell [2005]).

[1] See Barro and Sali-i-Martin [1995], Temple [1999], the 1996 *Economic Journal* symposium, and Durlauf, Johnson, and Temple [2004] for surveys of this literature.

[2] See Durlauf, Johnson, and Temple [2004] for analyses of other critiques of the regression approach to convergence tests.

[3] This distribution and the others we employ below are nonparametric kernel-based density estimates (essentially "smoothed histograms" of productivity levels).

[4] We employ statistical tests below to provide evidence about each of these stylized facts.

The literature on sources of economic growth and convergence harks back to the classic growth-accounting study of Solow [1957], which decomposes the growth of labor productivity in the U.S. into that attributable to increases in capital per worker and that attributable to changes in total factor productivity (the "Solow residual"). Development of rich international data sets has facilitated the extension of the Solow growth study to encompass many of the world's economies and to the incorporation of human capital into Solow's growth-accounting framework. Internationally comparable data on outputs, (physical) capital stocks, and labor are available from the Penn World Tables (Heston and Summers [1996]). Internationally comparable data on education (see, especially, Barro and Lee [1993, 1996, 2000]) and on the returns to education (Psacharopoulos [1994]) have enabled the construction of human capital indexes. We focus here on the more recent of these studies: Hall and Jones [1999] (hereafter HJ) and Bils and Klenow [2000] (hereafter BK).[5]

HJ and BK employed development-accounting (cross-sectional) methods to provide evidence about the relative contributions of the following factors to explaining cross-country differences in the level of labor productivity:

- differences in techologies (the Solow residual in a Cobb-Douglas production function with neutral technological differences among countries),
- differences in capital intensity (the ratio of physical capital to labor input in BK and of physical capital to output in HJ), and
- differences in the level of human capital (a labor-augmenting index obtained by multiplying the average number of years of education by the average rate of return to education).

HJ found that differences in technologies and human capital account for most of the cross-country variation in productivity levels, while differences in physical capital intensities account for very little of the variation. BK found that differences in technologies and physical capital intensities account for most of the variation whereas human capital differences account for little. The principal explanation for the difference between these two results is the

[5] Earlier growth-accounting exercises employing human capital indexes were carried out by Mankiw, Romer and Weil [1992], Klenow and Rodríguez-Clare [1997], and Prescott [1998]. See also the survey of these methods by Caselli [2004].

difference in the way they measure capital intensity: other than this, the basic accounting framework of the two studies is the same.[6]

A sharply different accounting framework has been employed by Henderson and Russell [2005] (hereafter HR) to provide some intertemporal evidence about the sources of both the mean changes in productivity and the changes in the international distribution of productivity noted above and illustrated in Figure 1. They posit a single (nonparametric) worldwide production frontier, or technology, that is potentially available to all countries.[7] HJ and BK assume that each country operates (efficiently) on its frontier; HR allows countries to lie below the frontier—that is, to operate inefficiently (because of imperfect markets, inapposite regulatory regimes, frictions in technology transfer, coordination failures, Leibenstein [1966] "X-inefficiency," or other causes of inefficiency). HR decompose productivity growth into components attributable to (a) capital deepening (changes in the capital-labor ratio), (b) efficiency changes (movements toward or away from the worldwide production frontier, (c) technological change ([possibly non-neutral] shifts in the production frontier), and (d) accumulation of human capital.[8]

The main findings of HR are as follows:

(1) The shift in the mean has been generated primarily by capital deepening, with substantial help from human capital accumulation, less help from technological change, and virtually no help from efficiency changes.

(2) Physical capital accumulation has been a statistically significant force for absolute beta convergence, whereas technological change has been a strong and statistically significant deterrent to convergence; the contributions of efficiency change and human capital accumulation, while pointing toward convergence, are not statistically significant.

[6] The rationale for the HJ notion of capital intensity, as opposed to the more-standard Solow notion, is that along a steady state growth path the capital/output ratio is constant, and the proximate contribution to productivity growth of capital deepening is more fundamentally attributable to technological progress, which raises output per capita and thus generates additional saving and investment.

[7] This approach to growth accounting was introduced by Färe, Grosskopf, Norris, and Zhang [1994].

[8] This quadripartite decomposition is an elaboration of the tripartite decomposition by Kumar and Russell [2002] into components (a)–(c). Los and Timmer [2005], adopting the Kumar-Russell decomposition and the terminology of Basu and Weil (1998), refer to these three components as (a) creating potential (or capital intensification), (b) assimilation of spillovers, and (c) localized innovation.

(3) Two-club convergence is generated primarily by changes in efficiency, with help from physical and human capital accumulation.

(4) the increased dispersion of the distribution is attributable primarily to capital deepening, with help from technological change and human capital accumulation.

The accounting frameworks in these studies are summarized in the following table:

Technology Assumption	Sources of Mean Changes or Differences	Sources of Convergence or Divergence
Country-Specific Production Frontiers	Hall-Jones [1999] and Bils-Klenow [2001]	
Worldwide Frontier	Henderson-Russell [2005]	Henderson-Russell [2005]

The objective of this paper is to fill in the blank cell of the above table. In particular, we apply the basic Bils-Klenow accounting framework, described above, to panel data on 52 countries for the 1965–1990 period and use the resulting tripartite decomposition of productivity growth to address each of the three changes in the distribution of productivity in terms of these growth-accounting factors. We then construct counterfactual (nonparametric) distributions that simulate the effects of changes in just one or two of the three factors over the sample period.[9] We employ tests for multimodality (Silverman [1981]) and for the difference between two unknown distributions (Chakravarti, Laha, and Roy [1967], Li [1996], and Fan and Ullah [1999]) to formally test for statistical significance of the effects of these three growth factors.

Our findings are as follows:

(1)' The increase in productivity, on average, has been generated primarily by capital deepening, with substantial help from human capital accumulation and some help from technological change.

[9] This approach was introduced by Kumar and Russell [2002] and further developed by Henderson and Russell [2005].

(2)' Human capital accumulation has been a strong and statistically significant force for absolute beta convergence; the contributions of technological change and physical capital accumulation, while pointing toward convergence, are not statistically significant.

(3)' Two-club convergence is generated primarily by changes in the Solow residual, with help from capital deepening.

(4)' the increased dispersion of the distribution is attributable primarily to capital deepening, with help from technological change and human capital accumulation.

The paper unfolds as follows. Section 2 lays out and applies our basic growth-accounting framework, yielding findings (1)' and (2)' above. Section 3 analyzes the evolving worldwide distribution of productivity, yielding findings (3)' and (4)' above. Section 4 contains some concluding remarks, focusing primarily on comparison of the results in HR, (1)–(4), and those of this paper, (1)'–(4)'.

2. Growth Accounting.

We employ a standard growth-accounting framework (see, *e.g.*, Bils and Klenow [2000]), first specifying a (particular) Cobb-Douglas technology,

$$Y_t = a_t K_t^{1/3} (H_t L_t)^{2/3}, \tag{2.1}$$

where Y_t, K_t, H_t and L_t are aggregate output, physical capital, human capital, and labor in period t and a_t is the Solow residual, representing the country-specific state of technology. Divide through (2.1) by L_t to obtain

$$y_t = a_t k_t^{1/3} H_t^{2/3}, \tag{2.2}$$

where $y_t = Y_t/L_t$ and $k_t = K_t/L_t$. Finally, denote the base and current periods by b and c and take ratios to obtain

$$\frac{y_c}{y_b} = \frac{a_c}{a_b} \left(\frac{k_c}{k_b}\right)^{1/3} \left(\frac{H_c}{H_b}\right)^{2/3}. \tag{2.3}$$

The first term on the right hand side reflects the contribution to productivity growth of technological change (the growth of the Solow residual), the second measures the effect of capital deepening, and the third measures the contribution of human capital accumulation.

For aggregate output, physical capital, and labor, we use the Penn World Tables data, focusing on the first and last years for which data (including human capital data) are available, 1965 and 1990, and the changes over that 25-year period.[10] For human capital, we adopt the Hall and Jones [1999] construction, which in turn is based on the Barro and Lee [1993, 1996, 2000] education data and the Psacharopoulos [1994] survey of wage equations evaluating the returns to education.[11] In particular, let ϵ_t represent the average number of years of education of the adult population at time t and define labor in efficiency units at time t by

$$\hat{L}_t = H_t L_t = h(\epsilon_t) L_t = e^{\phi(\epsilon_t)} L_t, \tag{2.4}$$

where ϕ is a piecewise linear function, with a zero intercept and a slope of .134 through the fourth year of education, .101 for the next four years, and .068 for education beyond the eighth year. Clearly, the rate of return to education (where ϕ is differentiable) is

$$\frac{d \ln h(\epsilon_t)}{d\epsilon_t} = \phi'(\epsilon_t), \tag{2.5}$$

and $h(0) = 1$.

The empirical results from applying the above decomposition to 52 countries for the period 1965–1990 are shown in Table 1.[12] The means in the last row suggest that, on average, physical capital accumulation has accounted for more than half of the labor productivity growth over this period, human capital accumulation has accounted for more than a quarter of the growth, and technological change (more accurately, changes in the Solow residual) has accounted for less than a quarter.[13]

[10] In particular, aggregate output is real gross domestic product (RGDPCH multipled by POP in the Penn World Tables, Mark 5.6) and aggregate inputs, capital stock and employment, are retrieved from capital stock per worker and real GDP per worker (KAPW and RGDPW). Real GDP and the capital stock are measured in 1985 international prices. Productivity is aggregate output per worker.

[11] Bils and Klenow [2000] suggest an alternative construction of a human capital index. For reasons spelled out in Henderson and Russell [2005], we prefer to stick with the Hall-Jones construction.

[12] Because of data limitations, we focus on two time periods, 1965 and 1990, and changes over that 25-year interval.

[13] These mean contributions are not additive, primarily because they are interactive and must be compounded but also because the contributions are averages of contributions rather than contributions of the averages. Taking logs of the growth factors for each country, averaging these logs, and dividing the average of the logs of the contributions by the average log of the productivity growth factor yields the following (additive) percentages for the contributions of changes in the Solow residual, physical capital accumulation, and human capital accumulation: 12 percent, 58 percent, and 30 percent.

Although our principal interest is in the evolution of the overall distribution of productivity (analyzed in the next section), several individual cases are worth noting. Consider first the five Asian "growth miracles," with output per worker almost tripling in Thailand, more than tripling in Hong Kong and Japan, quadrupling in Taiwan, and more than quintupling in South Korea over this 25-year span (Singapore is not in our data set). Although almost all of the growth factors are above average for these countries (the exceptions being relatively low human capital accumulation in Japan and slightly below average physical capital accumulation in Hong Kong), the extraordinary productivity growth appears to have been driven primarily by physical capital accumulation in Japan, Taiwan, and Thailand, by technological progress in Hong Kong, and by a combination of technological progress and physical capital accumulation in Korea.

The stagnation throughout much of Latin America appears to have been caused primarily by technological degradation, with the Solow residual declining for all of these countries in our sample except Columbia and Ecuador, both of which departed from the regional pattern with productivity growth at or near the worldwide mean. Especially noteworthy are the 30 percent and 39 percent declines in the Solow residual in Argentina and Peru.

The disastrous productivity performance throughout much of Africa[14] appears to be the result of technological degradation or stagnation (Zambia and Zimbabwe) or a declining stock of physical capital (Kenya, Zambia, and Zimbabwe).

Figure 2 contains plots of productivity growth and the growth of the three productivity components against output per worker in 1965, along with GLS regression lines. The (barely) statistically significant coefficient in panel (a) has led some to conclude that there is a tendency for the world's economies to converge over time. Only the negative slope in panel (d) is statistically significant, providing some evidence that, of the three growth factors, only human capital accumulation has been a force for convergence. We emphasize again, however, the Quah [1993, 1996b, 1997] critique of first-moment characterizations of convergence of the productivity distribution. In the spirit of that critique, we now turn to an analysis of the distribution dynamics of labor productivity.

[14] Unfortunately, because of data limitations, Africa is underrepresented in our sample.

3. Analysis of Productivity Distributions.

Having already analyzed the effects of the three factors on the mean change in productivity, we focus on *mean-preserving* shifts in the distribution when we sequentially introduce the three components. Figure 3 shows the 1965 and 1990 distributions of departures from the productivity mean, $y_t - \bar{y}$, where $\bar{y}$ is the productivity mean in year t; that is, each distribution has zero mean. The salient features of the shift are the switch from unimodal to bimodal and an increased dispersion. We aim to explain these features of the change in the productivity distribution from 1965 to 1990 in terms of the three components of the decomposition of productivity changes in (2.3).

We employ three statistical tests to assess the statistical significance of the contribution of each of the three factors (and pairwise combinations of these factors): the Silverman [1981] modality test (first employed in economic research by Bianchi [1997]) and the Kolmogorov-Smirnov (Chakravarti, Laha, and Roy [1967]) and Li [1996] tests for the difference between two unknown distributions. The null hypothesis of the Silverman test is that a kernel distribution has n modes and the alternative is that it has more than n modes. The Kolmogorov-Smirnov and Li tests attempt to determine if two data sets follow the same distribution. The null hypothesis of these tests is that the two distributions are identical and the alternative is that they differ over some range of the support.[15]

Re-write the tripartite decomposition of labor productivity changes in (2.3) as follows:

$$y_c = \frac{a_c}{a_b} \left(\frac{k_c}{k_b}\right)^{1/3} \left(\frac{H_c}{H_b}\right)^{2/3} y_b. \tag{3.1}$$

Thus, the labor productivity distribution in the current period can be constructed by successively multiplying labor productivity in the base period by each of the three contributing

[15] The Kolmogorov-Smirnov test statistic is the maximum difference between the empirical cumulative distribution functions of each data set. The null hypothesis is rejected if this test statistic is greater than the critical value. The Li test estimates the probability density functions of each data set using nonparametric kernel methods. The test statistic is based on the intergrated-square-error metric and was shown to be asymptotically distributed as a standard normal by Fan and Ullah [1999] (see Pagan and Ullah [1999 pp. 68-69] for more details). In practice, the critical values of these two tests (generally) need to be calculated via a bootstrap procedure.

factors. This in turn allows us to construct counterfactual distributions by sequential introduction of each of these factors. For example, the counterfactual 1990 labor-productivity distribution of the variable,

$$y^a = \frac{a_c}{a_b}\, y_b, \tag{3.2}$$

with its mean extracted, isolates the (mean preserving) effect on the distribution of changes in the Solow residual only, assuming no capital deepening and no accumulation of human capital, and the counterfactual 1990 labor-productivity distribution of the variable,

$$y^{ak} = \frac{a_c}{a_b} \left(\frac{k_c}{k_b}\right)^{1/3} y_b, \tag{3.3}$$

with its mean extracted, isolates the (mean preserving) effect on the distribution of changes in the Solow residual and capital deepening, assuming no accumulation of human capital.

Table 2 contains the Silverman test results for multimodality of the counterfactual distributions generated by sequential introduction of components of the tripartite decomposition, and Table 3 contains the Kolmogorov-Smirnov and Li test results for identity of the counterfactual distributions and the actual 1990 distribution. While these tests are not formally nested, the tests in Table 3 are intuitively more demanding, since the tests in Table 2 assess only one aspect (multimodality) of the distributions.

The first two tests in Table 2 (rows 0 and 1) confirm the stylized fact that the distribution contained one mode in 1965 and two modes in 1990. This test is reinforced by the test in the first row of Table 3, rejecting the hypothesis that the actual 1965 and 1990 distributions in Figure 3 are identical.

The next three tests (rows 2–4 in Tables 2 and 3) each introduce just one of the four components of productivity growth. The results in Table 2 indicate that the principal determinant of the polarization of the productivity distribution is the collection of changes in the Solow residual. Technological change, unlike the other two factors, can account for the shift to bimodality at the ten-percent significance level and can do so at the five-percent level when combined with capital deepening, whereas no other pairwise combination can explain the polarization.

On the other hand, the tests in Table 3 of the null hypothesis of identity of the counterfactual and actual 1990 distributions indicate that changes in the Solow residual play only a minor role in explaining the overall shift in the distribution between 1965 and 1990. Rather, physical capital accumulation appears to be the driving force in explaining the overall change: according to the Li test, at the five percent significance level, this factor alone can explain the shift in the distribution, and the only pairs that can explain the change entail a combination of capital deepening with each of the other two factors. The Kolmogorov-Smirnov test agrees with the Li test everywhere except in row 5, where it fails to reject the equivalence of the 1990 distribution and the counterfactual distribution incorporating technological change and human capital accumulation.

Figures 4–8 illustrate the facts teased from Tables 2 and 3, showing the shifts in the distribution brought about by sequential introduction of the three components of productivity change. Panel (a) in each figure is identical to Figure 3, displaying the actual distributions of deviations from the mean in 1965 and 1990, to facilitate comparisons to the counterfactual distributions for 1990 that follow. (As in Figures 1 and 3, the 1965 distribution is the dashed curve and the 1990 distribution is the solid curve.) Each of the succeeding panels contains the actual 1990 distribution and a counterfactual distribution (the dashed curves). Thus, Panel (b) of Figure 4 compares the actual 1990 distribution to the counterfactual 1990 distribution corresponding to equation (3.2); it shows what the 1990 distribution would have looked like if only the Solow residual had changed (*i.e.* with no changes in the capital-labor ratio or in the amount of human capital) for each country in our sample. A salient aspect of this comparison is the evident emergence of bimodalism in this counterfactual distribution, illustrating the test result in line 2 of Table 2 (significance at the ten-percent level). The dispersion of the counterfactual distribution, however, is not perceptibly different from that of the 1965 distribution in panel (a), and as a result the two curves in panel (b) are not close to one another; this comparison reflects the test result in line 2 of Table 3, definitively rejecting the null hypothesis that the two distributions are identical.

Panel (c) of Figure 4 contains the counterfactual distribution under the assumption that only the Solow residual and the capital stock per worker changed. Bimodalism is now even more palpable, reflecting the test result in line 5 of Table 2 (significance at the five-percent level). Also apparent is the widening dispersion of the counterfactual distribution when capital deepening is added, reflecting the test in line 5 of Table 3.

Panel (d) shows the effect of adding the third factor, human capital accumulation to the mix, and of course the two curves are identical.

In Figure 5, the order of introduction of physical and human capital accumulation is reversed. Panel (c) makes it evident that the inclusion of human capital acccumulation does nothing to explain the emergence of bimodality, reflecting the test result in line 6 of Table 2. The dispersion seems to increase somewhat in going from panel (b) to panel (c), but the difference between the two curves in panel (c) is greater than in panel (c) of Figure 4; this seems to reflect the contradictory test results using the Kolmogorov-Smirnov and Li tests in line 6 of Table 3.

In Figure 6, capital deepening is introduced first, and in panel (b) there is little evidence of bimodality (see the test in line 3 of Table 2) but dispersion in the counterfactual distribution increases substantially compared to the actual 1965 distribution in panel (a). As a result, the two distributions in panel (b) are not far apart, reflecting the test result in line 3 of Table 3. The introduction of the effect of human capital accumulation in panel (c) moves the two curves closer together (note the lower test statistics in line 7 compared to line 3 of Table 3). Bimodality does not emerge until the introduction of the effect of changes in the Solow residual in panel (d) (see line 7 of Table 2).

4. Concluding Remarks.

Comparison of the findings of this paper, (1)'–(4)' in Section 1 above, with those of HR, (1)–(4) in Section 1, reveals some similarities and consistencies and some contrasts.[16] Both

[16] Although the growth-accounting framework of BK is conceptually the same as the development-accounting framework of this paper, BK attribute more importance to the Solow residual and less to capital accumulation than do we. As shown by HR, this contrast appears to be attributable to differences between cross-sectional and panel-data analyses.

methods attribute the average growth of productivity to factor accumulation, especially physical capital accumulation. Also consistent is the primacy of physical capital accumulation in explaining the increased dispersion of the productivity distribution.

While HR attribute two-club convergence primarily to changes in efficiency, the results of this paper find the source to be changes in the Solow residual. In fact, it is not difficult to rationalize these results, since the Solow residual probably captures much the same phenomena as do technological change and efficency changes in the HR framework. In a sense, one could think of the HR structure as decomposing the Solow residual into these two components.

Perhaps the most intriguing contrast between the two approaches is that HR find that the principal contribution to absolute beta convergence is physical capital accumulation whereas the results in this paper suggest that the principal factor is human capital accumulation. While this contrast might merit further study, we note again the merit of the Quah [1993, 1996a, 1997] critique of these regression methods for assessing convergence.

Nevertheless, the two approaches do represent fundamentally different approaches to modeling technological change and the dissemination of technology. In HR, a common worldwide technology is in principal accessible to all countries, with most countries failing to achieve their potential because of inefficient exploitation of this technology. In this paper, and in almost all of the macroeconomic research on convergence and on growth and development accounting, country-specific technologies with neutral technological differences between countries are posited, with each firm always achieving its full potential. Which of these two visions is correct? Probably neither. Surely there are impediments to technology transfer that go beyond inefficiencies and surely many if not all countries fall below their potential because of inefficiencies. To accept the view that countries always operate on their (Cobb-Douglas) frontiers, one would have to accept the finding in Table 1 that there was, over the 1965–90 period, technological degradation in almost 40% of the countries, with the extent of deterioration around 40% in some countries.

Probably the truth lies somewhere in between these extreme formulations: the Solow residual reflects in part relative efficiencies in exploiting available technologies and the efficiency index in the nonparametric frontier analysis refects in part inaccessibility of extant technolgies rather than inefficiencies. Although the standard Cobb-Douglas growth accounting framework employed in this paper formally assumes that all countries operate on the frontier of their idiosyncratic technologies, one might argue that this frontier does not really represent the best available technology but rather the best technology that a particular country is able to access and assimilate because of various types of impediments to technology transfer. For example, Mankiw [1995, p. 301] (cited in Durlauf, Johnson, and Temple [2004]) argues that "for understanding international experience, the best assumption may be that all countries have access to the same pool of knowledge, but differ by the degree to which they take advantage of this knowledge by investing in physical and human capital."

Finally, let us acknowledge that the growth accounting factors analyzed in this paper are only the proximate causes of the evolving characteristics of the productivity distribution, and the results are undoubtedly consistent with more than one macrodynamic model; we see these results as establishing stylized facts about distribution dynamics that might be taken into account in modeling the macro economy. They raise questions that beg for the attention of macroeconomic model building. In particular, what is it about the process of technological change, or perhaps about technological transfer, that is causing the two-club convergence? Why is it that capital deepening seems to be driving the increasing dispersion of the worldwide productivity distribution, despite the fact that the extent of capital deepening appears (referring back to panel (c) of figure 2) to be unrelated to the initial level of output per worker? These questions suggest the need for additional research on the causes of the dramatic changes over time in the international distribution of output per worker.

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Table 1
Percentage Changes of Tripartite Decomposition Indexes: 1965–1990

Country	$\left[\frac{y_{90}}{y_{65}} - 1\right] \times 100$	$\left[\frac{a_{90}}{a_{65}} - 1\right] \times 100$	$\left[\left(\frac{k_{90}}{k_{65}}\right)^{1/3} - 1\right] \times 100$	$\left[\left(\frac{H_{90}}{H_{65}}\right)^{2/3} - 1\right] \times 100$
Argentina	4.6%	-30.4	26.5	18.8
Australia	42.7	11.6	23.2	3.8
Austria	95.1	10.7	62.2	8.7
Belgium	78.4	27.9	33.8	4.3
Bolivia	32.8	-3.2	28.9	6.5
Canada	54.6	4.5	32.4	11.6
Chile	16.6	-19.5	23.5	17.3
Columbia	68.9	20.3	22.7	14.3
Denmark	39.1	-1.1	32.8	5.9
Dominican Republic	51.8	-17.5	54.6	19.1
Equador	80.9	4.3	39.2	24.6
Finland	96.2	13.5	39.2	24.2
France	78.3	11.6	42.6	12.1
Germany, West	70.7	10.5	49.0	3.7
Greece	129.5	25.0	52.9	20.0
Guatemala	28.5	-3.3	19.8	11.0
Honduras	22.9	-10.9	15.1	19.7
Hong Kong	251.1	126.5	23.8	25.2
Iceland	66.4	2.4	41.3	15.0
India	80.5	9.8	35.3	21.5
Ireland	133.1	40.3	46.2	13.6
Israel	86.1	35.3	20.8	13.9
Italy	117.4	43.5	37.9	9.9
Jamaica	-3.6	-17.9	-0.7	18.3
Japan	208.5	45.3	90.6	11.4
Kenya	35.3	22.3	-5.7	17.3

Table 1 (Continued)

Country	$\left[\frac{y_{90}}{y_{65}}-1\right] \times 100$	$\left[\frac{a_{90}}{a_{65}}-1\right] \times 100$	$\left[\left(\frac{k_{90}}{k_{65}}\right)^{1/3}-1\right] \times 100$	$\left[\left(\frac{H_{90}}{H_{65}}\right)^{2/3}-1\right] \times 100$
Korea, Republic of	424.5	90.1	104.9	34.6
Malawi	43.9	-17.5	60.8	8.5
Mauritius	57.0	5.8	24.4	19.3
Mexico	47.5	-11.2	28.4	29.4
Netherlands	51.5	-3.7	29.9	21.0
New Zealand	7.4	-18.7	21.9	8.3
Norway	69.7	21.6	8.5	28.6
Panama	32.9	-19.8	33.8	23.7
Paraguay	63.2	-17.4	64.7	20.0
Peru	-16.1	-38.5	10.7	23.3
Philippines	43.8	4.1	12.9	22.3
Portugal	168.8	48.1	51.7	19.7
Sierra Leone	-5.8	-41.4	49.3	7.6
Spain	111.7	8.1	66.5	17.7
Sri Lanka	72.1	18.2	28.9	12.9
Sweden	36.0	-8.7	35.6	9.9
Switzerland	38.7	-9.2	33.7	14.2
Syria	107.9	38.6	15.6	29.8
Taiwan	319.0	59.0	105.5	28.3
Thailand	194.7	45.8	70.9	18.2
Turkey	129.3	31.2	47.5	18.5
United Kingdom	60.7	9.4	34.3	9.4
U.S.A.	31.1	-7.8	25.6	13.3
Yugoslavia	88.1	4.6	51.7	18.5
Zambia	-33.9	-35.4	-16.7	22.9
Zimbabwe	11.4	2.6	-11.8	23.1
Mean	**78.6**	**10.0**	**36.1**	**16.8**

Table 2: Modality Tests (p-values).

	Distribution	H_0: One Mode H_A: More Than One Mode	H_0: Two Modes H_A: More Than Two Modes
0.	$f(y_{65})$	.446 (H_0 not rejected)	.566 (H_0 not rejected)
1.	$f(y_{90})$	.001 (H_0 rejected)	.275 (H_0 not rejected)
2.	$f\left(y_{65} \cdot \frac{a_{90}}{a_{65}}\right)$	.091 (H_0 not rejected)	.484 (H_0 not rejected)
3.	$f\left(y_{65} \cdot \left(\frac{k_{90}}{k_{65}}\right)^{1/3}\right)$	.219 (H_0 not rejected)	.465 (H_0 not rejected)
4.	$f\left(y_{65} \cdot \left(\frac{H_{90}}{H_{65}}\right)^{2/3}\right)$	.304 (H_0 not rejected)	.531 (H_0 not rejected)
5.	$f\left(y_{65} \cdot \frac{a_{90}}{a_{65}} \cdot \left(\frac{k_{90}}{k_{65}}\right)^{1/3}\right)$	.020 (H_0 rejected)	.734 (H_0 not rejected)
6.	$f\left(y_{65} \cdot \frac{a_{90}}{a_{65}} \cdot \left(\frac{H_{90}}{H_{65}}\right)^{2/3}\right)$	.073 (H_0 not rejected)	.867 (H_0 not rejected)
7.	$f\left(y_{65} \cdot \left(\frac{k_{90}}{k_{65}}\right)^{1/3} \cdot \left(\frac{H_{90}}{H_{65}}\right)^{2/3}\right)$	.140 (H_0 not rejected)	.714 (H_0 not rejected)

Table 3: Distribution Hypothesis Tests.

	Null Hypothesis (H_0)	Kolmogorov-Smirnov Test (critical value: .250)	Li Test (critical value: 1.64)
1.	$f(y_{90}) = g(y_{65})$	.308 (H_0 rejected)	4.46 (H_0 rejected)
2.	$f(y_{90}) = g\big(y_{65} \cdot \frac{a_{90}}{a_{65}}\big)$	.288 (H_0 rejected)	3.13 (H_0 rejected)
3.	$f(y_{90}) = g\Big(y_{65} \cdot \big(\frac{k_{90}}{k_{65}}\big)^{1/3}\Big)$	.192 (H_0 not rejected)	1.31 (H_0 not rejected)
4.	$f(y_{90}) = g\Big(y_{65} \cdot \big(\frac{H_{90}}{H_{65}}\big)^{2/3}\Big)$	.269 (H_0 rejected)	3.13 (H_0 rejected)
5.	$f(y_{90}) = g\Big(y_{65} \cdot \frac{a_{90}}{a_{65}} \cdot \big(\frac{k_{90}}{k_{65}}\big)^{1/3}\Big)$	115 (H_0 not rejected)	0.29 (H_0 not rejected)
6.	$f(y_{90}) = g\Big(y_{65} \cdot \frac{a_{90}}{a_{65}} \cdot \big(\frac{H_{90}}{H_{65}}\big)^{2/3}\Big)$	.212 (H_0 not rejected)	1.77 (H_0 rejected)
7.	$f(y_{90}) = g\Big(y_{65} \cdot \big(\frac{k_{90}}{k_{65}}\big)^{1/3} \cdot \big(\frac{H_{90}}{H_{65}}\big)^{2/3}\Big)$	.115 (H_0 not rejected)	0.50 (H_0 not rejected)

Figure 1
Distributions of Output per Worker 1965 and 1990

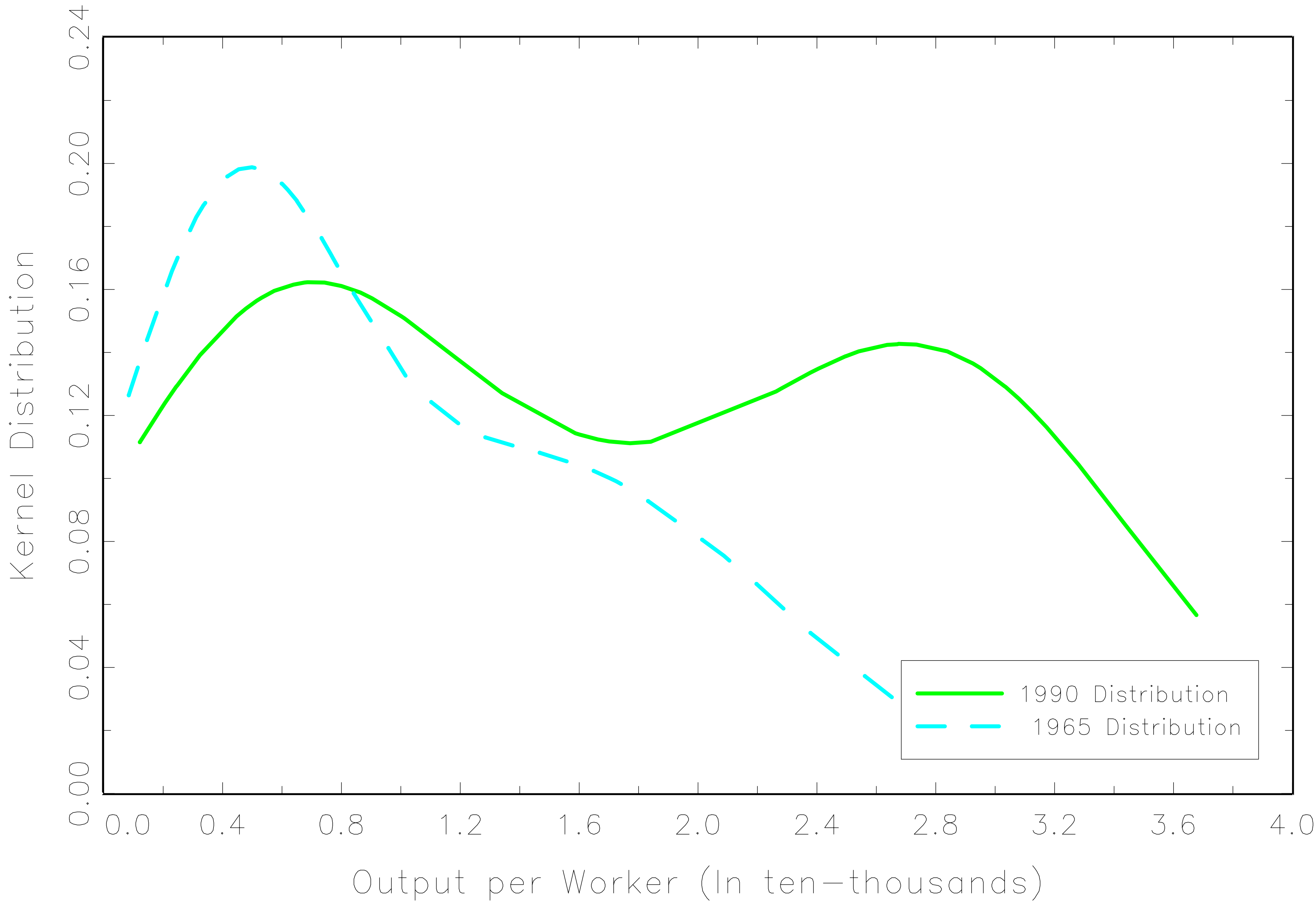

Figure 2

Growth Rates vs. Output Per Worker in 1965

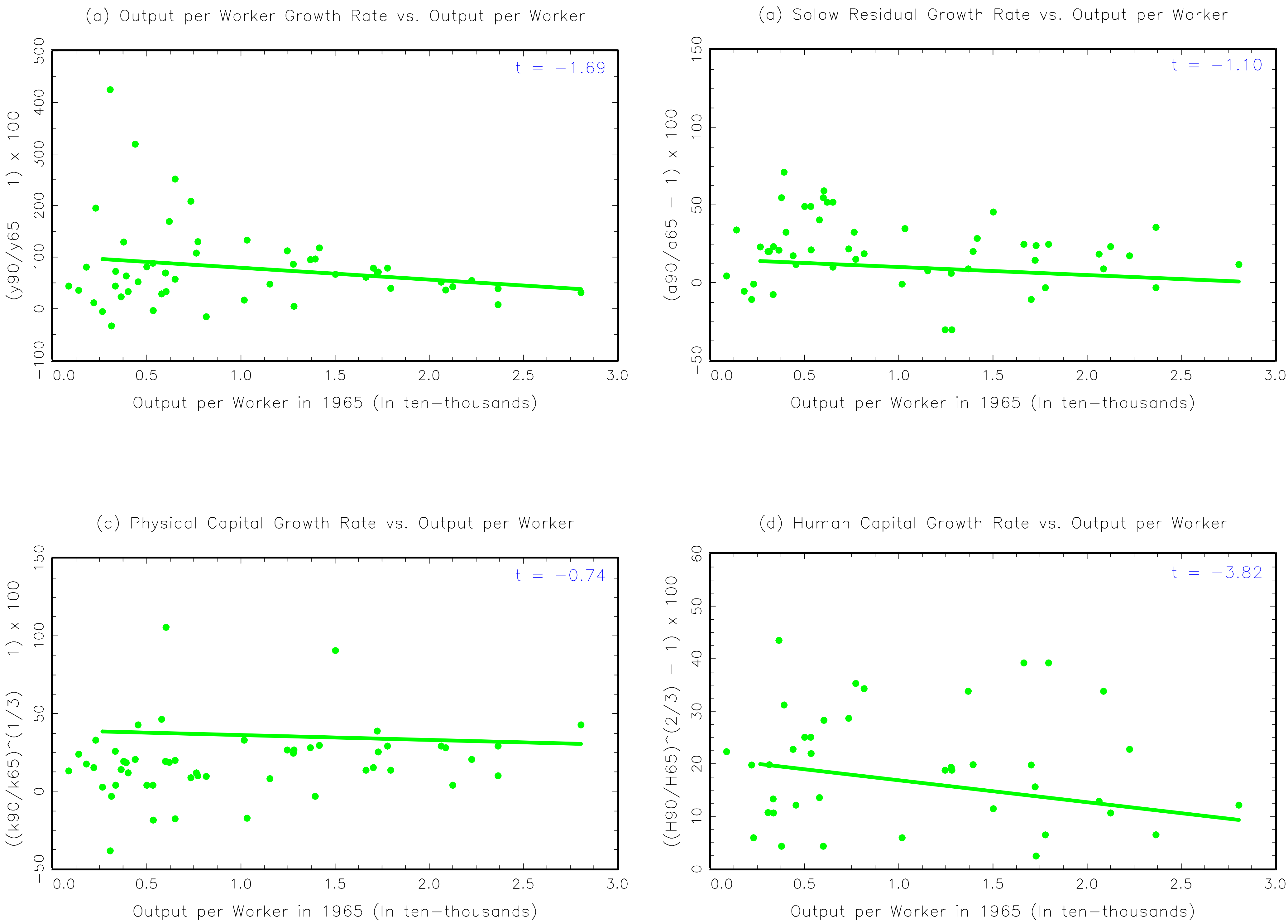

Figure 3
Mean Preserving Distributions of Output per Worker 1965 and 1990

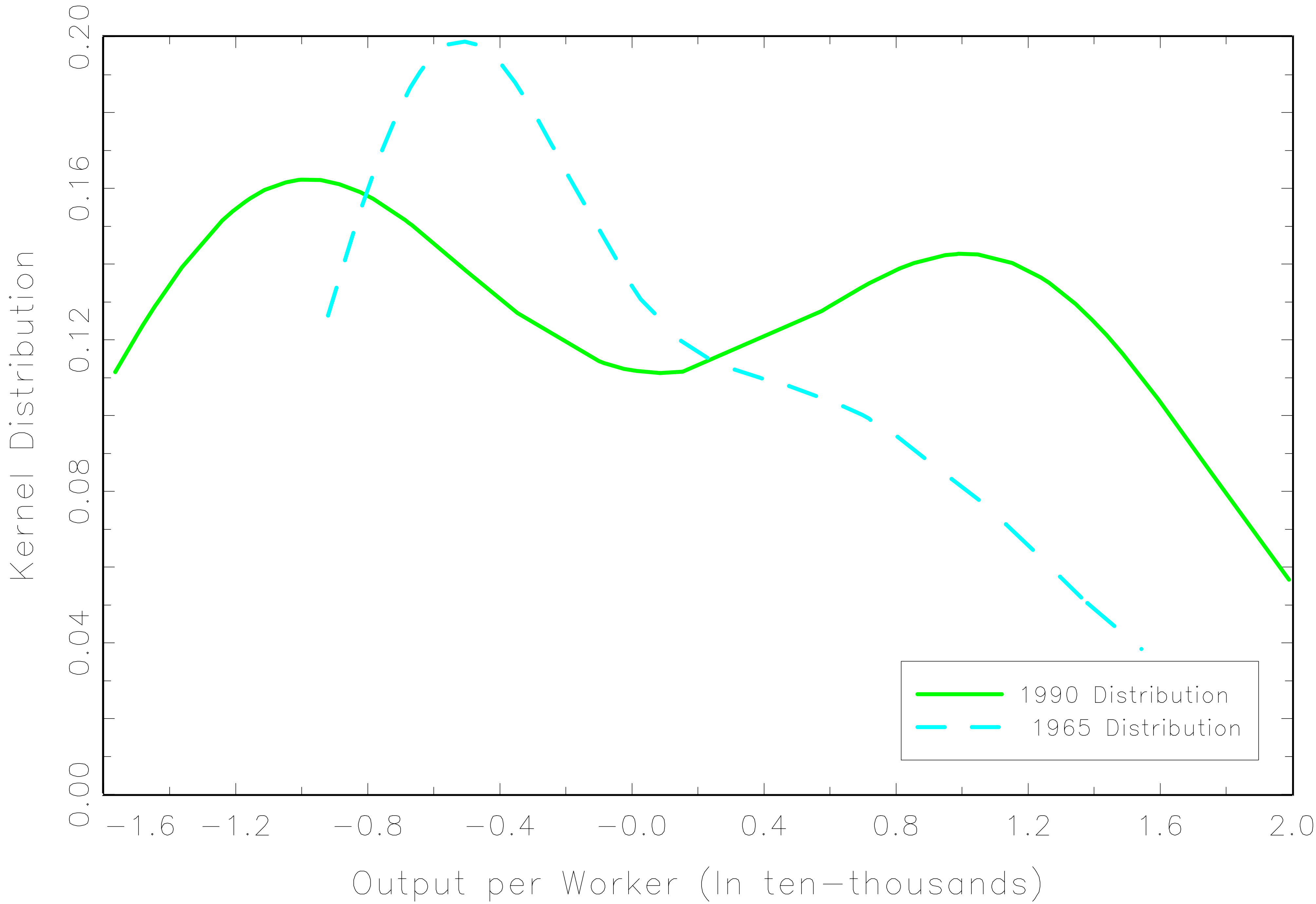

Figure 4

Counterfactual Distributions of Output per Worker

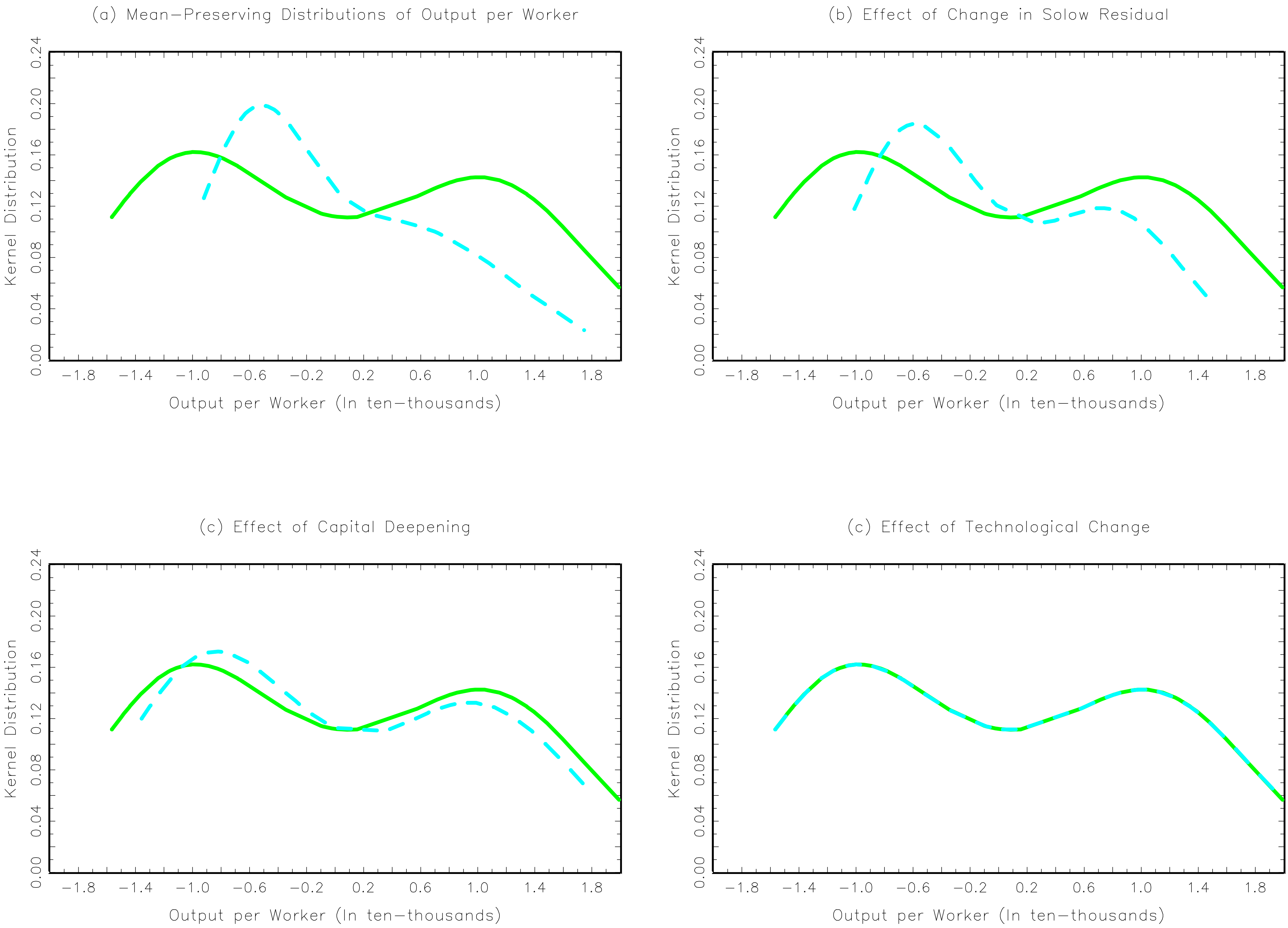

Figure 5
Counterfactual Distributions of Output per Worker

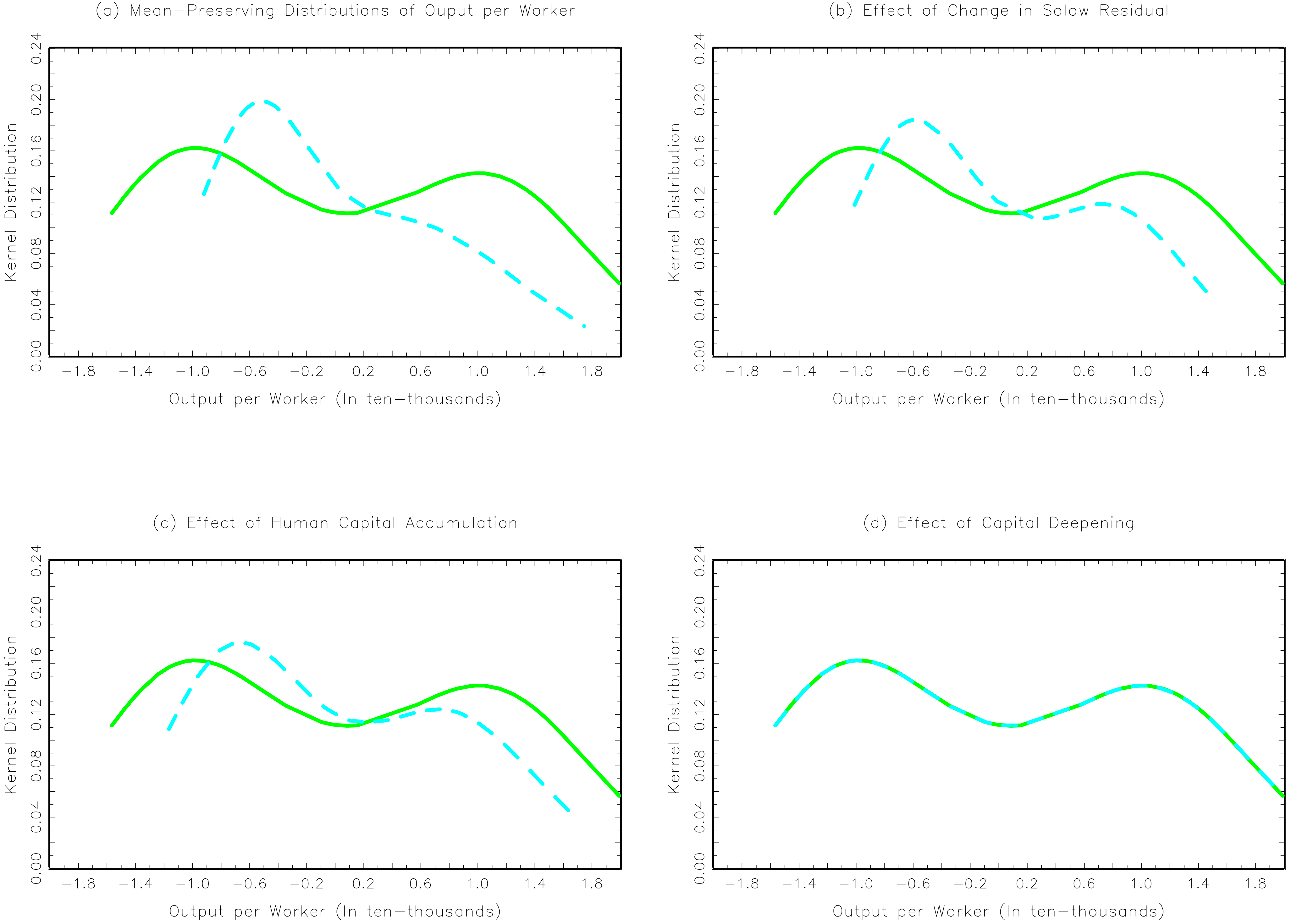

Figure 6
Counterfactual Distributions of Output per Worker