Growth accounting by decomposition: a modified NIRS approach

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Growth Accounting by Decomposition: A Modified NIRS Approach*

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Abstract

This paper points out the fallacy in the previous method of growth accounting by decomposition. Specifically, it points out that the previous studies tend to measure the contribution of technical progress to economic growth to be too low and that of capital accumulation too high.

JEL Classification Codes: O30, O47, C82

Keywords: production frontier, productivity growth, technical change

1 Introduction

Recently, a series of growth accounting literature, for example, Kumar and Russell (2002), Ray and Desli (1997) and Fare et al. (1994), examined the decomposition of change in productivity into a change in technology, capital accumulation and a change in efficiency. By the method of these studies, production frontier is estimated on a yearly basis from the cross-country data. Technical progress is measured in terms of these yearly production frontiers. However, if some yearly production frontier happens to intersect another frontier, it is possible that technical progress between the two years is declared to be "negative." In fact, as shown later, the more years the data is covered, the more cases arise in which a negative technical progress shows up.

Since technology consists of something intangible such as knowledge and since knowledge is transferable across generations, it is somewhat hard to believe that technology deteriorated for such broad ranges of countries and periods in reality. In the present analysis, the production frontier for each year is estimated not only from the data for that year but also from the ones for all the preceding years. After all, if some pair of capital and output is feasible in some year, then the pair is considered to be feasible also in the later years. This modified method rules out the possibility of a negative technical progress by construction.

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The empirical result based on this modified method shows the contribution to economic growth of capital accumulation to be smaller than measured previously. Moreover, the rates of technical progress are shown to be much more stable than the ones measured by the original method.

2 Fallacy in Previous Studies

Table 1: The results of decomposition under the original method (17 OECD countries)

Period	1979-1990				1965-1990			
Country	(1) Change in Productivity	(2) Change in Technology	(3) Capital Accumulation	(4) Change in Efficiency	(5) Change in Productivity	(6) Change in Technology	(7) Capital Accumulation	(8) Change in Efficiency
Australia	1.130	1.074	1.044	1.008	1.427	1.093	1.199	1.088
Austria	1.163	1.040	1.172	0.954	1.951	0.923*	2.532	0.835
Belgium	1.182	1.074	1.044	1.055	1.784	1.003	1.455	1.222
Canada	1.178	1.045	1.073	1.050	1.546	1.043	1.257	1.179
Denmark	1.138	1.020	1.064	1.049	1.391	0.979*	1.536	0.925
Finland	1.322	1.101	1.019	1.179	1.962	1.014	1.327	1.459
France	1.138	1.045	1.073	1.015	1.783	0.978*	1.768	1.031
Germany	1.104	1.085	1.033	0.985	1.742	1.002	1.468	1.184
Greece	1.146	0.972*	1.184	0.995	2.295	0.792*	2.676	1.083
Ireland	1.313	0.963*	1.268	1.075	2.331	0.778*	2.496	1.199
Italy	1.207	1.008	1.133	1.056	2.174	0.945*	1.742	1.321
Japan	1.438	1.053	1.320	1.035	3.085	0.887*	3.735	0.932
Norway	1.183	1.121	1.000	1.055	1.697	1.311	1.000	1.295
Spain	1.240	0.961*	1.329	0.971	2.117	0.818*	3.072	0.843
Sweden	1.151	1.047	1.071	1.027	1.360	1.007	1.414	0.956
United Kingdom	1.222	0.963*	1.269	1.000	1.607	0.796*	2.021	1.000
United State	1.121	1.031	1.087	1.000	1.311	1.017	1.289	1.000
Average	1.199	1.036	1.128	1.030	1.857	0.964	1.882	1.091
Annual Average	1.017	1.003	1.011	1.003	1.025	0.999	1.026	1.003

Notes: Change in Productivity = Real GDP per Worker at 1990 / Real GDP per Worker at base year. The Average is the geometric mean. Asterisks denote countries that experienced technological regress.

We use Penn World Tables (Version 5.6) data. Real GDP per worker (RGDPW) and capital stock per worker (KAPW) are used. Columns 2-4 of Table 1 present the contributions of a change in technology, capital accumulation and a change in efficiency, respectively, to a change in productivity of the 17 OECD countries for the period 1979-1990 measured based on the original NIRS (non-increasing returns to scale) method.[1] Note that the change in technology is negative for four out of seventeen countries.[2] Columns 6-8 show the same contributions measured for a longer period, i.e. for the period 1965-1990. Note not only that the number of countries with a negative technological change increases to 9 but also that the degree of the decline in technology is significant even for such major countries as U.K. and Japan. The change in technology for the whole OECD for this period is also measured as negative. In short, the original NIRS method tends to lead to a negative change in technology for a very broad ranges of countries and periods. This implication of the original method is somewhat hard to accept.

3 Methodology

Consider, for simplicity, a single input - output. Let x_t^i and y_t^i represent the input and output quantities of country i at year t. The production frontiers at year t are defined as;

$$F_t^O = \{(x_t^i, y_t^i) : D(x_t^i, y_t^i) = 1, \forall_i\} \tag{1}$$

[1] Ray and Desli (1997) analyzes the change in productivity based on the 17 OECD countries and the period 1979-1990.

[2] A negative change in technology is indicated by the measured contribution smaller than one in Table 1.

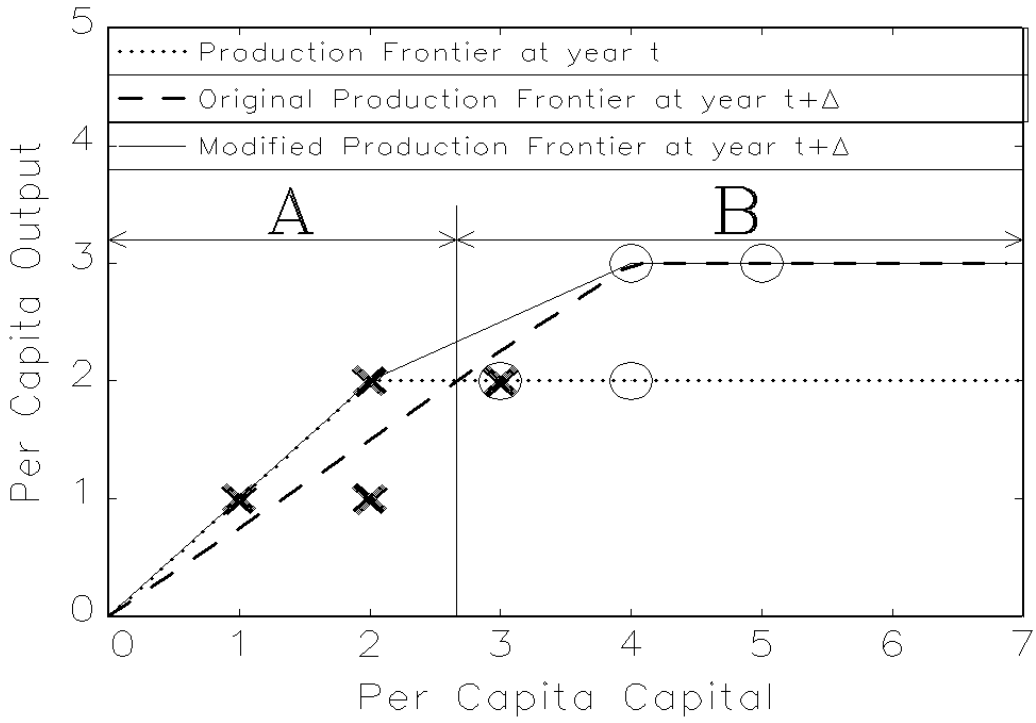

Figure 1: Illustration of Production Frontiers

under the original methods, and

$$F_t^M = \{(\cup_{j=1}^t x_j^i, \cup_{j=1}^t y_j^i) : D(\cup_{j=1}^t x_j^i, \cup_{j=1}^t y_j^i) = 1, \forall_i\} \tag{2}$$

under the modified method. In (1) and (2), $D(x, y)$ represents the output distance function which is defined in Fare et al. (1994) etc.

In Figure 1, the cross-country data at year t are drawn as crosses (x), while the ones for year $t + \Delta$ are drawn as circles (o). By the original NIRS method, the production frontier for year t is measured as the envelope of point x's, shown as the dotted curve in Figure 1. Similarly, the one for year $t + \Delta$ is measured as the envelope of point o's, shown as the dashed curve. If these two curves happen to intersect each other, the production frontier is considered to have shifted downward in area A and upward in area B between the two years.[3] The overall change in technology, measured as the geometric mean of these two shifts, could be negative.[4] The decomposition based original method may raise the problem of underestimation to the effect of technical progress on productivity growth.

In the present analysis, the production frontier for year $t+\Delta$ is estimated not only from the data at year $t+\Delta$ but also from the ones at year t. After all, if some pair of capital and output is feasible in year t, then the pair is considered to be feasible also in year $t + \Delta$. The modified NIRS method assumes the fact that

[3]In case of that the marginal productivity of capital decreases, the intersection is liable to happen.

[4]Note that, the larger the Δ is, the more these two groups are separated from each other due to capital accumulation. Thus, it is likely that the production frontiers intersect each other and technical progress is negative if the data covers longer years.

x's are not selected in year $t + \Delta$ is only because x's are not best practice in year $t + \Delta$, and not because they do not have the technology to produce x's in year $t + \Delta$. This modification of the NIRS method rules out the possibility of a downward shift in the production frontier by construction. The modified production frontier for year $t + \Delta$ is drawn as the solid curve in Figure 1.

4 Empirical Results

Table 2: The results of decomposition under the modified method (17 OECD countries)

Period	1979-1990				1965-1990			
Country	(1) Change in Productivity	(2) Change in Technology	(3) Capital Accumulation	(4) Change in Efficiency	(5) Change in Productivity	(6) Change in Technology	(7) Capital Accumulation	(8) Change in Efficiency
Australia	1.130	1.096	1.026	1.006	1.427	1.185	1.109	1.086
Austria	1.163	1.069	1.146	0.949	1.951	1.146	2.049	0.831
Belgium	1.182	1.095	1.026	1.052	1.784	1.146	1.277	1.219
Canada	1.178	1.071	1.049	1.048	1.546	1.163	1.130	1.176
Denmark	1.138	1.061	1.052	1.020	1.391	1.143	1.354	0.899
Finland	1.322	1.117	1.006	1.176	1.962	1.146	1.176	1.455
France	1.138	1.071	1.049	1.013	1.783	1.146	1.512	1.028
Germany	1.104	1.105	1.017	0.983	1.742	1.146	1.287	1.181
Greece	1.146	1.039	1.163	0.948	2.295	1.065	2.224	0.969
Ireland	1.313	1.028	1.244	1.027	2.331	1.048	2.106	1.056
Italy	1.207	1.051	1.124	1.022	2.174	1.131	1.515	1.269
Japan	1.438	1.083	1.286	1.032	3.085	1.146	2.896	0.929
Norway	1.183	1.124	1.000	1.052	1.697	1.314	1.000	1.292
Spain	1.240	1.029	1.307	0.922	2.117	1.097	2.472	0.781
Sweden	1.151	1.072	1.049	1.025	1.360	1.146	1.244	0.954
United Kingdom	1.222	1.028	1.244	0.956	1.607	1.043	1.758	0.877
United State	1.121	1.060	1.060	0.998	1.311	1.146	1.146	0.998
Average	1.199	1.071	1.109	1.013	1.857	1.139	1.603	1.059
Annual Average	1.017	1.006	1.009	1.001	1.025	1.005	1.019	1.002

Notes: Change in Productivity = Real GDP per Worker at 1990 / Real GDP per Worker at base year. The Average is the geometric mean.

Table 2 shows the contribution of each component to growth measured by the modified NIRS method discussed in the previous section.[5] A comparison of Column 3 of Table 2 with Column 3 of Table 1 implies that capital accumulation, measured by the modified NIRS method, contributed to a change in productivity less in any of the 17 OECD countries than the one measured by the original NIRS method. So does with the comparison of Column 7 of Table 2 with Column 7 of Table 1. Moreover, the average annual rate of the OECD capital accumulation for the period 1965-1990 is measured as 1.9% by the modified method in contrast to 2.6% by the original method.[6] Similar results were obtained in the case in which the data covers 59 countries for the period 1965-1990 as in Kumar and Russell (2002).[7] The results are provided in Table 3 in Appendix. In summary, the modified NIRS method indicates a smaller degree of the contribution of capital accumulation in general than the original NIRS method.

Figure 2 contains the empirically constructed the production frontiers of the 17 OECD countries for the period 1965-1990. In Figure 2 (a), there is a big technical regress shown in area A. This is exactly what was explained in Figure 1.

[5]The countries and the periods in Table 2 are identical to those in Table 1, respectively.

[6]The production frontier in 1990 is constructed from the 442 observations (26 years × 17 countries).

[7]These are the countries for which complete data set are available. Kumar and Russell (2002) consider the 57 OECD countries. We report our results with two countries, Iran and Venezuela. Under the modified method, excluding these two countries has no significant effect on the result. The annual averages of changes in productivity and the three components – technological change, capital accumulation and efficiency change – are 1.023, 1.007, 1.014 and 1.001, respectively. The detailed results excluding these two countries are available from the author on request.

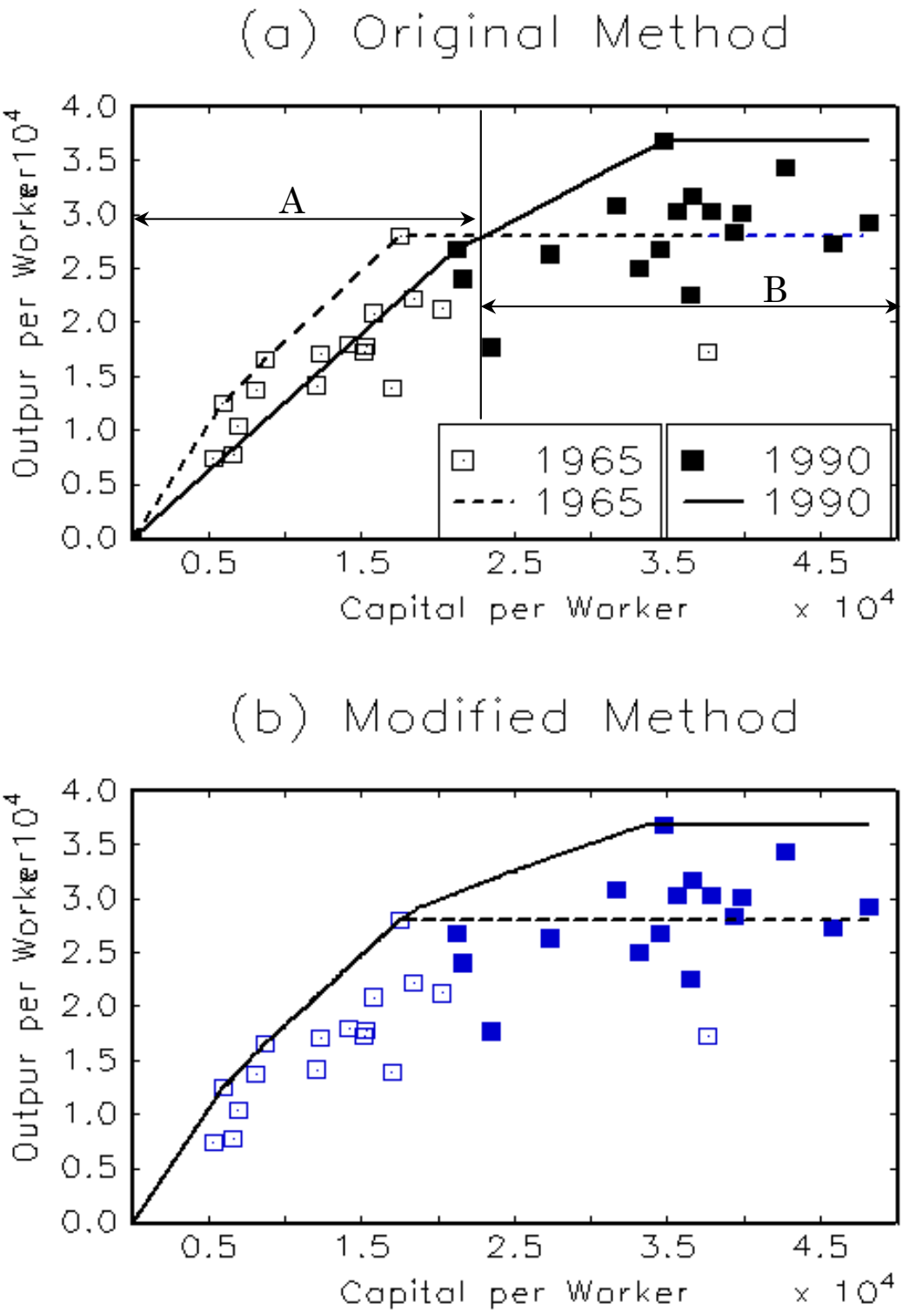

Figure 2: OECD Production Frontier (1965 and 1990)

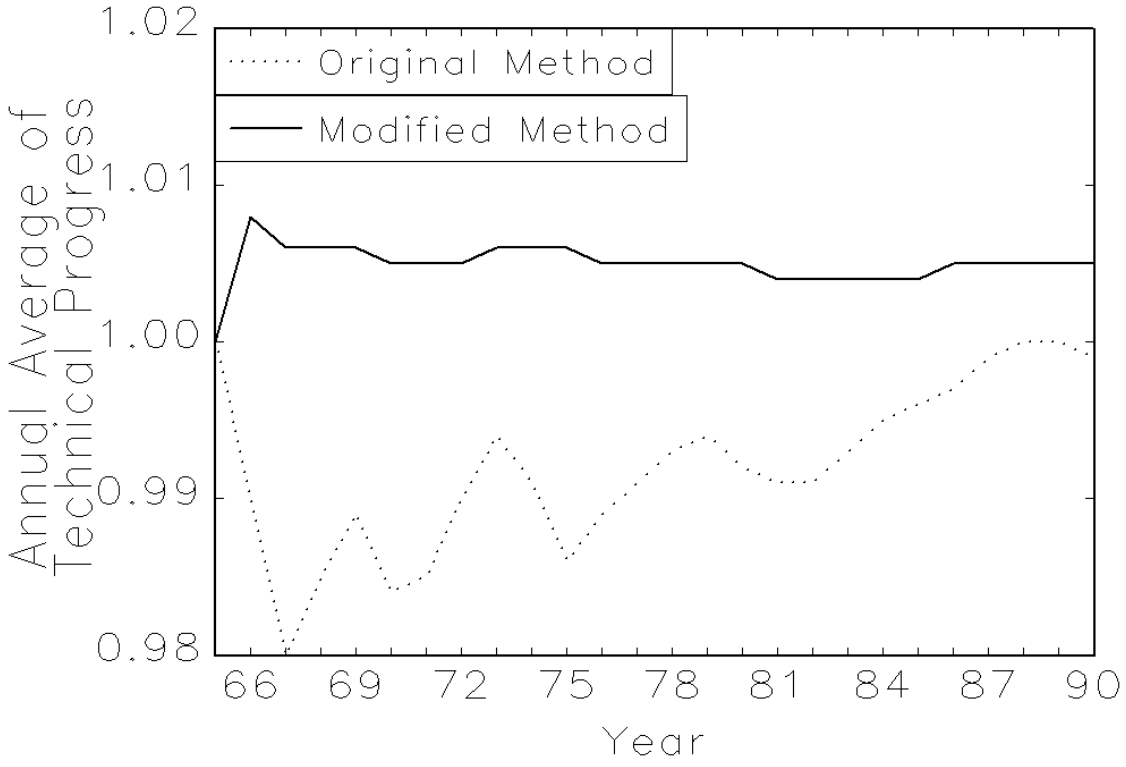

Figure 3: Change in Technology (1965-1990)

Figure 3 shows the measured changes in technology for the whole OECD for the period from 1965 to year t, which is drawn in the horizontal axis. The solid line indicates the changes measured by the modified NIRS method, while the dotted line indicates the ones by the original NIRS method. Note that the modified method produces much more stable measured changes in technology than that of the original method.[8]

References

[1] Fare R., Grosskopf S., Norris M., Zhang Z., 1994. "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries." American Economic Review, 84, 66-83.

[2] Kumar S., Russell R., 2002. "Technical Change, Technological Catch-up, and Capital Deepening: Relative Contribution to Growth and Convergence." American Economic Review, 92, 527-548.

[3] Ray S., Desli E., 1997. "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Comment." American Economic Review, 87, 1033-1039.

[8] A similar figure for the data of the world for the period 1965-1990 leads to a similar conclusion. The figure is provided in Figure 4 in Appendix.

5 Appendix

Table 3: The Results of Decomposition (59 countries)

		Original Method			Modified Method		
Country	(1) Change in Productivity	(2) Change in Technology	(3) Capital Accumulation	(4) Change in Efficiency	(5) Change in Technology	(6) Capital Accumulation	(7) Change in Efficiency
Argentina	1.046	0.920*	1.522	0.747	1.259	1.325	0.627
Australia	1.427	1.139	1.158	1.082	1.189	1.112	1.079
Austria	1.951	1.100	1.887	0.940	1.304	1.602	0.934
Belgium	1.784	1.118	1.283	1.244	1.179	1.220	1.240
Bolivia	1.327	0.819*	1.391	1.165	1.221	1.457	0.746
Canada	1.546	1.119	1.188	1.162	1.173	1.136	1.160
Chile	1.166	0.900*	1.431	0.905	1.275	1.304	0.701
Colombia	1.688	0.945*	1.475	1.210	1.220	1.287	1.075
Denmark	1.391	1.111	1.315	0.952	1.187	1.260	0.929
Dominican Rep.	1.518	0.885*	1.839	0.933	1.267	1.980	0.605
Ecuador	1.809	0.908*	1.801	1.107	1.188	1.522	1.001
Finland	1.962	1.114	1.225	1.438	1.170	1.168	1.436
France	1.783	1.140	1.443	1.084	1.221	1.353	1.080
Germany, West	1.742	1.122	1.293	1.201	1.184	1.229	1.197
Greece	2.295	0.971*	1.914	1.235	1.232	1.619	1.151
Guatemala	1.285	0.814*	1.278	1.235	1.165	1.327	0.831
Honduras	1.229	0.794*	1.181	1.311	1.166	1.216	0.867
Hong Kong	3.511	0.945*	1.498	2.481	1.220	1.301	2.212
Iceland	1.664	0.968*	1.710	1.005	1.199	1.491	0.931
India	1.805	0.918*	1.496	1.314	1.223	1.529	0.966
Iran	0.982	0.851*	2.489	0.463	1.070	2.194	0.418
Ireland	2.331	0.956*	1.822	1.338	1.207	1.560	1.238
Israel	1.861	1.000	1.274	1.462	1.113	1.237	1.352
Italy	2.174	1.107	1.422	1.382	1.207	1.345	1.340
Ivory Coast	1.150	0.831*	1.900	0.728	1.170	1.695	0.580
Jamaica	0.964	0.799*	0.992	1.217	1.181	0.991	0.824
Japan	3.085	1.062	2.397	1.212	1.330	1.922	1.207
Kenya	1.353	1.025	0.939	1.405	1.283	0.933	1.131
Korea, South	5.245	0.878*	3.072	1.944	1.079	2.745	1.771
Luxembourg	1.785	1.244	1.087	1.321	1.276	1.059	1.321
Madagascar	0.703	0.899*	1.085	0.721	1.191	1.098	0.538
Malawi	1.439	0.554*	2.215	1.173	1.120	1.592	0.807
Mauritius	1.570	0.825*	1.347	1.413	1.180	1.410	0.943
Mexico	1.475	0.935*	1.589	0.992	1.227	1.358	0.885
Morocco	1.529	0.878*	1.148	1.518	1.175	1.171	1.111
Netherlands	1.515	1.098	1.277	1.080	1.173	1.228	1.051
New Zealand	1.074	1.093	1.165	0.843	1.159	1.126	0.823
Nigeria	1.406	0.795*	1.600	1.105	1.160	1.457	0.832
Norway	1.697	1.330	1.009	1.264	1.333	1.008	1.263
Panama	1.329	0.919*	1.693	0.854	1.197	1.444	0.769
Paraguay	1.632	0.782*	2.088	1.000	1.153	1.755	0.806
Peru	0.839	0.914*	1.195	0.768	1.299	1.128	0.572
Philippines	1.438	0.792*	1.161	1.564	1.149	1.192	1.050
Portugal	2.688	0.884*	1.969	1.544	1.157	1.751	1.327
Sierra Leone	0.942	0.421*	2.237	1.000	1.017	1.529	0.606
Spain	2.117	1.001	2.107	1.004	1.278	1.737	0.954
Sri Lanka	1.721	0.880*	1.503	1.301	1.250	1.409	0.977
Sweden	1.360	1.116	1.265	0.964	1.176	1.204	0.961
Switzerland	1.387	1.284	1.052	1.026	1.307	1.034	1.026
Syria	2.079	0.954*	1.305	1.670	1.137	1.215	1.504
Taiwan	4.190	0.927*	2.818	1.603	1.148	2.417	1.510
Thailand	2.947	0.934*	2.029	1.555	1.299	2.257	1.005
Turkey	2.293	0.855*	1.740	1.542	1.209	1.759	1.078
United Kingdom	1.607	0.970*	1.578	1.049	1.172	1.416	0.969
United State	1.311	1.099	1.193	1.000	1.155	1.140	0.996
Venezuela	0.696	0.949*	1.108	0.662	1.048	1.100	0.603
Yugoslavia	1.881	0.859*	1.834	1.194	1.187	1.803	0.879
Zambia	0.661	0.869*	0.771	0.988	1.169	0.743	0.762
Zimbabwe	1.114	0.838*	0.838	1.584	1.286	0.818	1.059
Average	1.720	0.952	1.536	1.190	1.198	1.414	1.010
Annual Average	1.022	0.998	1.017	1.007	1.007	1.014	1.000

Notes: Change in Productivity = Real GDP per Worker at 1990 / Real GDP per Worker at 1965. The Average is the geometric mean. Asterisks denote countries that experienced technological regress.

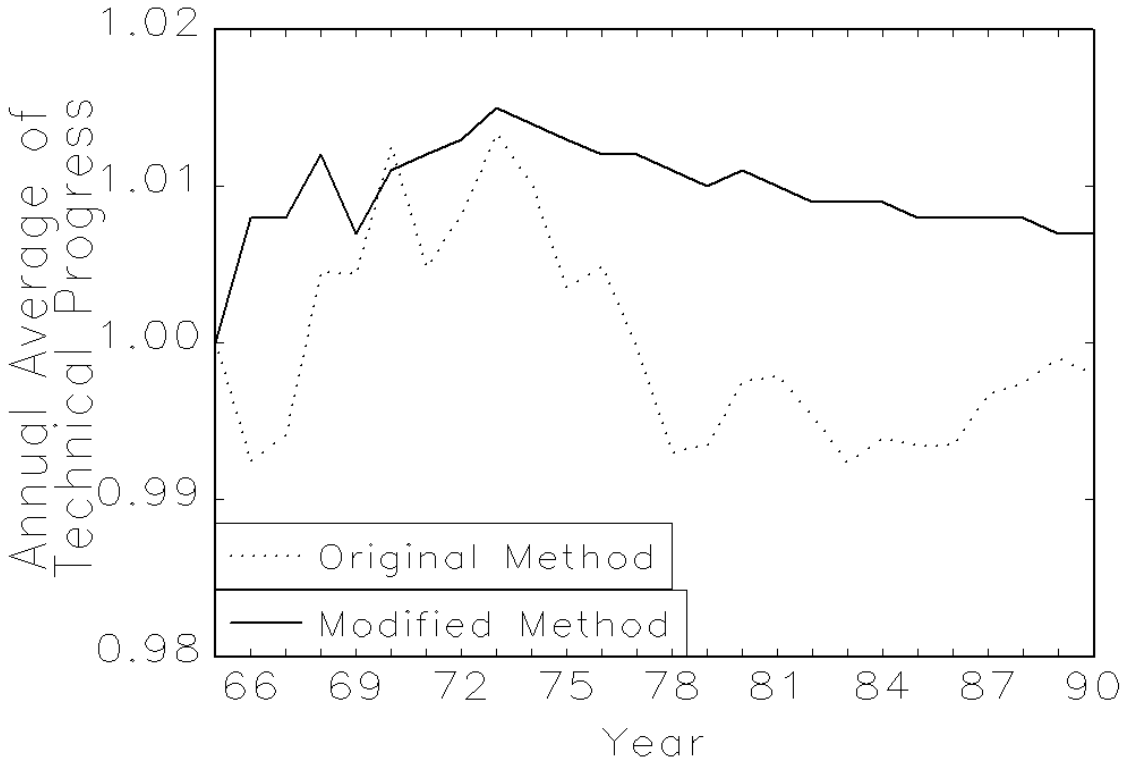

Figure 4: Change in Technology (1965-1990)