Accounting for Economic Growth in Taiwan and Mainland China: A Comparative Analysis

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Abstract: This paper provides a statistical summary of aggregate economic growth in Taiwan and mainland China using the standard national income accounting framework by decomposing aggregate growth into components due to growths in capital, labor and total factor productivity. For Taiwan, new series of capital stock and of human capital are constructed. The major findings include (a) the stability of input coefficients (under the assumption of constant returns) and of the rate of increase in TFP for the entire period 1951-1999, (b) a labor exponent of about 0.7 and a rate of annual increase in TFP of about 0.03, and (c) a slower exponential rate of growth of real gdp since 1987 to about 0.065 from the 1951-1999 average of 0.081 mainly as a result of the large reduction in the growth rate of labor input to half. For mainland China, a capital stock series of Chow (1993) was extended to 1998. The major findings include (a) the stability of the relative input coefficients for the entire period 1952-1998 but TFP did not increase until 1979, (b) a labor exponent of about 0.35 and a rate of increase in TFP of about 0.027 after 1979, and (c) the absence of equally large reduction in the rate of increase in labor input as in Taiwan and the smaller exponent of labor leading to a prospect of only a moderate reduction in future growth rate.

1. INTRODUCTION

In the second half of the 20^{th} century Taiwan and mainland China experienced different economic histories. They started with different initial conditions, adopted different development strategies during the first three decades and yet both succeeded in rapid development. It is the aim of this essay to provide a statistical summary of the growth histories of these two economies in a comparative perspective. The framework adopted is the familiar growth accounting using a Cobb-Douglas production. Institutional details are missing in such a framework, but the major historical trends together with their input components are clearly revealed. Readers interested in institutional changes can observe their consequences in terms of aggregate growth rates. The statistical summary is also useful for prediction if the aggregate relation between output and inputs can be expected to continue.

For Taiwan we build on the work of Dessus (1999) and others but we provide new estimates of physical capital stock and of human capital in section 2 which also contains data analysis of growth trends in Taiwan. Section 3 provides estimates of production functions of Taiwan using different measures of physical and human capital and arrives at five major conclusions concerning Taiwan's growth history at the end. A comparative analysis with mainland China is made in section 4, after a production function is estimated by updating the work of Chow (1993). Major conclusions concerning the mainland's growth history are presented at the end of section 4 for comparison. Section 5 concludes the paper.

2. DATA FOR TAIWAN

Data for real GDP and its components are available in *Statistical Yearbook of the Republic of China1999* (English edition, pp. 151-153) and *Quarterly National Economic Trends, ROC* (February 2000, pp. 22-23). For labor force we use two series, one is H, the number of hours worked during a year, which includes domestic and foreign workers and can be found in *Yearbook of Manpower Statistics* and *Bulletin of Labor Statistics*. Foreign workers have been employed since 1991 and their work hours are longer than domestic workers. These have been taken into account in our derivation of H. The second is H* which is the number of hours worked H adjusted for the quality of human capital by using the distribution of schooling weighted by a base-year relative earnings structure of schooling. As in Collins and Bosworth (1996), our measure of the quality of human capital S is given by the sum of the percentage of the jth schooling in the civilian population of age 15 or over multiplied by the relative earnings scale of the jth schooling prevailed in 1991 with the average earnings of primary and below taken as 100, which equals 722.4 per month in U.S. dollars. 1991 is chosen because it is also the base year of real GDP and other national income statistics. The relative scale of earnings is 102.38 for junior high, 105.17 for vocational, 114 for high school, 139.77 for junior college, and 176.94 for college and above. These relative scales are fixed throughout our sample period 1951-1999 while the distribution of schooling varies through time. H* is the product of H and S. An alternative measure of H* is the number of hours worked H adjusted by using the average number of years of schooling of the working population. According to the well-known Mincer equation explaining ln(wage), an important independent variable is the number of years of schooling. For Taiwan, based on a study by Wu (1988, p. 363), we can assume the coefficient of the number of years s to be 0.1 and adjust H(t) in year t to form H*(t) by the equation $\ln H^*(t) = \ln H(t) + 0.1[s(t) - s(1951)]$. Such an adjustment may overstate the improvement in the amount of human capital as measured by its marginal product or wage to the extent that education at the primary school level may not have as much effect as 0.1. We therefore choose the first measure rather than the second measure.

Estimation of capital stock presents two problems. One is the problem of obtaining a reliable initial stock in 1951 to start with. The second is to determine depreciation in real terms. Depreciation figures which result from dividing official nominal depreciation by the implicit deflator of gross fixed investment would underestimate real depreciation if prices have risen since nominal depreciation is based on historical prices. On the other hand, accounting depreciation tends to overestimate the true depreciation for tax-saving purposes. Although these two factors offset each other to some extent, the real depreciation figures as obtained above tend to be overestimated. Many works, such as Nehru and Dhareshwar (1993), Collins and Bosworth (1996) and Dessus (1999), have chosen a much lower depreciation rate (4 percent per year) than the depreciation rate estimated from deflating official nominal depreciation as above described. We also adopt a depreciation rate of 4 percent.

We apply the equation $K_t=(1-d)K_{t-1}+I_t$ to estimate capital stock, where I is real gross fixed investment and d is the rate of depreciation assumed to be 4 percent. To estimate initial capital stock in 1951, we have found the following three pieces of key information on the fixed capital stock, the inventory stock and land in early 1950s.

The first came from the First Census of Industrial and Commercial Industries in Taiwan for the year 1954. The Census gives a value of NT$18,869.2 million as total gross fixed assets for all industrial and commercial firms. Total gross fixed assets are in nominal book value and consist of land, plant and other construction, machinery and other equipment, transport equipment, and unfinished construction. The book value of gross fixed assets is inclusive of cumulative depreciation, which is an offsetting item in the balance sheet and will be reduced when an asset is disposed of. Thus we must exclude value of land and cumulative depreciation from total gross fixed assets to obtain a net value for non-land fixed assets. The value of land was 5.13 percent of total gross fixed assets in the industries of mining, manufacturing, construction, power, gas, and trade, whose main gross fixed assets was about 46.8 percent of all industrial and commercial gross fixed assets. Since the data for the remaining industries are not available and the 1961 Census indicated that the land ratio of these industries was higher, a 6 percent of total gross fixed assets is assumed for land for all industries. The resulting value of land is thus estimated as 1,132.2 million. This yields an amount of 17,737 million for non-land gross fixed assets in 1954.

Gross fixed assets are assumed to be the sum of the book values of all assets acquired and not depreciated until they are scraped after t years. In order to convert gross fixed assets into net fixed assets we take out cumulative depreciation which is the depreciation of all the assets included, namely,

$$D(t)=I_t d+I_{t-1}(1-d)d+I_{t-2}(1-d)^2 d+\ldots+I_1(1-d)^{t-1}d=I_1 d[(1+g)^{t-1}+(1+g)^{t-2}(1-d)+\ldots+(1-d)^{t-1}]$$

and the value of gross assets is

$$I(t)=I_t+I_{t-1}+\ldots+I_1=I_1[(1+g)^{t-1}+(1+g)^{t-2}+\ldots+1]$$

under the assumption that investment grows at an annual rate g. Assuming t=8, d=4 percent and g=27 percent (the rate observed over 1951-54 from National Income for all industries excluding agriculture), the ratio D(t)/I(t) equals 12.3 percent. If we changed t from 8 to 15, the ratio would be 15.3 percent. In view of large increases in new assets during the years after 1945, we apply a 12 percent ratio to the value 17,737 million of gross fixed assets to obtain net fixed assets equal to 15,608.6 million for all non-agriculture industries. This nominal figure is converted to 99,417.8 million in 1991 constant dollars for the year 1954 based on the average of the implicit deflators of non-agricultural gross fixed investment for 1951-54 (1991=100).

Solving the equation $K_t=0.96K_{t-1}+I_t$ backward using data on the non-agricultural real gross fixed investment from the national income account for the period 1952-54, the real net fixed capital stock in 1951 is estimated as 77,862 million for non-agriculture industries. The estimated 1954 nominal land value, 1,132.2 million as given above, is converted to 11,682 million at 1991 constant prices for 1951 by assuming a 8.73 percent growth rate of land value between 1951 and 1954 (the rate of increase over 1953-54 for those industries as provided by the Census), and using the GDP price index as the deflator.

The second piece of information consists of the estimates of land and non-land fixed capital for the agricultural sector found in a report on "Relationships between

Agricultural and Industrial Development in Taiwan during 1950-1959" prepared by the late Professor Mo-huan Hsing (1960). In Table 2.8 of the report (p.18), Professor Hsing provided estimates of farm land and total non-land fixed capital (including cattle and fixed equipment) in millions of 1953 constant New Taiwan dollars for the period 1950-1958. The estimate of total non-land fixed capital, 2,044 million for 1954, is converted to 17,758 million in 1991 constant dollars based on the implicit deflator of gross fixed investment in agriculture, which is further moved backward to obtain a value of 4,834.9 million for 1951 by using equation $K_t=0.96K_{t-1}+I_t$ and the estimates of real gross fixed investment of the agricultural industry in the national income account for the period 1952-1954. Hsing's estimate of land value is 19,131 million for 1951 in 1953 constant dollars and is 166,791 million in 1991 constant dollars based the 1953 GDP deflator with 1991=100. Thus the estimates of the agricultural land and non-land fixed capital are 166,792 million and 4,835 million, respectively, for 1951 in 1991 constant dollars.

The third piece of information is on the estimates of inventory stock from a special study (1978) prepared by the office of the Census of Industrial and Commercial Industries. The inventory stock of all industries in 1951 was estimated at 9,081 million in 1971 constant dollars and is converted to 22,241 million in 1991 constant dollars by the 1971 deflator of inventory investment with 1991=100.

To sum up, the estimates of non-land fixed capital, inventory and land for all industries in 1951 are 82,697 million (77,862+4,835), 22,241 million and 178,474 million (11,682+ 166,792), respectively, all in 1991 constant dollars. Their sum is 283,412 million, with 29.2 percent for non-land fixed capital, 7.9 percent for inventory stock, and 63 percent for land, which is more than double the non-land fixed capital in value. In 1951 Taiwan was largely an agrarian economy whose dominant factor of production was land. In the above estimation for non-agricultural industries, if the ratios of land value and cumulative depreciation were 8 percent and 15 percent instead of 6 percent and 12 percent we employed, the estimate would be 6,140 million or 7.4 percent smaller for non-land fixed capital but 3,892 million or 2.2 percent larger for land. The difference between the two sets of estimates is not large.

We use our 1951 estimates of non-land fixed capital (K1) and K1 plus inventory (K2), namely, 82,697 and 104,938, as the initial stocks to construct K1 and K2 for the period 1951-1999 based on two equations: $K1_t=0.96K1_{t-1}+I_t$, where I is real gross fixed investment, and $K2_t=K1_t+V_t$, where V is initial inventory plus cumulative real inventory investment. Another possible measure of capital is the sum of K2 and land which will not be used because we have not found data on the changes of land use during the sample period. Based on our estimates of capital, the capital/output ratio in 1951 with real GDP serving as output is found to be 0.5058 for K1, 0.6418 for K2, and 1.7333 for K2 plus land. The low value for non-land fixed capital is due to the facts that a large fraction, about 37.4 percent, of GDP in Taiwan in 1951 was from agriculture and land is excluded from the K1 and that industry after World War II was mainly labor-intensive manufacturing and handicraft which required a small amount of capital. As the economy became more industrialized, the K1/output (or K2/output) ratio gradually increased to 1.4614 (or 1.7047) in 1975 and to 2.2919 (or 2.4797) in 1999. Even after industrialization took place, much manufacturing in Taiwan was accounted for by small firms which employed less sophisticated tools and thus a small amount of fixed capital.

For comparison purposes and in order to check the sensitivity of our estimates of production function parameters, we also add to our K1 and K2 a measure of non-land fixed capital created according to the steps taken by Dessus (1999) in his estimation of Taiwan's production function. The steps involve first estimating the 1962 level of capital stock based on the assumption that gross fixed investment and the GDP grew at about the same rate g at a steady state during 1960-1964 period and then constructing the capital stock series based on the equation $K_t=0.96K_{t-1}+I_t$. Under the assumption net investment I-dK=gK, or K=I/(d+g) we obtain an amount of 331,576 million in 1991 constant dollars for 1962 and an amount of 134,307 million for 1951, to be designated K3. K3 in 1951 is much higher than K1. K3 may be an overestimate because in 1962 the growth of capital stock might not have reached a steady state as gross fixed investment grew faster than the rate of economic growth. The K3/output ratio is 0.8214 in 1951 and 2.2928 in 1999, which comes very close to 2.2919 for K1.

The annual data on real GDP, H, H*, K1, K2 and K3 are presented in Table 1 for the period 1951-1999. The average exponential rates of growth for each variable are summarized at the bottom of the table for five periods: 1951-1999, 1951-1975, 1975-1999, 1975-1987 and 1987-1999. The two sub-periods 1951-1975 and 1975-1999 represent the first-half and second-half of the sample period. The other two sub-periods 1975-1987 and 1987-1999 represent the first-half and second-half of the 1975-1999 period. Year 1987 happened to be the year when the Taiwan economy reached its pinnacle and its economic conditions began to deteriorate.

To conclude this section, we present two estimated series of total factor productivity

Table 1 Data on Outputs and Inputs for Taiwan

in millions of 1991 constant NT dollars or hours

Year	GDP	H	H*	K1	K2	K3
1951	163,509	7,481	7,582	82,697	104,938	134,307
1952	183,090	7,426	7,532	94,821	120,815	144,367
1953	200,175	7,118	7,228	111,066	139,427	158,630
1954	219,272	7,307	7,428	128,291	159,675	173,952
1955	237,045	7,734	7,871	141,911	175,463	185,746
1956	250,091	7,963	8,108	157,049	193,501	199,130
1957	268,500	8,126	8,288	171,209	211,087	211,607
1958	286,518	8,416	8,597	188,533	230,643	227,315
1959	308,438	8,658	8,854	211,091	256,674	248,322
1960	327,896	8,731	8,939	239,494	291,267	275,236
1961	350,450	8,780	9,001	268,401	326,743	302,712
1962	378,147	8,838	9,069	298,637	362,119	331,576
1963	413,520	8,970	9,213	335,371	405,166	366,993
1964	463,967	9,175	9,393	373,583	453,221	403,940
1965	515,628	9,393	9,640	421,390	516,887	450,533
1966	561,583	9,649	9,938	482,314	584,349	510,291
1967	621,737	10,160	10,489	559,541	675,598	586,399
1968	678,758	10,609	11,019	653,918	782,439	679,702
1969	739,495	10,864	11,271	757,230	896,966	781,983
1970	823,581	11,406	11,834	873,845	1,034,964	897,607
1971	929,784	11,806	12,266	1,019,527	1,199,989	1,042,339
1972	1,053,607	12,373	12,901	1,190,592	1,385,064	1,212,491
1973	1,188,812	13,369	14,019	1,377,387	1,605,980	1,398,410
1974	1,202,625	13,581	14,218	1,586,216	1,899,295	1,606,398
1975	1,261,896	13,798	14,546	1,844,184	2,151,154	1,863,560
1976	1,436,804	14,235	15,096	2,103,250	2,439,828	2,121,850
1977	1,583,209	15,038	15,975	2,371,924	2,736,506	2,389,780
1978	1,798,427	15,668	16,737	2,679,492	3,077,285	2,696,634
1979	1,945,430	16,374	17,548	3,026,414	3,492,365	3,042,871
1980	2,087,472	16,501	17,810	3,426,185	3,938,527	3,441,983
1981	2,216,116	16,801	18,159	3,830,707	4,374,944	3,845,873
1982	2,294,815	16,822	18,210	4,220,704	4,753,746	4,235,263
1983	2,488,657	17,312	18,787	4,584,422	5,130,361	4,598,399
1984	2,752,443	17,878	19,466	4,957,216	5,523,991	4,970,634
1985	2,888,758	18,105	19,744	5,289,117	5,859,791	5,301,999
1986	3,225,062	18,852	20,622	5,662,069	6,215,677	5,674,435
1987	3,635,979	20,136	22,125	6,126,214	6,725,795	6,138,085
1988	3,921,060	20,120	22,196	6,671,767	7,374,313	6,683,164
1989	4,243,891	20,337	22,505	7,313,031	8,070,351	7,323,971
1990	4,472,848	20,388	22,686	7,997,578	8,785,068	8,008,080
1991	4,810,727	20,649	22,997	8,744,879	9,586,104	8,754,962
1992	5,170,928	21,166	23,683	9,659,510	10,574,924	9,669,190
1993	5,533,607	21,534	24,245	10,688,849	11,665,874	10,698,141
1994	5,926,938	21,559	24,314	11,781,779	12,810,688	11,790,700
1995	6,307,686	22,431	25,405	12,942,094	13,995,543	12,950,658
1996	6,692,595	22,338	25,450	14,083,106	15,189,357	14,091,327
1997	7,139,450	22,729	26,045	15,355,114	16,581,388	15,363,006
1998	7,465,751	22,757	26,212	16,723,272	18,073,191	16,730,849
1999	7,889,155	23,092	26,766	18,081,131	19,562,794	18,088,405
			Average Exponential Rate of Growth			
1951-99	0.08076	0.02348	0.02628	0.11224	0.10892	0.10214
1951-75	0.08515	0.02551	0.02715	0.12936	0.12585	0.10959
1975-99	0.07637	0.02146	0.02541	0.09512	0.09198	0.09470
1975-87	0.08819	0.03150	0.03495	0.10005	0.09500	0.09934
1987-99	0.06455	0.01141	0.01587	0.09019	0.08897	0.09006

GDP is real gross domestic product, H is employment in annual work hours, H* is H adjusted for quality, K1 is non-land fixed capital as calculated from $K1_t = 0.96K1_{t-1}+I$, K2 is K1 plus inventory, K3 is non-land fixed capital based on Dessus' method.

(TFP) based on K1 with H or H*. The equation is

$$TFP=GDP/[(K^{KS})(H^{LS})]$$

where K=K1, H=labor without or with adjustment for quality, LS=labor share, KS=capital share=(1-labor share). Labor share includes the official share of paid-employee compensation and the imputed share of unpaid worker compensation. The official share is computed based on the national income account. Estimation of the imputed share of those unpaid workers, which include employers, own-account workers and unpaid family workers, is based on the input/ output tables and the national income account. The series of the official share of paid-employee compensation and the official and imputed share are shown by PLS and LS, respectively, in Table 2. The index of total input (the denominator of the TFP above) is shown by TFI with H and TFI* with H* in the same table. The computed TFP and TFP* are also given in the same table. As it can be seen on the bottom of the table, TFP has increased 0.0268 exponentially or 2.72 percent per year based on the unadjusted labor input (H) for the entire period 1951-1999 and it has increased 0.0252 exponentially or 2.56 percent per year based on the labor input adjusted for labor quality over the sample period. These two series and the estimated trend lines by OLS are displayed in Figure 1. The slope of the estimated trend line is 0.0324 with H and 0.0306 with H*.

As for the sub-periods, both TFP and TFP* grew faster for the first sub-period 1951-1975, which are 3.56 percent and 3.45 percent per year, respectively, than the second sub-period 1975-1999, which are 1.89 percent and 1.65 percent per year. The growth of TFP was slightly higher for the latest sub-period 1987-1999 at an annual rate of 1.99 percent with H and 1.72 percent with H* than the corresponding rates of 1.78 percent and 1.58 percent for the sub-period 1975-1987.

3. ACCOUNTING FOR TAIWAN'S GROWTH BY PRODUCTION FUNCTIONS

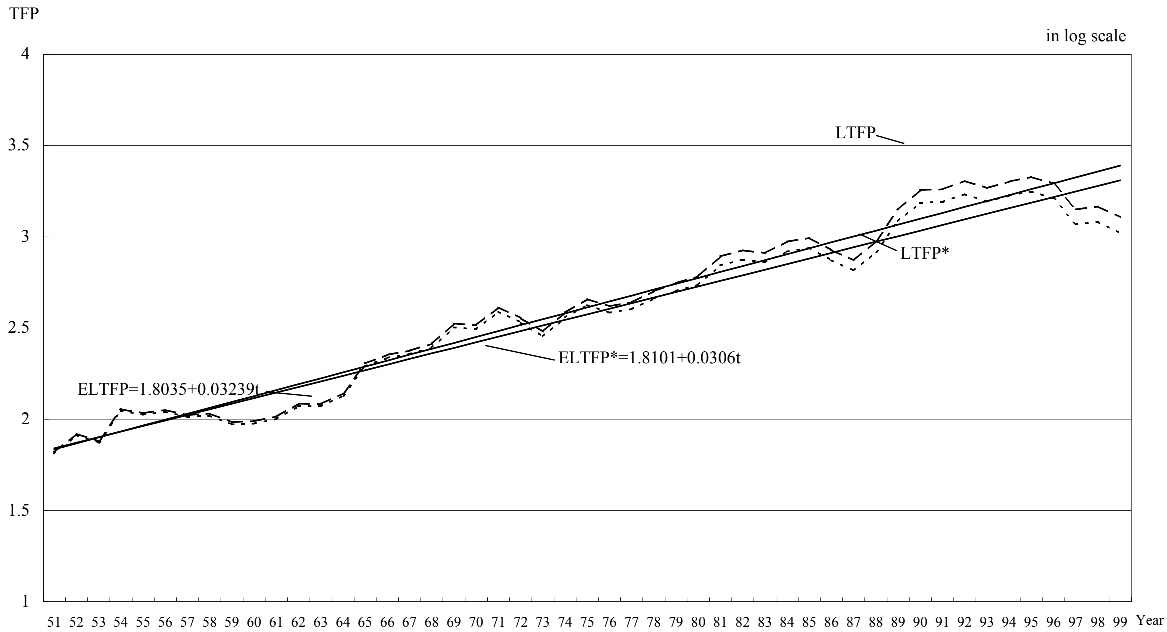
The data analysis of the last section has provided a general picture of the growth of Taiwan' economy since 1951. We now provide another means of growth accounting by estimating a Cobb-Douglas production function. The calculation of total factor

Table 2 Total Factor Productivity in Taiwan

Year	PLS	LS	KS	TFI	TFI*	TFP	TFP*
1951	0.3841	0.4733	0.5267	26,521	26,690	6.1653	6.1263
1952	0.4040	0.4956	0.5044	26,835	27,024	6.8229	6.7750
1953	0.3843	0.4696	0.5304	30,566	30,788	6.5489	6.5017
1954	0.4363	0.5301	0.4699	28,087	28,333	7.8068	7.7390
1955	0.4333	0.5227	0.4773	31,012	31,297	7.6437	7.5739
1956	0.4426	0.5321	0.4679	32,136	32,446	7.7824	7.7080
1957	0.4316	0.5161	0.4839	35,513	35,876	7.5606	7.4841
1958	0.4364	0.5185	0.4815	37,607	38,024	7.6188	7.5352
1959	0.4246	0.5024	0.4976	42,424	42,903	7.2703	7.1891
1960	0.4283	0.5058	0.4942	44,858	45,395	7.3097	7.2232
1961	0.4339	0.5111	0.4889	46,736	47,334	7.4985	7.4037
1962	0.4468	0.5255	0.4745	46,964	47,604	8.0519	7.9436
1963	0.4414	0.5179	0.4821	51,405	52,122	8.0443	7.9337
1964	0.4440	0.5193	0.4807	54,504	55,174	8.5125	8.4092
1965	0.4535	0.5533	0.4467	51,369	52,112	10.0378	9.8946
1966	0.4662	0.5628	0.4372	53,360	54,255	10.5244	10.3507
1967	0.4727	0.5663	0.4337	57,801	58,855	10.7564	10.5639
1968	0.4868	0.5767	0.4233	60,718	62,059	11.1789	10.9373
1969	0.4917	0.6006	0.3994	59,181	60,504	12.4956	12.2223
1970	0.4935	0.5936	0.4064	66,514	67,984	12.3821	12.1144
1971	0.5107	0.6069	0.3931	68,118	69,718	13.6496	13.3364
1972	0.5004	0.5863	0.4137	81,839	83,870	12.8741	12.5623
1973	0.4869	0.5670	0.4330	99,474	102,187	11.9510	11.6337
1974	0.5152	0.6013	0.3987	90,618	93,151	13.2713	12.9106
1975	0.5366	0.6207	0.3793	88,349	91,292	14.2830	13.8227
1976	0.5282	0.6007	0.3993	104,629	108,387	13.7324	13.2563
1977	0.5319	0.6016	0.3984	112,937	117,119	14.0185	13.5179
1978	0.5354	0.6028	0.3972	120,775	125,675	14.8907	14.3102
1979	0.5460	0.6108	0.3892	124,848	130,242	15.5823	14.9370
1980	0.5512	0.6147	0.3853	128,934	135,126	16.1903	15.4483
1981	0.5650	0.6336	0.3664	122,825	129,023	18.0429	17.1761
1982	0.5720	0.6399	0.3601	123,010	129,411	18.6555	17.7328
1983	0.5636	0.6313	0.3687	135,420	142,594	18.3773	17.4527
1984	0.5669	0.6332	0.3668	140,728	148,517	19.5586	18.5328
1985	0.5666	0.6339	0.3661	144,694	152,862	19.9647	18.8978
1986	0.5500	0.6117	0.3883	172,749	182,498	18.6690	17.6717
1987	0.5423	0.5933	0.4067	206,015	217,859	17.6491	16.6896
1988	0.5532	0.6043	0.3957	200,002	212,232	19.6051	18.4754
1989	0.5753	0.6276	0.3724	182,000	193,945	23.3181	21.8819
1990	0.5894	0.6426	0.3574	172,314	184,554	25.9575	24.2360
1991	0.5885	0.6378	0.3622	184,649	197,776	26.0534	24.3241
1992	0.5910	0.6419	0.3581	189,644	203,826	27.2664	25.3694
1993	0.5844	0.6324	0.3676	210,913	227,338	26.2365	24.3409
1994	0.5833	0.6330	0.3670	217,932	235,171	27.1963	25.2026
1995	0.5812	0.6365	0.3635	226,219	244,877	27.8831	25.7586
1996	0.5664	0.6261	0.3739	248,791	269,958	26.9005	24.7913
1997	0.5454	0.6010	0.3990	305,928	332,022	23.3370	21.5029
1998	0.5478	0.6020	0.3980	314,677	342,621	23.7251	21.7901
1999	0.5378	0.5908	0.4092	352,850	385,010	22.3584	20.4908
				Average Annual Exponential Rate of Growth			
1951-99	0.0070	0.0046	-0.0053	0.0539	0.0556	0.0268	0.0252
1951-75	0.0139	0.0113	-0.0137	0.0501	0.0512	0.0350	0.0339
1975-99	0.0001	-0.0021	0.0032	0.0577	0.0600	0.0187	0.0164
1975-87	0.0009	-0.0038	0.0058	0.0706	0.0725	0.0176	0.0157
1987-99	-0.0007	-0.0004	0.0005	0.0448	0.0475	0.0197	0.0171

PLS is labor share of paid employees, LS is PLS plus imputed share of unpaid employees, TFI (using H) and TFI* (using H*) are total factor input, TFP and TFP* are their factor productivity in level.

Figure 1 Total Factor Productivity



productivity in the last section is based on the conceptual framework that the rate of growth of real GDP can be decomposed into the contributions from changes in capital, labor and the remainder termed total factor productivity under the assumption of constant returns to scale (the exponents of capital and labor summing to unity). Using the same framework we have estimated productions using alternative capital stock series and labor hours H and H* (the latter adjusted for the quality of human capital). In view of the problem of multicolinearity we have adopted the assumptions of constant returns, a constant exponent of capital (and thus of labor hour), and a constant exponential growth rate of total factor productivity. Data on labor share as given in the column under LS in Table 2 suggest that a constant exponent of capital is a reasonable assumption. The production functions estimated should be interpreted as a short-hand means of summarizing the data under the above maintained assumptions.

We first present estimated Cobb-Douglas production functions (with or without the assumption of constant returns to scale) with a time trend for the entire period 1951-1999 using a capital stock K1 to K3 and labor H or H*. The variable H* is the product of H and S. One may imbed S in H and treat H* as one variable or considers S as a separate variable. Our preliminary regressions suggest that the effect of S should be imbedded in H* as one variable because using a separate lnS yields unstable and sometimes negative coefficients. The dependent variable is the log of real GDP as given in Table 1. Because of the presence of serial correlation in the residuals we have used the Cochran-Orcutt procedure to eliminate first-order serial correlation. The results are given in Table 3, where the standard errors (not t statistics) are in parentheses placed below the estimated coefficients, R^2 is adjusted, s is the standard error of the regression and DW is the Durbin-Watson statistic. We test the assumption that the capital and labor exponents sum to one and report the p-value for rejecting this hypothesis.

Equation 1 is based on K1 and H. The estimated output elasticity of capital is 0.2621 and that of labor is 0.5394. The estimated coefficient for t is 0.0387. The null hypothesis that the coefficients of lnK and lnH sum to one is rejected only at the 10.4 percent level. Under the assumption of constant returns, the estimates are given in equation 7. The coefficient of capital increases from 0.2621 to 0.2825 and that of t decreases to 0.0317 from 0.0387. Since the point estimates of the capital and labor coefficients in equation 1 sum to less than one, imposing the sum of one in equation 7 raises the contributions of these two factors to growth and reduces that of total factor productivity. The coefficients of t in equations 1 and 7 have the same order of magnitude as those reported by Kuo (1983, p.232) for the period 1961-71. The results using the quality-adjusted hours H* are given in equations 4 and 10 (corresponding to equations 1 and 7). The hypothesis of constant returns under H* can be rejected only at the 11.0 percent level. While the coefficients of in equations 4 and 10 are similar to those in equations 1 and 7, the variable H* is not an improvement over the unadjusted variable H as judged by the standard error of the regression s which turns out to be very slightly larger in each regression using H*.

The estimated coefficients and the fit using K2 (K1 plus inventory) are very close to those using K1 in all cases. Identical remarks to those in the last paragraph can be made and will not be repeated. By the size of the standard error of the regression s, the fit using K1 is very slightly better than using K2 in every case.

To find out the effects on our results of the choice of capital stock, we present results based on non-land capital K3 constructed by following Dessus' method. These are equations 3, 6, 9 and 12. Using K3 the coefficients of log capital are lower and of t higher as compared with results using K1 or K2. The hypothesis of constant returns is rejected at the 6.9 and 4.8 percent level under H and H*, respectively.

Table 3 Regression Equations with AR(1) Errors for Taiwan

Equation Using	Ln(K, K/H or	ln (H or H*)	t	t^2	C	R^2/s	DW	rho	p-value

	K/H*)								
1 K1&H	0.2621	0.5394	0.0387		4.212	0.9997/	1.383	0.291	0.104
	(0.0685)	(0.1395)	(0.0070)		(1.102)	0.0203		(0.096)	
2 K2&H	0.2539	0.5515	0.0402		4.137	0.9997/	1.388	0.284	0.112
	(0.0688)	(0.1376)	(0.0680)		(1.109)	0.0205		(0.097)	
3 K3&H	0.1820	0.5544	0.0490		4.930	0.9996/	1.466	0.173	0.069
	(0.1076)	(0.1661)	(0.0100)		(1.366)	0.0220		(0.080)	
4 K1&H*	0.2892	0.5093	0.0350		1.828	0.9997/	1.363	0.752	0.110
	(0.0684)	(0.1336)	(0.0074)		(1.076)	0.0204		(0.094)	
5 K2&H*	0.2822	0.5198	0.0365		1.699	0.9997/	1.365	0.748	0.118
	(0.0689)	(0.1343)	(0.0073)		(1.688)	0.0207		(0.095)	
6 K3&H*	0.1838	0.5112	0.0485		2.935	0.9996/	1.457	0.869	0.048
	(0.1162)	(0.1649)	(0.0111)		(2.025)	0.0222		(0.071)	
7 K1/H	0.2825		0.0317		2.405	0.9993/	1.416	0.269	
	(0.0750)		(0.0067)		(1.187)	0.0208		(0.090)	
8 K2/H	0.2696		0.0338		2.373	0.9993/	1.424	0.260	
	(0.0744)		(0.0640)		(0.204)	0.0210		(0.092)	
9 K3/H	0.2138		0.0396		2.508	0.9992/	1.502	0.136	
	(0.1097)		(0.0089)		(0.306)	0.0227		(0.080)	
10 K1/H*	0.3190		0.0266		-0.820	0.9992/	1.389	0.795	
	(0.0746)		(0.0064)		(0.160)	0.0209		(0.087)	
11 K2/H*	0.3089		0.0286		-0.914	0.9992/	1.393	0.785	
	(0.0743)		(0.0062)		(0.142)	0.0211		(0.089)	
12 K3/H*	0.2503		0.0348		-1.053	0.9990/	1.488	0.878	
	(0.1167)		(0.0091)		(0.216)	0.0231		(0.068)	
13 K1/H	0.2772		0.0325	-0.000005	2.416	0.9993/	1.415	0.777	
	(0.1048)		(0.0122)	(0.000075)	(0.242)	0.02080		(0.090)	
14 K2/H	0.2509		0.0363	-0.000019	2.417	0.9993/	1.421	0.763	
	(0.1039)		(0.0117)	(0.000073)	(0.265)	0.02100		(0.092)	
15 K3/H	0.1497		0.05094	-0.000127	2.645	0.9992/	1.438	0.759	
	(0.0975)		(0.00882)	(0.000054)	(0.268)	0.02169		(0.093)	

Dependent variables are ln(GDP), ln(GDP/H) or ln(GDP/H*). Equations are estimated by the ML method. Figures in parentheses are standard errors of estimates, H* is H (employment hours) adjusted for labor quality, K1 to K3 are various versions of capital stock, sample period=1951-1999, sample size=49, C=constant term, R^2 =adjusted R^2, s=standard error of the regression, DW=Durbin-Watson statistic, rho=estimated autocorrelation coefficient, p-value=probability value for the test of constant returns to scale.

Based on the standard errors of the regressions, we have two conclusions. First, K1 is very slightly better than K2 and both are better than K3. Second, H is very slightly better than H* in every corresponding case, suggesting that our measure of human capital is not an improvement over the quality-unadjusted labor H. The capital coefficients estimated from using K3 are below 0.3, and appear unreasonable from the data analysis of factor share in section 2. TFP growth rates obtained under K3 are also much higher than those obtained by Kim and Lau (1994), Young (1995), and Collins and Bosworth (1996). Our conclusion that K3 is an inferior measure of capital does not imply any criticism of Dessus (1999). His measure of output is in US dollars based on the work of Summers and Heston (1991) and his sample period is shorter. His estimation of a Cobb-Douglas production function for the period 1951-1990 yielded a sum of the estimated coefficients of capital and labor equal to 0.867 and an exponential growth rate of TFP equal to 0.024 by OLS (p.194). Using official output data, we are not able to produce similar estimates employing our K3 for the period 1951-1999 or 1951-1990. Although our K3 is inferior to K1 and K2, it will be employed for comparison.

To study whether the rate of growth of total factor productivity implied by a production function with constant returns has declined we supplement the analysis given in the bottom of Table 1 under TFP and TFP* (the latter showing very small decline since 1975 except for the period 1987-99 which is affected by the Asian financial crisis of the last two years) by estimating a quadratic trend function in equations 7, 8 and 9. The results are equations 13, 14 and 15 in Table 3. They indicate that linear trends are valid for K1 and K2, but the quadratic term is significant for K3. As seen from equation 15, adding a t^2 term lowers the capital elasticity from 0.2138 to 0.1497 and makes the variable K3 even less attractive.

Before accounting for the slowdown in Taiwan's GDP growth during the latest decades, we perform an analysis of cointegration for the variables used in Table 3 to examine their dynamic relationships. First, ln(GDP), ln(H), ln(H*), ln(K1), ln(K2) and ln(K3) are all found to have a unit root. Second, the variables in each restricted OLS regression are found cointegrated of order 1. Third, error correction models with AR(1) errors are estimated on the assumption of constant returns to scale, which correspond to equations (7) to (12) and 15 in Table 3. Dependent variables are expressed in the first differences in ln(GDP/H) or ln(GDP/H*). Explanatory variables ln(K/H) and ln(K/H*) are also expressed in first differences, where K is K1, K2 or K3. The error correction term is the estimated OLS residuals, lagged one period, from the preceding test of cointegration. The regression results in Table 4 indicate that both the short-term adjustment variable in first differences and the error correction term in level but lagged one period are all very significant in explaining the dependent variable in first differences. The adjustment coefficients of the error-correction term range from -0.4655 (under K3 and H*) to -0.5577 (under K3 and t^2). The effects of the short-run change of ln(K/H) on ln(GDP/H) range from 0.2497 (under K3 and t^2) to 0.3239 (under K1 and H*).

As pointed out in Section 2, Taiwan's GDP growth rates have slowed down during the second half of the period 1951-1999. The average exponential growth rate fell from 0.08515 or 8.89 percent per year in 1951-1975 to 0.07637 or 7.94 percent per year in 1975-1999. In particular, the average exponential rate was only 0.06455 or 6.67 percent per year during 1987-1999. The figures in Tables 1 and 2 also show declining rates for capital, labor and the TFP in the corresponding periods. We now use the exponential growth rates of these input variables in Table 1 and the estimated restricted equations in Table 3 to account for the exponential growth rates of the actual real GDP. The results are presented in Table 5 for each of the equations 7 to 12 and 15 in Table 3.

Table 4 Error Correction Models with AR(1) Errors

Equation	R^2/s	DW	rho
7 $\Delta \ln(Y/H)_t = 0.0293 + 0.3176\,\Delta \ln(K1/H)_t - 0.5092[\text{Est. Res. from } \ln(Y/H) \text{ in eq.7}]_{t-1}$	0.4320/	1.876	0.482
(0.0150) (0.0985) (0.1150)	0.018009		(0.126)
(0.004) (0.001) (0.000)			
8 $\Delta \ln(Y/H) = 0.0330 + 0.2862\,\Delta \ln(K2/H)_t - 0.5237[\text{Est. Res. from } \ln(Y/H) \text{ in eq.8}]_{t-1}$	0.4118/	1.867	0.482
(0.0099) (0.0995) (0.1167)	0.018412		(0.126)
(0.001) (0.004) (0.000)			
9 $\Delta \ln(Y/H) = 0.0341 + 0.2965\,\Delta \ln(K3/H)_t - 0.5056[\text{Est. Res. from } \ln(Y/H) \text{ in eq.9}]_{t-1}$	0.4162/	1.873	0.494
(0.0099) (0.1084) (0.1058)	0.018345		(0.126)
(0.001) (0.006) (0.000)			
10 $\Delta \ln(Y/H^*) = 0.0268 + 0.3239\,\Delta \ln(K1/H^*)_t - 0.4992[\text{Est. Res. From } \ln(Y/H^*) \text{ in eq.10}]_{t-1}$	0.4412/	1.879	0.521
(0.0100) (0.0979) (0.1146)	0.018135		(0.123)
(0.007) (0.001) (0.000)			
11 $\Delta \ln(Y/H^*) = 0.0301 + 0.2959\,\Delta \ln(K2/H^*)_t - 0.5093[\text{Est. Res. From } \ln(Y/H^*) \text{ in eq.11}]_{t-1}$	0.4237/	1.867	0.519
(0.0098) (0.0975) (0.1160)	0.018417		(0.123)
(0.002) (0.002) (0.000)			
12 $\Delta \ln(Y/H^*) = 0.0309 + 0.3108\,\Delta \ln(K3/H^*)_t - 0.4655[\text{Est. Res. From } \ln(Y/H^*) \text{ in eq.12}]_{t-1}$	0.4193/	1.896	0.525
(0.0099) (0.1085) (0.1011)	0.018487		(0.123)
(0.002) (0.004) (0.000)			
15 $\Delta \ln(Y/H) = 0.0381 + 0.2497\,\Delta \ln(K3/H)_t - 0.5577[\text{Est. Res. from } \ln(Y/H) \text{ in eq.15}]_{t-1}$	0.4044/	1.824	0.543
(0.0103) (0.1103) (0.1180)	0.018529		(0.121)
(0.000) (0.024) (0.000)			

Equation numbers are same as those given in Table 3. Constant returns to scale are assumed in the first and second stages of the regression for all equations. Est. Res. refers to the estimated OLS residuals from the first stage of the regression. Δ=first difference, R^2=adjusted R^2, s=the standard error of the regression. Figures in the first parenthesis under each estimate are the standard error of the estimate while those in the second parenthesis are the probability value.

Table 5 Sources of and Contributions to GDP Growth for Various Sample Periods

Equation Under	Sample Period	Sources of Growth K	H	t	S	A	S/A	Contributions to Growth(%) K	H	t	R
7 K1/H	**1951-75**	0.03655	0.0183	0.03175	0.0866	0.08515	1.01701	42.9	21.5	37.3	-1.7
	1975-87	0.02827	0.0226	0.03175	0.08262	0.08819	0.93679	32.1	25.6	36.0	6.3
	1987-99	0.02548	0.00819	0.03175	0.06542	0.06455	1.01341	39.5	12.7	49.2	-1.3
	1951-99	0.03171	0.01685	0.03175	0.08031	0.08076	0.99437	39.3	20.9	39.3	0.6
8 K2/H	**1951-75**	0.03393	0.01863	0.03381	0.08637	0.08515	1.01436	39.9	21.9	39.7	-1.4
	1975-87	0.02561	0.02301	0.03381	0.08243	0.08819	0.93468	29.0	26.1	38.3	6.5
	1987-99	0.02399	0.00833	0.03381	0.06613	0.06455	1.02448	37.2	12.9	52.4	-2.4
	1951-99	0.02937	0.01715	0.03381	0.08033	0.08076	0.99462	36.4	21.2	41.9	0.5
9 K3/H	**1951-75**	0.02343	0.02006	0.0396	0.08308	0.08515	0.97573	27.5	23.6	46.5	2.4
	1975-87	0.02124	0.02477	0.0396	0.0856	0.08819	0.97066	24.1	28.1	44.9	2.9
	1987-99	0.01925	0.00897	0.0396	0.06782	0.06455	1.05071	29.8	13.9	61.3	-5.1
	1951-99	0.02183	0.01846	0.0396	0.0799	0.08076	0.98929	27.0	22.9	49.0	1.1
10 K1/H*	**1951-75**	0.04127	0.01849	0.02664	0.0864	0.08515	1.01466	48.5	21.7	31.3	-1.5
	1975-87	0.03192	0.0238	0.02664	0.08236	0.08819	0.93389	36.2	27.0	30.2	6.6
	1987-99	0.02877	0.01081	0.02664	0.06622	0.06455	1.02588	44.6	16.7	41.3	-2.6
	1951-99	0.03581	0.0179	0.02664	0.08034	0.08076	0.99485	44.3	22.2	33.0	0.5
11 K2/H*	**1951-75**	0.03888	0.01876	0.02856	0.0862	0.08515	1.01236	45.7	22.0	33.5	-1.2
	1975-87	0.02935	0.02415	0.02856	0.08206	0.08819	0.93052	33.3	27.4	32.4	6.9
	1987-99	0.02748	0.01097	0.02856	0.06701	0.06455	1.03817	42.6	17.0	44.2	-3.8
	1951-99	0.03365	0.01816	0.02856	0.08037	0.08076	0.99519	41.7	22.5	35.4	0.5
12 K3/H*	**1951-75**	0.02743	0.02036	0.03476	0.08254	0.08515	0.96935	32.2	23.9	40.8	3.1
	1975-87	0.02486	0.02620	0.03476	0.08582	0.08819	0.97316	28.2	29.7	39.4	2.7
	1987-99	0.02254	0.01190	0.03476	0.06920	0.06455	1.07197	34.9	18.4	53.8	-7.2
	1951-99	0.02556	0.01970	0.03476	0.08002	0.08076	0.99088	31.7	24.4	43.0	0.9
15 K3/H	**1951-75**	0.01641	0.02169	0.04765	0.08575	0.08515	1.00705	19.3	25.5	56.0	-0.7
With t^2	**1975-87**	0.01487	0.02678	0.0431	0.08476	0.08819	0.96105	16.9	30.4	48.9	3.9
	1987-99	0.01348	0.0097	0.04006	0.06325	0.06455	0.97982	20.9	15.0	62.1	2.0
	1951-99	0.01529	0.01996	0.04462	0.07987	0.08076	0.98902	18.9	24.7	55.2	1.1

Equation numbers are those given in Table 3. K=capital, H=labor, t=time, S=sum of estimates, A=actual GDP exponential growth rates, R=100-contributions of K, H and t.

To explain Table 5, consider the case of K1/H. We have for each of the four periods, 1951-1975, 1975-1987, 1987-1999 and 1951-1999 the following simple decomposition:

(3.1) Estimated g_{GDP}=0.2825*g_{K1}+0.7175*g_H+0.0317 or

S=K + H + t

where the g's are the exponential growth rates as given in Table 1 for various variables and the coefficients are the estimates in Table 3. We use equation (3.1) to account for the changes in the GDP growth rates in the specified sample periods. In Table 5, the GDP exponential growth rates are given in column A. Columns K and H are the product of the estimated restricted coefficients in Table 3 multiplied by the exponential growth rates in Table 1 and t is given by the estimated coefficient for the time trend in Table 3. As seen from the top three rows of the table, the decline of the growth rate in the real GDP during the period 1975-1999 resulted from the decreases in the growth of capital and labor, in fact more due to capital in 1975-1987 and more to labor in 1987-1999. The predicted growth rates from the equation (3.1) is given in column S and the ratios of the predicted to actual rates in column S/A. The values of S/A are close to one except for the period 1975-1987. For the entire period 1951-1999, the main sources of contribution to the GDP growth came from the growth in capital and in total factor productivity, each about 39.3 percent (columns K and t under Contributions to Growth).

Sources of and their contributions to growth can be similarly read from Table 5 for other equations using K2 and K3 with H or H*. In the case of equation 15 with t and t^2, the exponential growth rates of TFP for various sample periods are given by the average values calculated from the equation: 0.05094-0.000254t. Several observations from Table 5 may be noted. First, the rates of growth due to capital had decreased for all equations over the two periods 1975-1987 and 1987-1999 because the rates of growth of capital itself as shown in Table 1 had decreased. Second, the growth due to either measure of labor increased in the period 1975-1987 but decreased very substantially during 1987-1999 in all equations because the labor variable itself so behaved in Table 1. The data may suggest a shortage of labor since 1987. Third, the contribution of increasing TFP to economic growth generally exceeded the contribution of capital except for the cases of K1/H* and K2/H*. The addition of t^2 in the equation using K3/H has raised the contribution of TFP and lowered that of capital tremendously. Fourth, figures in the R column under Contributions to Growth are residuals in our explanation of the growth in real GDP. They are small for various sample periods except the period 1975-1987 using K3 and H*. Therefore we shall retain only the equations using K1/H, K2/H and K3/H with t^2 in making forecasts for the period 2001-2010.

Growth accounting decomposes the rate of growth into its three components and can serve as a means for forecasting if we can forecast the inputs H and K, the latter depending on forecasts of investment I (real gross fixed investment) and possibly also V (real inventory). The equations based on K1/H are given by:

$H_t = aH_{t-1}$
$I_t = bRGDP_{t-1}$
$K1_t = (1-d)K1_{t-1} + I_t$
$RGDP_t = fe^{2.4046+0.0317t}K1_t^{0.28252}H_t^{0.71748}$
t(year 2000)=50

The equations based on K2/H are given by

$H_t = aH_{t-1}$
$I_t = bRGDP_{t-1}$
$V_t = cRGDP_{t-1}$
$K2_t = (1-d)K1_{t-1} + I_t + V_t$
$RGDP_t = fe^{2.373+0.0338t}K_t^{0.2696}H_t^{0.7304}$
t(year 2000)=50

The equations based on K3/H with t^2 are given by:

$H_t = aH_{t-1}$
$I_t = bRGDP_{t-1}$
$K3_t = (1-d)K3_{t-1} + I_{tt}$
$RGDP_t = fe^{2.6446+0.050942t-0.00012652t^2}K3_t^{0.1497}H_t^{0.8503}$
t(year 2000)=50

The coefficients b and c are set to equal 0.2663 and 0.1864, respectively. They represent the average ratios of I and V to real GDP lagged one period for the last ten years. The adjustment factor f is set to make the right-hand side of the equation taken from Table 3 equal to the latest official forecast on RGDP for year 2000. The depreciation rate d is equal to 4 percent and the labor coefficient a assumes four possible values 1.008 (least favorable), 1.01, 1.013 and 1.015 (most favorable). As shown in Table 1, the growth of total employment hours has decreased substantially since 1987. The average exponential growth rate was 0.03150 during 1975-1987 but only 0.01141 during 1987-1999. The growth rate is expected to decrease further in view of the shortening of weekly work hours in the coming years. At present the legal work time is 48 hours per week. The weekly hours will be reduced to 42 hours per week beginning January 2001 and could be further reduced to 40 hours per week in

2002. Moreover, the employment of foreign workers will be reduced by 15,000 persons over one year starting January 2001 and may be further reduced thereafter. Thus, the growth of labor is more likely to continue to decrease and constitutes a limiting factor in production during the coming decade.

Table 6 gives our forecasts from 2001 to 2010 using different set of equations. The first set is based on K1/H. It has four scenarios depending on the rates of growth a for labor. Real GDP would grow at 5.80 percent on average over the next 10 years under the smallest a (1.008) and at 6.38 percent under the largest a (1.015). Based on the equation using K2/H, the corresponding real GDP average growth rates would be 5.93 percent and 6.53 percent, respectively. If the equation with K3/H and t^2 is applied, the predicted real GDP average growth rates would be 5.43 percent and 6.21 percent. The differences are small. Based on all these scenarios, forecasts by decomposition of GDP growth into growths in inputs suggest that the average growth rate of the real GDP in Taiwan for the coming decade would be somewhere between 5.4 percent and 6.5 percent, with a reasonable point estimate of about 6 percent.

Table 6 Forecasts on Real GDP Growth from 2000 to 2010

%

Year	Using K1/H				Using K2/H				Using K3/H & t^2			
	0.8	**1.0**	**1.3**	**1.5**	**0.8**	**1.0**	**1.3**	**1.5**	**0.8**	**1.0**	**1.3**	**1.5**
2000	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73
2001	5.97	6.12	6.34	6.49	6.08	6.24	6.47	6.62	5.61	5.87	6.10	6.25
2002	5.92	6.08	6.31	6.46	6.03	6.19	6.43	6.59	5.57	5.85	6.08	6.24
2003	5.88	6.04	6.28	6.44	6.00	6.16	6.41	6.57	5.53	5.83	6.07	6.23
2004	5.84	6.00	6.25	6.41	5.96	6.13	6.38	6.55	5.49	5.81	6.06	6.22
2005	5.80	5.97	6.22	6.39	5.93	6.11	6.36	6.53	5.45	5.80	6.04	6.21
2006	5.77	5.94	6.19	6.36	5.91	6.08	6.34	6.51	5.41	5.78	6.03	6.20
2007	5.74	5.91	6.17	6.34	5.88	6.06	6.32	6.50	5.37	5.77	6.02	6.19
2008	5.71	5.89	6.15	6.33	5.86	6.04	6.31	6.48	5.33	5.75	6.01	6.19
2009	5.69	5.87	6.13	6.31	5.84	6.02	6.29	6.47	5.30	5.74	6.00	6.18
2010	5.67	5.84	6.11	6.29	5.82	6.00	6.28	6.46	5.26	5.73	6.00	6.17
Average	5.80	5.97	6.22	6.38	5.93	6.10	6.36	6.53	5.43	5.79	6.04	6.21

0.8, 1.0, 1.3 and 1.5 are the rates of growth assumed for labor. The growth rate of GDP for year 2000 is the official forecast announced on May 19, 2000. K1/H, K2/H and K3/H & t^2 refer to equations 7, 8 and 15 in Table 3, where K1=non-land fixed capital, K2=K1 plus inventory, K3=fixed capital based on Dessus' method, and H= employment.

We end this section by stating the following conclusions concerning economic growth of Taiwan from 1951 to 1999:

1. One production function with a constant exponent for capital (and thus of labor

under constant returns) and a constant rate of increase of TFP suffices in explaining the growth of real GDP in Taiwan for the entire period.

2. The exponent of capital is about 0.3 and the rate of increase of TFP is about 0.03 (see equations 7, 8, 10 and 11 of Table 3) no matter whether capital stock includes inventory and whether labor incorporates a quality adjustment.
3. For the entire period capital contributes about 40 percent (because of the rapid rate of capital accumulation), labor only 20 percent and TFP 40 percent to the exponential rate of growth of GDP (see Table 5 under K1/H) which averaged 0.08 annually.
4. The period 1987-99 experienced a slower exponential growth rate of about 0.065 resulting mainly from the slower growth in labor force (see H and H* columns in the bottom of Table 1).
5. Using the production functions and projections of inputs, we forecast the GDP growth rate for the decade 2000-2010 to be about 6 percent which is mainly limited by the expected slow growth in the labor force.

4. COMPARATIVE ANALYSIS WITH MAINLAND CHINA

How do the above conclusions compare with findings about mainland China for the period 1952-1998 for which official data are available? *China Statistical Yearbook 1999 (CSY99)* provides data on nominal GDP 1952-1998 (p. 55), real GDP 1978-1988 (p. 58), labor force (p.134), nominal gross capital formation 1978-1988 (p. 68). Since this section is an extension of Chow (1993), data on GDP, labor and capital are taken from Chow up to 1980 and then constructed for the years thereafter based on the sources cited above. For the period before 1980, we rely on Chow (1993) which provides K=2213 (non-land fixed capital plus inventory=1493 and land=720, Table VI, p. 822) at the end of 1952. To update Chow (1993) we keep land=720 (which is a constant included in capital stock) and accumulate non-land net capital formation. From 1953 to 1980, official data on "accumulation" (in Table III of Chow 1993, p. 815) include net fixed investment and inventory changes and are the sums of accumulations of total assets by three types of enterprises and individuals (Table IV of Chow 1993, p. 818), all in 1952 prices or 1978 prices which are assumed to be identical. After 1980 we adopt the following method to convert nominal into real gross capital formation in order to construct capital stock. First, comparing nominal and real GDP provides a GDP deflator which we use to deflate the sum of nominal consumption and gross capital formation to obtain real domestic final expenditures. Second, we convert nominal into real consumption by using the general consumer price index (*CSY99*, p.294), which is linked with the general retail price index (p. 294) for the period 1981-1985. Third, We subtract real consumption from real domestic final expenditures to obtain real gross investment (including inventory investment) I. We then construct our capital series K for the period 1981-1998 based on the equation: K(t)=(1-d)[K(t)-720]+I(t)+720, where K(t=1952)=2213 and land=720. The depreciation rate d equals 0.04, which is slightly lower than the average depreciation rate of non-land fixed capital 0.045 found in *China Report: Social and Economic Development 1949-1989*, published by China Statistical Information and Consultancy Service Center, 1990. We use a slightly lower depreciation rate because our K includes inventory. We thus have all the data to update the production function of Chow (1993).

The data on real GDP in 1978 prices, labor input in ten thousand persons and capital stock in 1978 prices are presented in Table 7 for the period 1952-1998. The average exponential rates of growth for each variable are summarized at the bottom of the table for three periods: 1952-1998, 1952-1978 and 1978-1998. The two sub-periods are the periods before and after the economic reform. As can be seen from the table, the GDP growth rates are much higher in the second period, whose average exponential growth rate is 0.09268 or 9.7 percent per year as compared with the 0.05815 exponential growth rate or 6.0 percent per year in the first period, yielding an average exponential growth rate of 0.07316 or 7.6 percent per year for the entire period. The average exponential growth rates of labor and capital are 0.02776 (2.8 percent) and 0.09019 (9.4 percent), respectively, for the second period as compared with the rates of 0.02543 (2.6 percent) and 0.07126 (7.4 percent) for the first period. Thus the growth rates of labor and capital are also higher in the second period but only moderately, supplementing the significant contribution of increasing total factor productivity to the GDP growth during this period. Note that there is a substantial increase in the official estimate of labor force in 1990 which was the result of a new census, but we chose not to make any smoothing of the data since this study is concerned with long term trends which are hardly affected by this census result.

Since Chow (1993) found no increase in TFP before 1980, we estimate a Cobb-Douglas production function with or without the restriction of constant returns by introducing a trend beginning with t=1 in 1979, the year after economic reform started (see Table VIII of Chow 1993, p. 825, for the positive deviations of log output from estimates by a production after 1979). As explained in Chow (1993) the years 1958-1969 are considered and shown to be abnormal years to be excluded in all regressions. Table 8 presents three estimated equations for the period 1952-1998. Equation 1 is

Table 7 Data on Mainland China

Year	GDP	L	K	t
1952	799	20,729	2,213	0
1953	911	21,364	2,381	0
1954	964	21,832	2,576	0
1955	1,026	22,328	2,761	0
1956	1,170	23,018	2,978	0
1957	1,223	23,771	3,211	0
1958	1,492	26,600	3,590	0
1959	1,615	26,173	4,148	0
1960	1,591	25,880	4,649	0
1961	1,119	25,590	4,844	0
1962	1,046	25,910	4,943	0
1963	1,158	26,640	5,126	0
1964	1,349	27,736	5,389	0
1965	1,578	28,670	5,754	0
1966	1,846	29,805	6,224	0
1967	1,713	30,814	6,528	0
1968	1,601	31,915	6,826	0
1969	1,910	33,225	7,183	0
1970	2,355	34,432	7,801	0
1971	2,520	35,620	8,485	0
1972	2,592	35,854	9,133	0
1973	2,807	36,652	9,874	0
1974	2,839	37,369	10,615	0
1975	3,075	38,168	11,445	0
1976	2,993	38,834	12,193	0
1977	3,227	39,377	13,025	0
1978	3,624	40,152	14,112	0
1979	3,900	41,024	15,273	1
1980	4,204	42,361	16,438	2
1981	4,425	43,725	17,268	3
1982	4,824	45,295	18,297	4
1983	5,349	46,436	19,515	5
1984	6,161	48,197	20,928	6
1985	6,991	49,873	22,755	7
1986	7,611	51,282	24,822	8
1987	8,491	52,783	27,123	9
1988	9,448	54,334	30,085	10
1989	9,832	55,329	33,445	11
1990	10,209	63,909	36,565	12
1991	11,148	64,799	39,776	13
1992	12,735	65,554	43,589	14
1993	14,453	66,373	48,994	15
1994	16,283	67,199	55,006	16
1995	17,994	67,947	61,856	17
1996	19,719	68,850	69,304	18
1997	21,455	69,600	77,218	19
1998	23,129	69,957	85,692	20
	Average Exponential Rate of Growth			
1952-98	0.07316	0.02644	0.07949	
1952-78	0.05815	0.02543	0.07126	
1978-98	0.09268	0.02776	0.09019	

GDP = real GDP in 1978 prices, L = labor in 10,000 persons, K = capital in 1978 prices, t = time.

Table 8 Regression Equations with AR(1) Errors for Mainland China

Equation Using	ln(K or K/L)	Ln (L)	t	t^2	C	R^2/s	DW	rho	p-value
1 K&L	0.7741 (0.0960)	0.0020 (0.2354)	0.0255 (0.0050)		0.789 (0.602)	0.9986/ 0.0338	1.712	0.765 (0.109)	0.126
2 K/L	0.6467 (0.0412)		0.0268 (0.0043)		-0.110 (0.127)	0.9964/ 0.0349	1.627	0.680 (0.124)	
3 K/L	0.6377 (0.0360)		0.0380 (0.0077)	-0.00059 (0.00036)	-0.092 (0.111)	0.9965/ 0.0338	1.631	0.604 (0.135)	

Dependent variable is ln(GDP) or ln(GDP/L). Equations are estimated by the ML method. Figures in parentheses are standard errors of estimates. L = labor, K = capital stock, C = constant term, sample period = 1952-1998, sample size = 35 (1958-69 omitted), R^2 = adjusted R^2, s = standard error of the regression, DW = Durbin-Watson statistic, rho = estimated auto-correlation coefficient, p-value = probability value for the test of constant returns to scale.

the unrestricted estimation. The coefficient is 0.7741 for ln(K) and 0.0020, subject to a large error, for ln(L). as compared with 0.6353 and 0.3584, respectively, obtained by Chow (1993, p.882) for the period 1952-1980. Both estimates of the coefficient for labor are subject to large errors but the data for the period up to 1980 and for the entire period 1952-1998 both support the assumption that the sum of the coefficients of lnK and lnL equals one. For the entire sample, this hypothesis can be rejected only at the 0.126 level of significance. We thus impose this restriction to find the capital exponent to be about 0.647 and the exponential trend coefficient to be about 0.027, as given by equation 2 in Table 8. The first coefficient is in agreement with the result given in Table VII of Chow (1993, p.823) using old official national income data (revised in 1994) for output and a sample period of 1952-1980, excluding 1958-1969. To examine whether the output elasticity of capital has remained unchanged throughout the entire sample period 1952-1998, we add a variable dd* ln(K/L) to equation 2 in Table 8, where dd is a dummy taking the value one for the period 1979-1998 and zero otherwise. This variable measures the incremental coefficient of ln(K/L) for the period 1979-1998. The estimated coefficient is 0.0035 (s=0.0099) and is statistically insignificant. The coefficients of ln(K/L) and t are 0.6433 and 0.0262, respectively, remaining almost the same as in the absence of the added dummy variable. In addition, we also estimate equation 2 with the square of ln(K/L) as an additional variable and find it insignificant, with a coefficient of -0.0352 and its standard error being 0.0426. The data are thus consistent with a constant output elasticity of capital throughout the entire sample period 1952-1998. To examine whether the rate of growth of total factor productivity implied by a production function with constant returns has declined we estimate a quadratic trend function as given in equation 3. We find the coefficient of t^2 significant only at the 0.096 level.

Table 9 presents the decomposition of the rate of GDP growth into its factor components, similar to Table 5. In the period 1952 to 1978 when there was no increase in TFP, capital contributed 0.046 and labor 0.009 to the rate 0.058 of exponential growth of GDP. In the period 1978-1998, capital contributed 0.058, labor 0.010 and increase in TFP 0.027 to the rate 0.093 of exponential growth of GDP. For the entire period 1952 to 1998 capital contributed 0.051, labor 0.009 and increase in TFP 0.012, which is 20/46 of 0.027, to the rate of 0.073 of exponential growth of GDP. The sum of the estimated contributions for each period is not far from the actual GDP growth rate as shown by the S/A ratios in Table 9. In percentage terms, these amount to 70, 13 and 16 from 1952 to 1998 as compared with approximately 39, 21 and 40 for Taiwan from 1951 to 1999.

Table 9 Sources of and Contributions to GDP Growth for Various Sample Periods

Equation Under	Sample Period	Sources of Growth						Contributions to Growth(%)			
		K	L	t	S	A	S/A	K	L	t	R
K/L	1952-78	0.04609	0.00898	0.00000	0.05507	0.05815	0.94703	79.3	15.4	0.0	5.3
	1978-98	0.05833	0.00981	0.02675	0.09489	0.09268	1.02382	62.9	10.6	28.9	-2.4
	1952-98	0.05141	0.00934	0.01163	0.07238	0.07316	0.98934	70.3	12.8	15.9	1.1

K = capital, L = labor, t = time, S = sum of estimates, A = actual GDP exponential growth rate, R = 100 - contributions of K, L and t.

One very important difference between the two economies is the relatively small exponent of labor in the production function for the mainland. The accuracy of this small estimate was carefully examined in Chow (1993) where factor shares during the market economies of 1953 and the 1920's were cited to support such a low estimate. Low labor exponents were also found in Table XII of Chow (1993, p.833) for production functions of the three sectors of industry, construction and transportation.

The rationale for the low estimate is that the elasticity of output with respect to labor is low because labor is in abundance in the mainland. In the extreme such surplus labor may yield almost zero output. Since the Cobb-Douglas production function is an approximation to the input-output relation with constant elasticities, the small marginal output of labor is reflected in its small exponent. As the economy grows the ratio of capital to labor will increase and labor will not be in such abundance; the labor exponent will increase. Our examination of Chinese data indicates that the abundance of labor has persisted after two decades of rapid growth since 1978. This finding is consistent with the existence of very poor regions in Western China and the low wage rates of workers in those regions.

We end this section by stating the following conclusions concerning economic growth of mainland China from 1952 to 1998 for comparison with the conclusions concerning Taiwan stated at the end of section 3:

1. Ignoring the interruptions in the period 1958-1969 resulting from the Great Leap and the Cultural Revolution, GDP growth in mainland China can be characterized by a constant exponent for capital (and thus of labor under the empirically supported assumption of constant returns), no increase in TFP up to 1978, and a constant rate of increase in TFP from 1979 to 1998.
2. Exponent of capital is about 0.65 and the rate of increase of TFP after 1979 is about 0.027.
3. In the period 1978-1998, capital contributes about 62 percent (because of the large capital exponent and the rapid rate of capital accumulation), labor only 10 percent and TFP 28 percent to the average exponential rate 0.093 of GDP growth.
4. There is no obvious sign of decline in the growth rate of GDP since 1978 as there has been no decline in the rate of growth of labor in the last decade similar to the decline in Taiwan and the contribution of labor to growth is small. A factor which may have a small impact on the future growth rate is the anticipated decline in the growth of labor force in the mainland.

5. CONCLUSIONS

Having constructed capital stock data for Taiwan and mainland China and estimated Cobb-Douglas production functions we have reached the following conclusions.

First, one production function with constant returns, constant capital and labor exponents and constant exponential rate of increase in TFP can explain the data on GDP growth in Taiwan from 1951 to 1999. The same is true for mainland China from 1952 to 1998 except that TFP remains constant in 1952-1978 and begins to increase in a constant rate since 1978.

Second, the capital exponent is about 0.3 and the trend coefficient about 0.03 in Taiwan. The capital exponent is about 0.6 and the trend coefficient beginning 1979 is about 0.03 in the mainland.

Third, for the entire period 1951-1999 capital contributes about 40 percent, labor 20 percent and TFP 40 percent to the 0.08 exponential rate of GDP growth in Taiwan. For the period 1978-1998, capital contributes about 62 percent, labor 10 percent and TFP 28 percent to the 0.093 exponential rate of GDP growth in the mainland.

Fourth, in the last decade of the sample period Taiwan's GDP growth rate decreased to about 0.065 mainly as a result of the slower increase in labor input and the large exponent of labor in the production. No such phenomenon is observed for the mainland, but future growth might be slightly slower because of the anticipated slower growth rate of labor force which only has a small effect on output.

Fifth, a significant finding is the small exponent of about 0.4 for labor in the mainland which can be interpreted as resulting from the very large supply of labor relative to capital stock. Approximating the input-output relation by a function with a constant elasticity with respect to labor yields a low estimate of this elasticity. The elasticity is expected to increase as the economy accumulates more capital, but there is no evidence up to this point of its increase, suggesting that labor is still in abundance in the mainland.

Sixth, capital accumulation has been the most important factor for increasing output in both economies, contributing 40 percent to the growth in Taiwan in 1951-1999 and about 70 percent in the mainland in 1952-1998. Both are the result of a large rate of gross investment relative to GDP which amounts to about 25 percent in Taiwan and over 30 percent in the mainland in the last decade.

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