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ABSTRACT

This paper uses data for nineteen industrial countries over the period 1960-1985 to examine the evidence for international convergence of technical progress. Several models of convergence, including a model in which convergence is affected by changes in a country's openness to trade, are evaluated against competing alternatives. We also assess the extent to which convergence depends on some key measurement issues, including the use of purchasing power parities to compare real output in different countries, the use of different capital stocks in aggregate production functions, and alternative ways of representing embodied or disembodied technical progress. The various models of technical progress are assessed by non-nested tests of both the estimated output equations, using the factor utilization model, and their related factor demand equations. The results show significant evidence of international convergence in the rates of growth of labour efficiency, and some evidence that convergence is faster for countries that have been increasing their openness to international trade. A more general model of output determination, encompassing variations in factor utilization as well as the autocorrelated technology shocks used in real business cycle models, was found to be preferred over more restricted alternatives.

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1. Introduction

Most studies of international transactions treat countries as being essentially unaffected by trade, with their basic production technologies remaining unchanged by these international contacts. However, there is a growing body of evidence that there is some international convergence of technical progress, especially among the industrial countries that have dominated world production and trade over the past thirty years. This paper attempts to evaluate this evidence, based on data for nineteen industrial countries over the period 1960-1985. One important goal of the paper is to see whether the extent of convergence is altered by the degree to which countries have become more open to international trade. We shall also assess the extent to which the cross-country evidence supports the hypothesis that there are increasing returns, at the national level, in the use of knowledge as a factor of production.[1]

A second aim, based on the focus of the conference on issues of measurement, is to see to what extent the evidence of convergence depends on some key questions of measurement, including the exchange rates used to compare real output in different countries, the measurement and selection of the capital stocks to use in aggregate production functions, and alternative ways of representing embodied or disembodied technical progress.

This evidence on the international transmission of longer-term trends in technical progress will be based on a model in which the level of output is jointly determined by the underlying production structure and unexpected changes in demand and cost conditions. In a subsequent section dealing with shorter-term fluctuations of aggregate output, this framework will be compared with the production sector specification frequently used in real business cycle models of output determination, in which the level of output is based on a continuously binding production structure plus an autocorrelated series of technology shocks.

The three objectives listed above will each be the focus of a separate section of the paper, to be followed by a concluding section summarizing our results, and by two appendices, the first describing the sources and construction of our alternative data series, and the second describing our econometric specifications and test results in more detail.

2. What is the Evidence for International Convergence?

An important element in the international comparison of the levels and growth of per capita income and factor productivity has been the idea that growth rates, and perhaps levels of productivity and real income, should converge over time.[2] To test this notion, it is first necessary to have internationally comparable measures of real income. This in turn requires data on purchasing power parities, in order to make income levels internationally comparable.[3] To extend the analysis to factor productivity, it is also necessary to have comparable data on real output, as well as on the inputs of capital and labour, if not also of natural resources. In this section we shall make use of what we think to be the most comparable data for these purposes, and in the following section we shall consider how the results might differ if alternative assumptions or data sources were used for some of the key variables.

The intuition behind the convergence hypothesis is that the ideas and techniques underlying economic progress are increasingly easily transportable across national boundaries, so that nations starting out with lower levels of per capita income should be able to benefit not only from improvements in international best-practice technology, but also from the ability to close the gap between their previous methods and those used in the more advanced economies. Many qualifications are necessary:

1. The technologies of the richer countries may be relevant for relative factor prices and education levels existing in the richer countries, but not directly applicable to conditions existing in the poorer countries.[4]
2. The political and social systems of the poorer countries may not be ready or willing to accept the degree of international interdependence implied by the relatively unrestricted movement of technologies and production.[5]
3. The technologies themselves may be privately owned, in the sense that their importation by the poorer countries might lead to higher levels of GDP per capita, but not of GNP per capita, in the poorer countries, if the rents attributable to the technologies accrue to foreign-owned firms.
4. Countries that may at one time have been in the vanguard of economic progress may for any number of reasons lose the desire or ability to design or keep up with productivity improvements.[6]

All of these qualifications suggest that the evidence for convergence is likely to be stronger among countries with reasonably comparable initial levels of income, and open enough to international trade and investment that the necessary conditions for convergence are likely to be met. Evidence covering 100 years of development of the currently rich countries shows considerable evidence of convergence (Maddison 1982, and Baumol 1986). However, De Long (1988) emphasizes that there may be a sample selection problem here, and shows that the evidence for convergence is much weaker, and may even disappear, if the sample is increased to include some countries that were seen 100 years ago to be promising candidates for continued economic growth.[7] Evidence for much larger samples of countries[8], which include many of the poorest countries, shows weaker evidence of convergence over the past thirty years. For these much larger samples of countries, the necessary conditions for convergence are less likely to be met, and the data are not available to assess the extent to which productivity and income levels are simultaneously converging. To allow a clear focus on productivity comparisons, we restrict ourselves in this paper to a consideration of the growth experience of nineteen industrial countries for which reasonably comparable annual data are available for PPP exchange rates, for capital stocks, for real output and for labour inputs for the period from 1960 through 1985. Even here, a number of difficult and sometimes arbitrary decisions have to be made to achieve completeness and comparability of data. We shall return to these issues in the next section, after presenting our initial results on convergence among the nineteen industrial countries.

The primary sources of our data are the national accounts published by the OECD for the industrial countries, converted to common currency using PPP exchange rates for GDP.[9] The capital stock and employment data are also mainly from OECD sources, as described in Appendix I. The primary measure of productivity used for the convergence tests is, for each country, a time series of real GDP attributable to each worker, derived by inverting a CES production function with common parameters, using a country-specific average real return to aggregate capital. International differences in average returns to capital thus pick up average returns to natural resources, education, market power, and other factors to the extent that they are not captured by differences in real wages.

The maintained hypothesis, in our base case, is that technical progress is labour-augmenting, and follows a growth path that asymptotically approaches a path parallel to that of the United States. The United States is taken to be the base for the initial tests of the convergence hypothesis since the PPP data show it to have the highest level and the smallest average rate of growth of capital-adjusted real output per employee over the sample period. We shall consider later the implications that increasing internationalization might have for the definition of the source and rate of growth of technical progress seen from a global perspective. In order to separate cyclical movements in output per employee from longer-run improvements in factor productivity, the U.S. series used to define the convergence path is a smooth trend based on the average growth of the U.S. series over the sample period.[10]

Following Gordon and Baily (1989) the algebraic form of the basic hypothesis of asymptotic convergence of country i's productivity growth rate to that of the United States is specified as follows:

$$d\ln(\pi_{i,t}/\pi_{us,t}) = c_i + \alpha_i(\ln\pi_{us,t} - \ln\pi_{i,t-1}) \quad (1)$$

where d is the first-difference operator, ln is the natural log, and α_i is the country-specific rate of convergence of country i's productivity level to that of the United States. The constant term c_i is equal to $-\alpha_i$ times the proportion by which, after the convergence process is complete, the U.S. productivity level in year t exceeds that in country i in the preceding year. Equation (1), as it stands, is not suitable for estimation, since the productivity indices are not observed variables. For estimation purposes we use the time series for output attributable to each employee, calculated, as described in Appendix 1, by inverting the production function and attributing a sample-average rate of return to the capital stock.[11] The initial estimation equations are thus:

$$d\ln(\pi_{m,i,t}/\pi_{m,us,t})=c_i+\alpha_i(\ln\pi_{m,us,t}-\ln\pi_{m,i,t-1})+u_{i,t} \quad (2)$$

where $\ln\pi_m$ is the log of measured output attributable per worker and the $u_{i,t}$ are disturbance terms.[12] These disturbances are assumed to have classical properties for individual countries, but the possibility of contemporaneous cross-country error covariance is allowed for by the use of the Zellner Seemingly Unrelated Regression (SUR) estimator, which also facilitates the imposition and testing of coefficient restrictions across countries.

Table 1 shows the results of fitting equation (2) for each of the eighteen industrial countries excluding the United States. If there were no evidence of convergence, the U.S. productivity index would have a zero coefficient, and the constant term would measure the difference between the longer-run trends of technical progress in country i and in the United States. However, the results appear to show strong evidence of convergence, with positive coefficients on the U.S. measured index in all countries, with t-values above 2.0 in all but five countries, and exceeding 3.0 in a third of the cases.[13] The constant terms suggest that for almost two-thirds of the countries, the estimated level of the asymptotic growth path for capital-adjusted labour productivity is not significantly different from that of the United States, while in the rest it remains below. There are substantial international differences in the rates at which the countries are converging.

The convergence process implied by equation (2) involves relatively easy international transmission of technical progress, so that a good part of the early 1960s gap between U.S. and foreign productivity levels is closed by 1985. A rather different view of the external effects of technical progress is assumed by Romer (1986), whereby there are external economies of technical progress available to other firms operating in the domestic economy, but not to firms operating in other countries. This implies an element of increasing returns at the national level (in terms of aggregate GDP, rather than, as sometimes inferred, in terms of GDP per capita). The largest economies would gain the most from the external economies and would hence have continuing reductions in their relative costs. If the largest economy is also the one with the highest income per capita, as was the case in the 1960 to 1985 period being studied, then divergence might be expected, rather than the convergence we have modelled. It is

Table 1
The Catch-up Model of Technical Progress

	$\ln(\pi_{mus}/\pi_{mi-1})$	CONSTANT	SEE	R2	DURBIN WATSON
JAP	0.1089	-0.0503	0.0362	0.1412	1.7087
	(5.95)	(3.21)			
GER	0.0641	-0.0234	0.0282	-0.1681	1.4658
	(2.87)	(1.55)			
FRA	0.0778	-0.0248	0.0273	-0.1054	1.2160
	(5.43)	(2.39)			
UKM	0.0607	-0.0379	0.0310	-0.0486	1.7277
	(1.12)	(0.96)			
ITA	0.1215	-0.0591	0.0375	-0.0225	1.4089
	(5.54)	(3.57)			
CAN	0.0739	-0.0134	0.0209	-0.1633	0.8804
	(2.73)	(1.54)			
AUS	0.0978	-0.0383	0.0288	-0.0752	1.6486
	(1.81)	(1.50)			
OST	0.0798	-0.0431	0.0389	-0.1546	1.5667
	(3.61)	(2.27)			
BEL	0.0607	-0.0137	0.0329	-0.1080	1.7974
	(2.90)	(1.07)			
DEN	0.0679	-0.0346	0.0301	-0.0072	2.3499
	(1.99)	(1.33)			
FIN	0.0578	-0.0333	0.0407	-0.0628	1.6772
	(2.36)	(1.37)			
IRE	0.0573	-0.0337	0.0463	-0.0813	1.6982
	(1.93)	(1.08)			
NET	0.0577	-0.0045	0.0339	-0.1141	1.4992
	(2.20)	(0.40)			
NZL	0.1295	-0.0544	0.0391	0.0474	1.2372
	(2.47)	(2.66)			
NOR	0.0364	-0.0093	0.0311	-0.0449	1.9688
	(1.08)	(0.39)			
SPA	0.0752	-0.0196	0.0315	0.1351	1.7462
	(4.93)	(1.57)			
SWE	0.1695	-0.1017	0.0385	-0.0942	1.95674
	(3.21)	(2.91)			
SWI	0.1337	-0.0431	0.0334	-0.1148	1.83924
	(2.77)	(2.23)			

Note: The dependent variable for each non-US country 'i' is specified in logarithmic change form as $d\ln(\pi_{mi}/\pi_{mus})$. π_{mi} is the measured output attributable to labour for each country 'i' and π_{mus} is the US measured value. The independent variable for each country is the logarithm of US measured output attributable to labour divided by the lagged measured value for each country. See the section onspecification in Appendix II for a more complete description. Estimation was by SUR using sample 1961-1985.

possible to make a direct test of the importance of national returns to scale by adding to equation (2) the logarithm of a smoothed average of the ratio of each country's GDP to that of the United States. The variable takes a coefficient of -.075 (t=-3.57), suggesting that there are not technology-improving returns to scale at the national level. Thus we feel more secure in continuing to model convergence, based on the assumed international transfer of best-practice methods and techniques. We next turn to consider whether the pace of such transfer is related to some measure of relative openness.

Table 2 extends the basic convergence hypothesis by adding a variable representing the increase in each country's openness to foreign trade, as measured by the increase in its five-year average ratio of foreign trade to GDP. The cross-sectional hypothesis being tested here is that convergence is likely to be more rapid for countries that have increased their international linkages, with trade being used as an easily available proxy measure. The functional form used implies that it is proportionate changes in the trade share that affect the productivity level, and that the equilibrium efficiency level will be unaffected by the level of the equilibrium trade share.[14] The results reported in Table 2 show that the openness variable attracts a significant positive coefficient, with the coefficient value constrained to be the same for all countries to capture the cross-sectional effect. This supports the hypothesis that productivity growth has been faster in countries that have increased their openness to foreign trade. Subsidiary tests show that this effect is strongest in Europe, and is weaker and sometimes perversely signed for countries outside Europe. The more restricted version embodied in Table 2 will be used for the further tests reported later.

Systematic tests of the two versions of the convergence model, as shown in Tables 1 and 2, against alternative models are reported in Tables A.4 to A.6 in Appendix II. The two alternative models considered are the 'constant' case (Appendix Table A.1) and the 'break' case (Appendix Table A.2). The former involves the assumption that Harrod-neutral technical progress follows a constant rate in each country, while the rate differs among countries. In the 'break' model, there are two separate rates of technical progress for each country, one applicable from 1960 to 1973, and the second applicable thereafter, to embody the frequently noted post-1973 slowdown of output growth in the industrial countries (e.g. Bruno and Sachs 1985).[15] Before 1974, the average rate is shown as the coefficient on RTIME in Table A.2, while for 1974 and after, the rate is adjusted by the value of the coefficient on the auxiliary time trend T74. In each country, there was an apparent reduction in the average rate of technical progress, (with a t-value above 2.0 in all but five countries), by an amount averaging about 0.6 percentage points.

To provide a test of the productivity models estimated for the constant, break and convergence cases, it is necessary to derive non-cyclical indexes of technical progress for each of the

Table 2
The Effects of Globalization on the Catch-up Model

	$\ln(\pi_{mus}/\pi_{mi-1})$	DOPENA	CONSTANT	SEE	R2	DURBIN WATSON
JAP	0.0971	0.4971	-0.0521	0.0336	0.1694	1.7886
	(4.49)	(10.18)	(3.00)			
GER	0.0527	0.4971	-0.0276	0.0252	0.0890	1.9740
	(2.33)	(10.18)	(1.89)			
FRA	0.0755	0.4971	-0.0395	0.0223	0.3136	1.8298
	(5.82)	(10.18)	(4.35)			
UKM	0.0771	0.4971	-0.0547	0.0280	0.0836	1.9760
	(1.49)	(10.18)	(1.46)			
ITA	0.0883	0.4971	-0.0523	0.0334	0.2297	1.6637
	(3.76)	(10.18)	(3.15)			
CAN	0.0688	0.4971	-0.0215	0.0215	-0.2119	0.9666
	(2.19)	(10.18)	(2.24)			
AUS	0.1222	0.4971	-0.0516	0.0305	-0.1681	1.6672
	(2.05)	(10.18)	(1.86)			
OST	0.0789	0.4971	-0.0535	0.0353	0.0567	1.8758
	(3.66)	(10.18)	(2.99)			
BEL	0.0430	0.4971	-0.0139	0.0300	0.1226	2.2481
	(1.99)	(10.18)	(1.12)			
DEN	0.0396	0.4971	-0.0232	0.0290	0.0321	2.4740
	(1.08)	(10.18)	(0.86)			
FIN	0.0514	0.4971	-0.0326	0.0384	0.0523	1.8390
	(1.98)	(10.18)	(1.30)			
IRE	0.0577	0.4971	-0.0478	0.0498	-0.1821	1.6097
	(1.53)	(10.18)	(1.24)			
NET	0.0392	0.4971	-0.0059	0.0279	0.1327	2.0922
	(1.78)	(10.18)	(0.64)			
NZL	0.1230	0.4971	-0.0600	0.0388	0.1349	1.3045
	(2.14)	(10.18)	(2.63)			
NOR	-0.0350	0.4971	0.0345	0.0299	0.0200	2.0673
	(1.06)	(10.18)	(1.53)			
SPA	0.0336	0.4971	-0.0132	0.0335	-0.1794	1.6343
	(1.67)	(10.18)	(0.87)			
SWE	0.1487	0.4971	-0.0951	0.0381	-0.0254	2.0195
	(2.54)	(10.18)	(2.51)			
SWI	0.1229	0.4971	-0.0492	0.0310	0.0455	2.0103
	(2.63)	(10.18)	(2.69)			

Note: This model is specified in the same way as the catchup model described in Table 1 but it includes the additional variable DOPENA. DOPENA is the annual change in 'openness' defined as the log difference of current and lagged values of the five year moving average of exports plus imports divided by GNP. See the section on specification in Appendix II for a more complete description. Estimation was by SUR using sample 1963-1985.

models, and then use them comparably in equations that attempt to explain the actual movements of output in terms of the underlying production function (including the alternative derived series for technical progress) and other short-term demand and profitability factors possibly causing temporary departures from the normal productivity performance. As explained in Appendix II, the technical progress indexes for the convergence models are calculated cumulatively, starting from a base chosen so that the calculated labour productivity index should equal the measured values on average, without any of the cyclical variance present in the measured values of the series for capital-adjusted output per employee.

The output equation used for the non-nested tests of the alternative indexes of technical progress is the factor utilization model, as described in Helliwell and Chung (1986). This approach treats the output decision of the representative firm as depending on its employed stocks of labour and capital (including explicit allowance for technical progress, based on whatever model of technical progress is being assumed), conditioned by unexpected sales, profitability, and inventory disequilibrium.[16] In this framework, the employed stocks of labour and capital, when combined with the index of technical progress in the synthetic production function, represent the expected level of demand to the extent that firms foresaw it as being sufficiently profitable and permanent to justify changes in investment and employment. Temporary and unexpected changes in demand and cost conditions are then accommodated partially by changes in the intensity of factor use[17], and partially by price changes. Inventories then act as a buffer for any residual excess demand or supply, to an extent that is influenced by the current discrepancy between the current and normal ratios of inventory stocks to expected sales.

The output equation tests for the United States are reported in Table A.3, while those for the non-US countries are reported in Table A.4. For the United States, four competing models of technical progress are tested. These models are the constant productivity growth model, the constant growth model adjusted for the post-1974 productivity break, the constant growth model adjusted for the effects of increased openness and a declining growth model.[18] Overall, the tests reject the break model, shown by the significant additional information provided by the competing models in the P test, and by the lower C-test coefficients for the break model when it is compared directly with each alternative model. The C-test indicates weak preference for the constant growth model over the model including the effects of increased openness, but it does not provide much guidance in choosing between the constant growth and declining growth models. The Godfrey tests do not support one particular model. For the convergence models reported in this paper, we therefore have chosen the constant model for the United States to derive the non-U.S. technical progress indexes.[19]

To summarize the output equation tests reported in Table A.4, the constant and break models of technical progress are very strongly rejected in favour of either of the convergence models.[20] As between the two convergence models, the model without openness effects is preferred. This suggests that the openness effects are potentially important, but that the current specification does not capture them quite right.[21]

Tables A.5 and A.6 extend the tests to include the derived investment and labour demand equations. These equations show much less power to discriminate among the different models of technical progress. In the case of the investment equations, for which the tests are reported in Table A.5, the F statistics show that none of the four models can simultaneously reject all of the other three. As for the pattern among the models, the catch-up and break models are clearly the worst, and the constant model less clearly the best, with the convergence model with openness effects falling in between. For the derived employment equations, the F statistics show the catch-up model to be the least sufficient of the models, and the catch-up model with openness effects to be slightly better than the constant model, which is preferred to the break model. Although the statistical significance of these results is far less than for the comparisons of the alternative output equations, they do tend to confirm the rejection of the break model, while qualifying the dominance of the convergence models over the model assuming constant technical progress.

3. Issues of Data and Measurement

In this section we emphasize issues of data and measurement, through the use of three sorts of sensitivity test. In section 3.1, we consider the consequences of using PPP rather than market exchange rates, while in section 3.2 we test the effects of adopting alternative measures of the aggregate capital stock in the specification of the aggregate technology. Finally, in section 3.3 we present some preliminary evidence with an alternative production model in which technical progress is embodied in capital via gross investment.

3.1 Exchange Rates and the Convergence of Productivity Levels

In the productivity comparisons of this paper, the OECD 1985-based PPP exchange rates for GDP are used to convert real values (in terms of national currencies at constant prices) into 'international dollars'. What difference would it make if market exchange rates were used instead? The answer to this question depends on the year chosen for the conversion base, since the departures of market exchange rates from PPP differ considerably from year to year. To test the impact of using market rather than PPP exchange rates, we can re-fit the models using market exchange rates for conversion, and then see to what extent the conclusions would differ about the extent to which the convergence model predicts international convergence of income levels, both between the United States and the converging countries as a group, and among the eighteen non-U.S. countries.

Table 3 shows the results of tests of productivity level convergence using the PPP and market rates (for both 1980 and 1985) to convert the real incomes and capital stocks.[22] The top half of the table shows the results of tests of the basic convergence model of Table 1, and the bottom half shows the same tests for the model of Table 2, which includes the productivity effects of increasing trade shares. The Wald test results show that the use of market rather than PPP exchange rates makes the most difference when the specification constrains the convergence models to have the same asymptotic level of productivity in each country. In these cases, there is significantly more evidence of convergence when PPPs rather than 1980 or 1985 market exchange rates are used. This is true for both models assessed, and for comparisons including the United States as well as those among the converging countries outside the United States.[23]

3.2 Alternative Measures of the Aggregate Capital Stock

In this section we test the implications, for the derived equations for the determination of aggregate output, of using alternative measures of the capital stock. In the tests thus far, we have used the aggregate fixed capital stock, including business, housing, and government. In Appendix Table A.8.1 we show the output equations resulting if we instead employ the gross private stock of fixed capital (comprising business and housing), while Table A.8.2 shows the corresponding results using the stock of business fixed capital. As shown by the test comparisons in Table A.8.3, the results, in terms of the goodness of fit of the derived output equations, favour the use of the stock of business fixed capital over the other alternatives, and favour the private capital stock over the total stock.

The implied low contribution of public and housing investment to subsequent levels of real GDP may reflect the nature of the data, as the GDP accounts do not take into direct account the value added by the public capital stock, and the returns to the housing stock are heavily influenced by the assumptions about scrapping rates and the implied ownership return on the stock of owner-occupied housing.

We have also tested capital stock measures that include the stock of inventories along with one or more of the measures of the stock of fixed capital. The results of fitting the output equations using the gross stock of business fixed capital plus total inventories (which are mainly business inventories, including farm stocks) are shown in Table A.8.5. For all three definitions of fixed capital, the models including inventories in the capital stock are inferior, in terms of the derived output equations, to the models based only on the fixed capital stocks.

Table 3
The Effects of Using PPPs versus Market Exchange Rates

Tests of Table 1 model (using 1980 GDP PPPs)	Wald		X^2
(a) Homogeneity of catch-up coefficients	59.64	(17df)	vs 28.0
(b) Constants=0.0	52.94	(18df)	vs 28.9
(c) (a) + (b)	411.73	(35df)	vs 43.8
(d) Constants equal for non-US	47.31	(17df)	vs 28.0
(e) (a) + (d)	400.60	(34df)	vs 43.8
Tests of Table 1 model using 1980 market exchange rates			
(a) Homogeneity of catch-up coefficients	59.64	(17df)	vs 28.0
(b) Constants=0.0	120.17	(18df)	vs 28.9
(c) (a) + (b)	555.21	(35df)	vs 43.8
(d) Constants equal for non-US	116.51	(17df)	vs 28.0
(e) (a) + (d)	510.87	(34df)	vs 43.8
Tests of Table 1 model using 1985 market exchange rates			
(a) Homogeneity of catch-up coefficients	59.64	(17df)	vs 28.0
(b) Constants=0.0	130.07	(18df)	vs 28.9
(c) (a) + (b)	555.20	(35df)	vs 43.8
(d) Constants equal for non-US	128.04	(17df)	vs 28.0
(e) (a) + (d)	511.48	(34df)	vs 43.8

Tests of Table 2 model (using 1980 GDP PPPs)	Wald		X^2
(a) Homogeneity of catch-up coefficients	82.47	(17df)	vs 28.0
(b) Constants=0.0	90.20	(18df)	vs 28.9
(c) (a) + (b)	221.60	(35df)	vs 43.8
(d) Constants equal for non-US	63.92	(17df)	vs 28.0
(e) (a) + (d)	221.60	(34df)	vs 43.8
Tests of Table 2 model using 1980 market exchange rates			
(a) Homogeneity of catch-up coefficients	82.47	(17df)	vs 28.0
(b) Constants=0.0	106.86	(18df)	vs 28.9
(c) (a) + (b)	267.63	(35df)	vs 43.8
(d) Constants equal for non-US	106.55	(17df)	vs 28.0
(e) (a) + (d)	260.75	(34df)	vs 43.8
Tests of Table 2 model using 1985 market exchange rates			
(a) Homogeneity of catch-up coefficients	82.47	(17df)	vs 28.0
(b) Constants=0.0	136.16	(18df)	vs 28.9
(c) (a) + (b)	267.82	(35df)	vs 43.8
(d) Constants equal for non-US	121.29	(17df)	vs 28.0
(e) (a) + (d)	261.63	(34df)	vs 43.8

Note: The chi-square (X^2) statistics in the the above table are approximate.

3.3 Capital-Embodied Technical Progress

The models used thus far assume Harrod-neutral technical progress. The CES production function employed has a near-unitary elasticity of substitution between capital and labour, and hence there is little consequence, in terms of the variance of the synthetic output series, of attributing technical progress to labour rather than capital, so long as the progress accrues equally to new and existing capital. It makes potentially much more difference if one assumes that technical progress accrues only to the new vintages of capital, and hence requires gross investment for its realization. Baily (1981)[24] and others have suggested that the simultaneous post-1973 declines in both gross investment and observed productivity performance, in the aftermath of obsolescence-inducing increases of energy prices indicate the likelihood of capital-embodiment effects. Previous efforts using data for the G-7 industrial countries to look for linkages between gross investment and productivity growth have not been encouraging.[25] We now have comparable data for a much larger sample of countries, so we can try again. To provide a simple comparison between our base case and a capital-embodied vintage model, we compare our constant and convergence cases with an alternative model based on the assumption that all technical progress inheres in new fixed investment. We estimate the rate of such technical progress in just the same way as was done in estimating the country-specific rates of Harrod-neutral technical progress in our constant case. Thus we calculate for each country the rate of investment-embodied technical progress that causes synthetic output from the production function to have the same rate of growth as actual output, averaged over the entire sample period.

When the derived output equations for the capital-embodied model (as shown in Table A.9.2) are compared with those of the basic convergence model (as reported in Table A.7), they show an overall preference for the convergence model, but there is an interesting pattern to the results. For ten European countries, including all of the original members of the EEC, the convergence model is preferred, usually by a substantial margin. For the United States the two models have the same fit (there is, in any case, no convergence in the Table A.7 equation for the United States), and the comparisons are also rather close for New Zealand, Australia, Spain and Sweden. For Norway and Japan, there is an apparent preference for the capital-embodiment hypothesis over the convergence hypothesis. In both countries, the largest growth of productivity were apparently linked to spurts of investment. For Norway, this is probably linked to the offshore oil developments, while for Japan it is more likely based on the addition of modern manufacturing capacity. By contrast, for the main EEC countries, the rapid growth of productivity appears to be more closely linked to the gradual integration of markets, and less tied to the variations in the rate of business investment.

The fact that the same pure vintage model of technical progress is for some countries preferred to the convergence model, and for most countries preferred to the model assuming Harrod-neutral technical progress at a constant rate, suggests that further research would be justified. In particular, it might be possible to generalize the capital embodiment hypothesis by adding some flexibility to the putty-clay assumption,[26] and to experiment with alternative ways of combining convergence with some degree of capital-embodiment.[27]

4. Modelling Business Cycles

Much recent analysis of business cycle fluctuations has made use of a neoclassical growth model with a production structure almost identical to that underlying the productivity analysis of this paper. Most of the real business cycle models surveyed by King, Plosser and Rebello (1988) use an aggregate Cobb-Douglas production function based on fixed capital and efficiency units of labour, with Harrod-neutral productivity growing at a constant expected annual rate. We also make use of the Harrod-neutral productivity assumption, and technical progress at a constant rate is one of the main alternatives we have assessed. In this section we attempt to compare the two approaches.

The main empirical applications of the real business cycle approach have involved the use of autocorrelated technology shocks to generate distributions of key macroeconomic variables, with the aim of seeing to what extent these experimental distributions compare with those of actual data. Although it is theoretically possible to generate autocorrelated movements of output and investment in real business cycle models without autocorrelated technology shocks[28], King, Plosser and Rebello (1988) show that if realistic assumptions are made about the longevity of capital it is necessary to have serially correlated technology shocks in order to generate realistic amounts of persistence in the simulated series for investment, output and employment. The usual assumption made is that of first-order autocorrelation of the technology shocks[29], and that is the form we shall consider here.

A modest generalization of the factor utilization model, using the constant technical progress assumption and adding some dynamic adjustment to the output equation, includes the output sector of the real business cycle model and the constant case of the factor utilization approach as nested special cases. This permits the encompassing principle (Mizon and Richard 1986) to be applied to see whether the general model can be reduced to either of the special cases without significant loss of information.

The generalization required is to add the lagged value of the utilization rate to the estimation of the output equation. Under the assumption of a serially correlated multiplicative technology shock, the previous period's factor utilization rate is the previous period's technology disturbance, and represents all the systematic information available, beyond the stocks of currently employed factors represented by the synthetic production function, to explain current output. If the production function with autocorrelated disturbances is a sufficient explanation of actual output, then the three additional variables reflecting current unexpected or temporary levels of demand, profitability and inventories will add nothing to the explanation of current output. On the other hand, if the dynamics of the actual output decision are as specified in earlier sections, then the lagged dependent variable[30] should not have a significant coefficient.

Table A.10 shows the results of estimating the more general hypothesis in the constant case, while Table A.11 shows the corresponding results for the catch-up case.[31] F-tests of the restricted hypotheses against the more general ones show that the restricted hypotheses are strongly rejected. This means that unexpected demand and cost conditions, with consequential changes in the rate of utilization of employed factors, are likely to be an important part of the cyclical movements in output, and that there are significant dynamics in the response of output to these changes that are not captured by the contemporaneous versions of the output equation tested earlier in this paper.

5. Conclusions

Over the period since 1960, data for nineteen industrial countries show significant evidence of international convergence in the rates of growth of labour efficiency. The evidence is much less strong for eventual convergence of the asymptotic levels of real output attributable to each worker. However, there remain many international differences in natural resources, education levels, and other factors that would justify continuing differences in measured productivity levels.

There is also significant evidence that technical progress has been faster, other things being equal, for countries that have been increasing their openness to international trade. The results also suggest that more work needs to be done to develop better data and theory to explain the linkages between technology transfer and openness to trade and capital movements.

We also found some evidence that capital embodiment may contribute more to productivity growth than our previous research had suggested. Although we found convergence to be more important than embodiment effects, both effects appear to help in explaining international differences of the levels and rates of growth of productivity. When the two are combined in a single model, however, the embodiment effects were not strong.

Our results in favour of the convergence hypothesis should be regarded as provisional, especially as they involve joint tests within a specific model of output determination. Caution is especially appropriate because the tests based on the derived factor demand equations, while being much weaker in their preference rankings, are also less supportive of the convergence models.

Turning to questions of data, we found that the use of PPP exchange rates made some difference to the estimated extent of international convergence in productivity levels. This was clear when the PPP results were compared to results based on the use of either 1980 or 1985 market exchange rates, which differed markedly from PPP rates for many country pairs.

We also found that narrower measures of the capital stock appeared to determine output more closely than broader measures. Further research may help to suggest whether this result is due to greater measurement problems with the stocks of housing and public capital, to problems in measuring and attributing the real output effects of these forms of capital, or to lower marginal returns to these forms of investment. Adding inventories to fixed capital in the synthetic production function tended to worsen the fit of the derived output equations.

Finally, the constant and convergence versions of the factor utilization models estimated in earlier sections were compared to the output sector frequently used in real business cycle models, with both being nested in a more general model. The tests showed significant evidence that the more general model, including the demand and profitability effects of the factor utilization model, and the dynamics of the technology shock model, was to be preferred over either of the more restricted alternatives.[32]

Overall, the importance of the openness effects and the potential importance of capital-embodiment effects supports the recent emphasis in the theoretical literature (Romer 1988, Grossman and Helpman 1989a) on the idea that the rates of generation and diffusion of technical progress are endogenous rather than exogenous variables, and are hence potentially affected by a variety of domestic and international policies.

A final general conclusion, supporting the focus on international data issues, is that the use of comparable data for a substantial number of countries has permitted far stronger tests and results than would be available from the analysis of times series data for one or even several countries.

FOOTNOTES

1. If this knowledge is domestically produced and owned, this implies that levels of per capita real income should diverge rather than converge as time passes, and that growth rates should "be increasing not only as a function of calendar time but also as a function of the level of development." (Romer 1986, 1012) If the external benefits of technical progress are available freely to all those in the national economy, as in the models developed by Romer (1986), and Grossman and Helpman (1989b), then the appropriate scale variable is the level of aggregate total output rather than per capita output.

2. Convergence has also been seen as one of the factors explaining some of the post-1973 slowdown of productivity growth in countries outside the United States, e.g. by Nordhaus (1982), Lindbeck (1983), Maddison (1987), Helliwell, Sturm and Salou (1985), and Englander and Mittelstadt (1988). There is also international evidence of convergence at the industry level, as shown by Dollar and Wolff (1988).

3. Unless market exchange rates alter so as to maintain PPP in level form. Even then, estimates of PPP exchange rates would be required to assure that the exchange rates had indeed moved so as to maintain absolute PPP. In any event, Heston and Summers (1988) show that there are large and systematic departures of market exchange rates from their PPP values, such that market exchange rates consistently fall below PPP values for the poorer countries. Thus international real income comparisons based on market exchange rates overstate the real income differentials between the rich and poor countries, as emphasized by Kravis and Lipsey (1984).

4. Rauch (1989) tests this idea by defining a 'convergence club' of 20 countries that had illiteracy rates below 5% in 1960, and finds much stronger evidence of convergence than for much larger groups of countries. His proposed convergence club based on 1960 literacy levels differs from our sample of 19 industrial countries by excluding Italy and Spain and adding three very small countries (Barbados, Iceland and Luxembourg).

5. Following Ohkawa and Rosovsky (1973), Abramovitz (1986) refers to the factors influencing the ability of a society to benefit from catch-up or convergence as 'social capability', which he roughly approximates by a measure of average years of schooling, combined with consideration of the adaptability of the nation's political, commercial, industrial and financial institutions. Psacharopoulos (1984) reviews various studies of the contribution of education to growth, most of which assume that the contribution is continuous and separable, and not part of the definition of the necessary conditions for a 'take off' (Rostow 1978) for sustained catch-up growth.

6. These possibilities are emphasized by Abramovitz (1986) and De Long (1988).

7. See De Long (1988) and Baumol and Wolff (1988).
8. For example, those reported in Chenery, Robinson and Syrquin (1986) and in section 2 of Helliwell and Chung (1988).
9. The data sources are described in more detail in Appendix I. The PPP exchange rates are the 1985-base calculations (Blades and Roberts 1987), which are collaboratively produced by the national statistical agencies, and based on the U.N. program described in Kravis, Heston and Summers (1978) and Kravis and Lipsey (1989), and on previous OECD efforts reported by Hill (1986).
10. The constant United States trend series is used to derive the technical progress indexes for the convergence models, as outlined in the appendix. We also test several competing models of technical progress against the maintained hypothesis of constant United States growth. These include a declining growth model which tests the possibility, emphasized by Nordhaus (1982), that there also has been a steady decline in the longer run rate of technical progress in the United States, due to the depletion of natural resources and other factors that supported rapid growth in the early part of the sample period. We also test a popular form of this model in which longer-term productivity grows at a slower rate in and after 1974.
11. With a Cobb-Douglas production function, this series only differs by a constant term from the total-factor index of technology often referred to as the Solow residual, based on the influential analysis in Solow (1957).
12. The algebraic form used eliminates the effects of cyclical variance that is common to country i and the United States. Equation (2) differs from the form used in both an earlier version of this paper and in Helliwell and Chung (1988), where the logarithm of the measured productivity index was regressed on its lagged value and a constant growth US trend index, with the coefficients restricted to sum to one. The current form was chosen because the output equations using efficiency indices derived using equation (2) fit somewhat better. The estimated catch-up coefficients are also slightly lower than with our previous specification. An alternative method of adjusting for estimation bias caused by the cyclical variance in the measured series for output attributable to labour, which also gives slower rates of convergence, is reported in Table 3 of Helliwell, Sturm, Jarrett and Salou (1986).
13. Note that since the estimator is iterative Zellner, the r-squares are unbounded. Thus the standard error of the estimate can be greater than the raw standard deviation of the unexplained dependent variable. In any event, the success of the equations explaining the trends in technical progress is not determined by the goodness of fit of the equations explaining measured productivity growth, because of the strong cyclical variance of measured productivity growth, but by the fit of the derived equations for output and factor demands.
14. Tests of an alternative functional form, where the efficiency level was influenced by the level of the trade share, as reported in Helliwell and Chung (1988), produced inferior results.

Following a suggestion by Robert Lipsey, we have also tested a measure of openness based on the residuals from an equation that explains trade shares by country size and a trend, with the latter constrained to have the same coefficient for all countries. The resulting measure of residual openness attracted a positive but insignificant coefficient when added, along with the change in openness, to equation (2), and hence has not been used in our subsequent tests.

15. A catchup model was also subsequently tested which included, as an additional explanatory variable, a separate break term set equal to one from 1974, and zero from 1960 to 1973. The break term was not significantly different from zero when constrained across equations and hence we chose not to pursue this case further.

16. As shown in Helliwell (1986), this formulation is general enough to include the Lucas (1973), Barro (1978) and Keynesian output functions as nested hypotheses. The tests reported there showed that the more general formulation of the factor utilization approach rejected the more restricted models when fitted to data from each of the G-7 economies. Comparisons with the technology shock approach frequently used in real business models will be presented in section 4 of this paper.

17. The use of buffering changes in factor utilization, with recognition that the usage of both labour and capital can be shifted back and forth between direct production and maintenance activities, is also starting to appear in real business cycle models, e.g. Greenwood, Hercovitz and Huffman (1988).

18. The declining growth model uses a trend which declines by 30% (as described in the Appendix). The 30% declining growth model produced the output equation with the best fit when several alternative rates of decline were tested. Compared with the constant growth model which has an efficiency index that grows at .73% throughout the sample, the 30% declining growth model produces a U.S. efficiency index that grows at an average rate of .81% for the period 1961-73, .67% for the period 1974-85, and .54% for the period 1985-2000.

19. Tests of convergence assuming a 30% declining growth model for the United States indicated that the output equations for the non-U.S. group of countries prefer the declining growth model. These new tests thus provide further support for one surprising feature of our earlier results: that most countries outside the United States show evidence of a convergence process that is projected to leave non-U.S. productivity levels below, and sometimes well below, those in the United States. Post-1985 data will help to show whether this is a continuing feature of the evidence, or due to the widespread recessions in the first half of the 1980s.

20. A declining growth model for all countries was later tested to examine whether there has been a steady decline in the longer run rate of technical progress as suggested by Nordhaus (1982). The 30% declining trend was used, as this trend was favoured for the United States. The C-tests of the non-US output equations

indicated that both convergence models were strongly preferred to the declining growth model, and that the declining growth model was preferred to the constant growth and 'break' models. Thus for the current data sample, the non-US countries generally prefer some slowdown as evidenced by the relatively good performance of the convergence and declining growth models. Although our current results show that the convergence models contain more information than the declining growth model, they also warrant further investigation, using models with possibly a broader range of targets for convergence and estimated over a longer sample period.

21. A supplementary test of the output equations using the two convergence models was also done and this showed the pure catch-up model to only slightly out-perform the model with openness effects. The investment and employment equations estimated under each model were used to derive predicted values for the factor demands. The predicted capital stock and employment series were then placed in the CES production function to calculate an alternative normal output (q_s) series for each country, and the output equations were re-estimated as before. C-tests of these new output equations showed that the catchup model with openness effects was only marginally inferior to the pure catchup model. These results thus illustrate the potential importance of the former model given the superior fit of its estimated factor demands.

22. Heston and Summers (1988, p. 471) note that PPPs for investment goods can be materially different from those for GDP, so that we should in principle be using different PPPs for converting the real capital stocks into international dollars. Tests of this alternative have not yet been carried out.

23. These results differ from those that appeared in an earlier version of this paper which used a level form for the dependent variable in equation (2). In the earlier version, there appeared to be significantly more convergence of both rates of growth and levels when PPPs rather than 1985 exchange rates were used. The differences were also less marked when 1980 market exchange rates were used for comparison.

24. Baily emphasizes the reduction in capital services per measured unit of capital, because of increased obsolescence due to changes in energy prices and other changes in market opportunities and regulations. This implies that capital is not malleable ex post, and, other things equal, that technical progress will be faster the higher is that rate of gross investment, and hence the rate at which new techniques and current relative prices are embodied in the capital stock.

25. Some earlier attempts to test for these effects using data for the G-7 countries revealed no apparent link between gross investment rates and the growth of the capital-adjusted productivity measure used in this paper. See Helliwell, Sturm, Jarrett and Salou (1986, 91-95). However, cross-sectional evidence reviewed by Englander and Mittelstadt (1988), covering seventeen countries, suggests that capital accumulation may have

more impact on productivity growth than would be consistent with Harrod-neutral technical progress.

26. For example, in Helliwell, Sturm and Salou (1986), a putty/semi-putty model for energy/capital substitution was developed, wherein an estimated fraction of the existing capital stock was able to be retrofitted to employing the same optimal energy/capital ratio being built into new investment.

27. Our tests of convergence models containing capital-embodiment effects have so far not produced strong embodiment results. The tests were done by adding the logarithm of the smoothed ratio of gross investment to gross domestic product divided by the United States smoothed investment ratio to the basic catch-up model. When the embodiment variable was constrained to be the same across countries it had a positive (.0213) but insignificant coefficient (t=1.40).

28. e.g. Long and Plosser (1983).

29. Examples include Kydland and Prescott (1982) and Hansen (1985).

30. Adding the lagged factor utilization rate is equivalent to adding the lagged dependent variable under the maintained hypothesis that the log of synthetic output is constrained to have a unit coefficient in the equation for the log of output.

31. In both cases, the inventory gap coefficient is constrained to have the same value for all countries.

32. This is in line with the real business cycle research agenda proposed by Plosser (1989, pp. 70-1), who emphasizes the need to study the source characteristics of the 'technology shocks', and to undertake systematic comparisons of alternative approaches.

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APPENDIX I - DATA SOURCES

List of Variables and Parameters

Variable		Description
a		Real absorption, billion 1980 currency
c		Real personal consumption expenditures, billion 1980 currency
e_r		Exchange Rate, US dollar per domestic currency
g		Real government current and capital expenditures on goods and services, billion 1980 currency
i		Real total fixed investment, billion 1980 currency
ib		Real business fixed investment, billion 1980 currency
ip		Real private fixed investment, billion 1980 currency
i_{inv}		Real value of physical change in inventories, billion 1980 currency
k		Real total gross fixed capital stock, billion 1980 currency
kb		Real business gross fixed capital stock, billion 1980 currency
kp		Real private gross fixed capital stock, billion 1980 currency
k_{inv}		Real stock of inventories, billion 1980 currency
m		Real imports of goods and services, billion 1980 currency
N		Total employment, millions of persons
N_{pop}		Total population of labour force age, millions of persons
p_a		Implicit price of absorption, 1980=1.0
p_{gdp}		GDP deflator, defined as ratio of nominal GDP to real GDP
p_k		Price of capital services
p_m		Price of imported goods and services, 1980=1.0
p_q		Implicit price for gross domestic output, 1980=1.0
p_x		Price of exports of goods and services, 1980=1.0
q		Real gross output (at factor cost), billion 1980 currency
q_s		Real synthetic supply, billion 1980 currency
r		Average interest rate, annual percent
r_l		Average yield on government bonds, 10 years and over, percent
r_s		Average yield on government bonds, 1-3 years, percent
t		Time; 1960 = 1, 1961 = 2, etc.
T_i		Total indirect taxes less subsidies, billion currency
W		Wage rate, thousands of dollars per year per employed person
x		Real exports of goods and services, billion 1980 currency
y		Real Gross National Product, billion 1980 currency
δ_1		Scrapping rate for capital stock (including housing)
Π		Labour productivity index for Harrod-neutral technical progress in CES function for q
ρ_r	Estimated parameter	Real supply price of capital

τ	Estimated parameter	Elasticity of substitution between labour and capital in the CES function
μ	Estimated parameter	Distribution parameter in the CES function
ν	Estimated parameter	Distribution parameter in the CES function

[Units exceptions to those specified above are for Japan and Italy. Data for these two are in trillions, demographic data are in billions, while wages remain in thousands.]

Data Sources:

Data for this study were taken from:
IMF International Financial Statistics
OECD, Flows and Stocks of Fixed Capital, 1960-85
OECD Standardized National Accounts [SNA], VOL I & II
OECD 1984, 1986 and 1987 INTERLINK supply block tapes for G7 countries
OECD 1987 supply block tape for the smaller OECD countries
Sample period : 1960-85

Most of the supply block data for this study can be derived from the OECD National Accounts (denoted by SNA) as indicated below.

Square brackets indicate source and data mnemonic.
Note that $ is used to denote domestic currency.
YGDP= GDP in current $ billion [SNA GDP]
PGDP= GDP deflator (1980=1.00) [SNA GDPE/GDPEV]
I=Private, housing and government investment in 1980 $ billion [SNA GF]
IB=Business investment=I-IG-IH
IG=Government investment [SNA Vol. II and OECD87 for smalls]
IH=Housing Investment [SNA Vol. II and OECD87 for smalls]
IP=Private investment=I-IG
A=Absorption in 1980 $ billion [SNA PC+GF+GC]
PA=Absorption deflator (1980=1.00) [SNA A/(PCV+GFV+GCV)]
C=Private consumption in 1980 $ billion [SNA PC]
G= Govt. expenditures in 1980 $ billion [SNA GC]
IINV=Change in inventories in 1980 $ billion [SNA STV]
TI=Indirect taxes less subsidies in current $ billion [SNA ITX-SUB]
N=Total employment, million of persons [OECD86,OECD87 ET]
W=Average annual wage ('000S of $ per employed person per year) [OECD86, OECD87 (WSSE*EE+CGW)/(EG+EE)]
X=Exports of goods and services in 1980 $ billion [SNA EXPV]
PX=Price of exports (1980=1.00) [SNA EXP/EXPV]
ER=Exchange Rate [IFS]
RS=Short-term nominal interest rate [Can. Dept. of Finance and IFS 60]
RL=Average yield of long-term govt. bonds (%) [Can. Dept. of Finance and IFS 61]
R=Average interest rate=.5*RS+.5*(RL-1+RL-2+RL-3)/100/3
XIY=Total investment income receipts from abroad in current $ billion [SNA FIFW]
MIY=Total investment income payments to foreigners in current $ billion [SNA FITW]
M=Imports of goods and services in 1980 $ billion [SNA IMPV]
PM=Price of imports (1980=1.00) [SNA IMP/IMPV]

NPOP = Total population (millions of persons) [IFS and SNA]
RSCR = Scrapping rate [OECD84 RSCRB and OECD87 for smalls]
KS = Kickoff value for capital stock in 1980 $ billion [see below]
KINVS = Kickoff value for inventory levels in 1980 $ billion [for G7 OECD86 STOCKV, for smalls an approximation of .06*K (1960) was used]
Q = (YGDP−TI)/PGDP Real gross output
Y = YGDP/PGDP + XIY/PGDP−MIY/PGDP Real gross national product

The wage and employment data for both the G7 and smalls were derived from INTERLINK supply block data supplied by the OECD.

Capital stock series:

For the G7 countries, total capital stocks were generated from base (1959) kick-off values (KS). For each year, the previous year's stock was added to new investment after allowing for some portion which is scrapped off i.e., K(t) = (1−RSCR)K(t−1) + I. The KS data were taken from the OECD84 tape for the G7 countries and it is the kick-off value for the total gross stock series. In the case of Japan, however, data were available only from 1966; some extrapolation was done to get the 1960 total capital stock as the kick-off value. Business capital stocks were the KBV series from the OECD86 tape, rebased to 1980$ where applicable. For Japan, data were available only from 1966; extrapolating backwards using the formula KBV(t) = (1−RSCRB)KBV(t−1) + IBV (RSCRB is business scrapping rate; IBV is business investment), the business capital stock was estimated for 1960–65. A business scrapping rate of 4.15% per year was assumed for the 1960–65 period, to approximate the rate of 4.197% in 1966, the first year when data were available. In the case of France, the business capital stock series was built up using a kick-off value of 2138.2 billion francs in 1960 and RSCRB from the OECD86 tape. This kick-off value is obtained from OECD, Flows and Stocks of Fixed Capital. Private capital stocks were generated the same way as total capital stocks, using a base (1960) kick-off value and business scrapping rate. As no data are readily available on private capital stocks, the kick-off stock is estimated based on the assumption that the 1960–69 average ratio of private investment to business investment applies to the stock ratio. For example, for the U.S., private investment was 165% of business investment in the 1960s. This ratio was applied to business capital stock of $2251.6 billion in 1960 to get $3722.2 billion as the kick-off value for private capital stock.

For the 12 smaller industrial countries, business capital stock data were readily available from the OECD87 supply block tape, with those for Austria, New Zealand and Switzerland having to be rebased to 1980$.

The OECD87 tape has data on government, business and housing investments. These data were compared with corresponding data available from OECD SNA, Volume II and updated/revised where necessary. The private investment series was then generated as the sum of business and housing investments, (IPV = IBV + IHV). From this, the 1960s average ratio of private investment to business investment was applied to the stock ratio to derive the kick-off private capital stock in 1960, as in the case with the G7 countries. The private capital stock series was then generated for each of the 12 smaller industrial countries, using business scrapping rate to approximate the scrapping rate for private capital stock. (The RSCRB data were available from the OECD87 tape. For some countries, however, estimates had to be made for the earlier years, particularly 1960 and 1961.) In the same way, a government capital stock series was generated, which was then added to private capital stock to get the total capital stock series.

The inventory stock series was calculated using the equation KINV = KINV−1 + IINV, with KINVS being the base kick-off value.

The 1980 GDP Purchasing Power Parities are obtained from the OECD Annual National Accounts: Main Aggregates computer tape (July 1988). They are available for the full sample of 19 countries examined in this paper. The values used are: USA 1.00; JAP 258.51; CAN 1.149; FRA 5.941; GER 2.702; ITA 866.974; UKM 0.517; ASL 1.042; OST 16.626; BEL 42.918; DEN 8.517; FIN 5.022; IRE 0.543; NET 2.734; NZL 1.004; NOR 7.334; SPA 70.554; SWE 6.888; SWI 2.449.

Table I.1
The Ratio of Market Exchange Rates to GDP PPPs:

	1980	1985
usa	1.000000	1.000000
jap	0.8771030	1.074504
can	1.017599	1.119246
fra	0.7112601	1.235930
ger	0.6727126	1.187086
ita	0.9878616	1.466543
ukm	0.8322910	1.371914
aus	0.8426105	1.154839
ost	0.7781757	1.246373
bel	0.6813535	1.331365
den	0.6617346	1.081227
fin	0.7427306	1.038193
ire	0.8968693	1.308438
net	0.7271399	1.302353
nzl	1.022908	1.498520
nor	0.6734392	0.9961731
spa	1.016243	1.784251
swe	0.6141105	1.055706
swi	0.6843606	1.016550

Note: Market exchange rates are defined as domestic currency per US dollar.

APPENDIX II - SPECIFICATION AND RESULTS

(I) Modelling Labour Productivity:

The CES two factor production function which defines normal output q_s is:

$$q_s = [\mu(\Pi N)^{(\tau-1)/\tau} + \nu k^{(\tau-1)/\tau}]^{\tau/(\tau-1)} \qquad (1).$$

The following will first discuss the procedure used to derive expressions for the country-specific parameters ν, μ and Π. The final values of these parameters depend on the value of τ, the elasticity of substitution between labour and capital, which is determined iteratively. The iteration method used to calculate τ will be examined last.

(1) can be rewritten by setting $q=q_s$ and by isolating the following expression for Π:

$$\Pi = [(q^{(\tau-1)/\tau} - \nu k^{(\tau-1)/\tau})/(\mu N^{(\tau-1)/\tau}]^{\tau/(\tau-1)} \qquad (2).$$

(2) is used to obtain an expression for the parameter ν. First the optimum factor ratio is derived. The partial derivatives of (1) with respect to labour and capital are first calculated and set equal to the prices W and p_k. Assuming the factor ratio is optimal provides the following ratio:

$$\Pi N^*/k^* = (p_k \Pi/w)^{\tau}(\mu/\nu)^{\tau} \qquad (3).$$

where the price of capital services is:

$$p_k = (<\delta_2>+0.01\rho_r)p_a$$

and where $\rho_r = 100<1-(WN + <\delta_2>\bar{k}p_a)/(qp_q)>/<(\bar{k}p_a)/(qp_q)>$

so that the ratio of factor costs to revenues is unity, on average (as $<x>$ denotes the sample average of x).

(2) is substituted into (3). The parameter μ drops out and can be determined empirically when Π is normalized, as shown below. The parameter ν is isolated in the substituted equation and sample averages are taken to provide the following expression:

$$\nu = <(p_k/W)(q/N)^{(\tau-1)/\tau}>/[<(N/k)^{1/\tau}> +$$

$$<(p_k/W)(k/N)^{(\tau-1)/\tau}>] \qquad (4).$$

Note that we normalizing so that the sample average of the ratio of the factors raised to the $1/\tau$ power is equal to the average for optimum proportions.

The value of Π, the labour productivity index for Harrod-neutral technical progress, is derived by the following procedure. Output attributable to labour is defined by rewriting (2):

$$\mu\Pi^{(\tau-1)/\tau} = (q^{(\tau-1)/\tau} - \nu k^{(\tau-1)/\tau})/N^{(\tau-1)/\tau} \quad (5).$$

In the constant growth model, the technical progress index is modelled to grow at a constant rate. The model is estimated by ordinary least squares by regressing the logarithm of the measured efficiency level which is the logarithm of the value provided by (5), referred to as $\ln \pi_{mi}$, for country 'i', on an annual time index. Given the final value of τ, the fitted values $\ln \hat{\pi}_i$, can be estimated for each year. Using the latter, the value of μ is calculated by setting $\Pi_i = 1.0$ in 1980. Given that the value of μ is constant throughout the sample period, the labour efficiency index Π_i is defined simply as the exponent of $\ln \hat{\pi}_i$ minus 1980 $\ln \hat{\pi}_i$, which ensures it has a value of 1 in 1980.

In the second model, the growth of technical progress in the non-US countries is assumed to 'catch-up' to the US rate of growth. This is modelled by regressing $d\ln(\pi_{mi}/\pi_{mus})$, where π_{mi} is the measured productivity index for country 'i' and π_{mus} is the measured value for the US, on $\ln(\pi_{mus}/\pi_{mi-1})$. The fitted values $\ln \hat{\pi}_i$ are then calculated by multiplying the estimated regression parameters by the right hand side variables (the exception being the measured US index which is replaced by the smoothed US constant trend series $\hat{\pi}_{us}$). The series $\hat{\pi}_i$ is then used to derive the non-cyclical technical progress index Π_i, as was done for the constant case. In the third model, in order to allow for the effects of globalization on the model, we include the variable DOPENA along with the catch-up variables in the non-US equations. DOPENA is the annual change in "openness" defined as the log difference of current and lagged values of the five year moving average of exports plus imports divided by GNP. The values of the CES parameters are derived in a similar way to the constant case, using the fitted values of the catch-up case, $\ln \hat{\pi}_i$. The fourth model tests the 'break' hypothesis. The technical progress index is modelled with a constant time index, but includes an additional index starting in 1974. If the latter index is negative, there is some evidence for the hypothesis that there was general reduction in the underlying rate of productivity growth starting in 1974. The last model assumes declining growth, and is modelled by regressing $\ln \pi_{mi}$ on a 30% declining trend which straightforwardly replaces the single time trend for the constant case. The declining trend takes on values such if the step from the first period to second is 1.0, then the step from the next-to-last to last period is only 0.7 (i.e., the rate of growth has declined by 30% over the 25 year sample).

Finally an estimate of τ is needed to derive final values of the above parameters. The iterative procedure uses the expression for the optimum factor ratio, (3). The log of this equation provides the following form that can be estimated:

$$\ln(\Pi N^*/k^*) = \tau \ln(\mu/\nu) + \tau \ln(p_k \Pi/W) \quad (6).$$

τ is the coefficient of the inverse price ratio. An arbitrary value of τ is used to define μ, ν, and Π. (6) is then estimated by ordinary least squares and the estimated coefficient provides a new value of τ, which is used to redefine the other parameters in the next round. The process is repeated until the value of τ in (6) converges. This value is used to obtain the final values of μ, ν, Π and normal output, q_s. For our final estimates, a variant of equation (6) was used in which the lagged capital labour ratio was included along with cyclical demand and profitability variables (outlined in Helliwell and Chung 1986) as right hand side variables. The latter were included since the factor share ratio has, in addition to its responsiveness to relative prices, a cyclical variance caused by the fact that labour adjusts more quickly than the capital stock to changes in desired output. The distributed lag response on the relative price term (which tends to produce a higher estimated equilibrium elasticity of substitution) also provides more reasonable elasticities across countries.

In the pooled estimation, we use an average of the country-specific τ and ν (with value of .99 for τ) thus providing common production function parameters. The econometric technique used to estimate the productivity equations is Zellner's seemingly unrelated regression technique, since there is significant evidence of cross-country correlation of the error terms. The systems of equations are estimated with the Generalized Least Squares procedure, although the iterative procedure for the covariance matrix of residuals across equations is not used.

(II) <u>Output, Investment and Employment:</u>

The following provides a brief description of the specification of the equations used in the non-nested tests reported in the tables.

(i) The Output Equation:

We follow the 'factor utilization' approach outlined in Helliwell and Chung (1986). The rationale for explicitly modelling factor utilization rates lies in the observation that factors of production are quasi-fixed. That is, it is costly for firms to adjust the levels of inputs in response to short-run changes in demand and cost conditions. Consequently, temporary fluctuations in demand are met by varying the intensity of factor use - working the inputs harder or less hard - or, in other words, by changing the factor utilization rates.

One difficulty with this approach is that factor utilization rates are not directly observable. In particular, we have no idea what constitutes a "normal" factor utilization rate. A simple way round the problem is to define the utilization rate as the ratio of actual to normal output and to form suitable proxies for the demand and cost conditions. When the proxy variables are at their normal values- the sample averages- then we have a normal rate of factor utilization.

The output equation thus has the following specification:

$$\ln q = \ln q_s + beta^* \ln sgap + beta1^* \ln cq + beta2^* \ln igap + e$$

where sgap is the ratio of sales to normal sales, igap is the ratio of desired to lagged actual inventories and cq is the ratio of current unit cost relative to output price (an inverse measure of profitability). Normal sales is defined as $<s/q_s>^* q_s$ and desired inventories is $<kinv{-}1/q_s>^* q_s$, where kinv is inventory stock. The sample averages ensure that the means of sgap, igap and cq are 1, which ensures 'normal' utilization rates on average.

(ii) Investment Equation:

The equation explains fixed investment as a fraction of the corresponding capital stock, with the lagged ratio entering the equation to enrich the distributed lag response. Driving the investment equation is the gap between desired and the actual capital stock $(k^* - \bar{k})/\bar{k}$. The desired k^* is derived as follows. First, define a level of output (q^*) which is the expected desired output for firms. We define $q^* = q_a^*(q/q-2)$, where q_a is aggregate demand (output minus unintended change in inventories). The time horizon implicit in q^* is thus two years. Given our CES production function, the level of desired output is used in the long-run production function to determine the levels of capital and labour that would minimize costs if future relative prices were the same as those currently prevailing. Analytic expressions for k^* and N^* are thus easily obtained:

$$k^* = [\nu+\mu^\tau(\Pi p_k/w\nu)^{\tau-1}]^{\tau/(1-\tau)} q^*$$

and

$$N^* = (1/\Pi)[(q^{*(\tau-1)/\tau} - \nu k^{*(\tau-1)/\tau})/\mu]^{\tau/(\tau-1)}$$

Lastly we include cq. This attempts to capture financial market conditions by defining profitability as the ratio of current unit operating costs to the current output price, where the numerator includes a rental charge of capital which varies with the long-term nominal interest rate.

(iii) Employment Equation:

The employment equation describes a partial adjustment to the two year forward looking demand for labour (N^*). The employment equation follows a simple adaptive adjustment, with right hand side variables, lagged and desired employment levels, constrained to sum to one.

Table A.1

The Constant Model of Technical Progress

	RTIME	CONSTANT	SEE	R2	DURBIN WATSON
USA	0.0072 (6.70)	33.4020 (423.48)	0.0414	0.6331	0.3284
JAP	0.0408 (14.46)	30.2260 (147.11)	0.1078	0.8894	0.1356
GER	0.0295 (24.41)	31.1750 (354.14)	0.0462	0.9582	0.2292
FRA	0.0371 (20.33)	30.6200 (229.90)	0.0699	0.9408	0.0876
UKM	0.0170 (17.27)	31.9880 (445.85)	0.0376	0.9198	0.5007
ITA	0.0350 (14.47)	30.7230 (174.47)	0.0924	0.8896	0.1311
CAN	0.0193 (16.53)	32.2570 (379.93)	0.0445	0.9131	0.2151
AUS	0.0164 (15.50)	32.2880 (417.60)	0.0406	0.9024	0.4871
OST	0.0338 (21.16)	30.7010 (263.30)	0.0612	0.9451	0.1297
BEL	0.0316 (26.16)	31.1250 (353.71)	0.0462	0.9634	0.2327
DEN	0.0237 (18.41)	31.4890 (335.75)	0.0492	0.9287	0.3029
FIN	0.0327 (27.24)	30.6430 (350.52)	0.0459	0.9661	0.3588
IRE	0.0367 (27.82)	30.2820 (314.71)	0.0505	0.9675	0.5218
NET	0.0296 (22.60)	31.4430 (329.66)	0.0500	0.9516	0.2528
NZL	0.0018 (1.34)	33.4420 (334.86)	0.0524	0.0645	0.4934
NOR	0.0251 (33.25)	31.4520 (572.53)	0.0288	0.9770	0.6848
SPA	0.0423 (24.16)	30.1740 (236.40)	0.0670	0.9573	0.2139
SWE	0.0174 (13.75)	32.0350 (348.41)	0.0482	0.8792	0.3070
SWI	0.0163 (11.52)	32.3790 (313.38)	0.0542	0.8361	0.1858

Note: The dependent variable is ln πm, measured output attributable to labour. RTIME is an annual time trend equal to 60 in 1960, 61 in 1961. See the section on specification in Appendix II for a more complete description. Estimation was by SUR using sample 1960-1985.

Table A.2

The 'Break' Hypothesis

	RTIME	T74	CONSTANT	SEE	R2	DURBIN WATSON
USA	0.0163	-0.0071	32.8140	0.0280	0.8318	0.6124
	(9.11)	(5.54)	(276.22)			
JAP	0.0657	-0.0196	28.6030	0.0675	0.9566	0.5292
	(15.25)	(6.35)	(99.92)			
GER	0.0362	-0.0053	30.7360	0.0402	0.9683	0.3431
	(14.13)	(2.89)	(180.36)			
FRA	0.0477	-0.0083	29.9300	0.0601	0.9563	0.2098
	(12.46)	(3.03)	(117.52)			
UKM	0.0192	-0.0017	31.8430	0.0369	0.9230	0.5021
	(8.17)	(1.04)	(203.59)			
ITA	0.0515	-0.0130	29.6450	0.0736	0.9299	0.3602
	(10.97)	(3.87)	(94.98)			
CAN	0.0230	-0.0029	32.0150	0.0427	0.9200	0.2345
	(8.43)	(1.50)	(176.67)			
AUS	0.0247	-0.0065	31.7510	0.0295	0.9482	1.0096
	(13.10)	(4.80)	(253.52)			
OST	0.0410	-0.0056	30.2360	0.0562	0.9536	0.2443
	(11.42)	(2.18)	(126.81)			
BEL	0.0371	-0.0044	30.7620	0.0422	0.9694	0.3152
	(13.80)	(2.27)	(172.01)			
DEN	0.0337	-0.0078	30.8400	0.0359	0.9620	0.7215
	(14.68)	(4.77)	(202.34)			
FIN	0.0390	-0.0049	30.2320	0.0406	0.9734	0.4968
	(15.03)	(2.67)	(175.42)			
IRE	0.0346	0.0017	30.4220	0.0500	0.9682	0.5372
	(10.85)	(0.74)	(143.60)			
NET	0.0352	-0.0044	31.0770	0.0463	0.9585	0.3985
	(11.92)	(2.09)	(158.30)			
NZL	0.0062	-0.0034	33.1610	0.0503	0.1366	0.6051
	(1.92)	(1.47)	(155.37)			
NOR	0.0262	-0.0009	31.3770	0.0286	0.9774	0.7505
	(14.39)	(0.69)	(259.13)			
SPA	0.0514	-0.0071	29.5820	0.0595	0.9663	0.3745
	(13.53)	(2.63)	(117.18)			
SWE	0.0258	-0.0066	31.4840	0.0389	0.9215	0.7236
	(10.40)	(3.74)	(190.91)			
SWI	0.0287	-0.0097	31.5770	0.0348	0.9324	0.9470
	(12.90)	(6.08)	(213.86)			

Note: The dependent variable is ln πm, measured output attributable to labour. RTIME is an annual time trend equal to 60 in 1960, 61 in 1961. T74 is a time trend equal to zero before 1974 and equal to 1 in 1974, 2 in 1975. See the section on specification in Appendix II for a more complete description. Estimation was by SUR using sample 1960-1985.

Table A.3
Non-Nested Tests of US Output Equations

The following models of labour productivity were estimated and tested using non-nested tests of the US output equations. H0 denotes the maintained hypothesis, which is tested against the competing models. The output equations were estimated by two stage least squares over the sample 1963-1985 for all models. See Appendix for variable definitions.

Case 1: H0: Constant case: $\ln \pi_m$=a1*RTIME+c
H1: Break case: $\ln \pi_m$=a1*RTIME+a2*T74+c
H2: Open case: $\ln \pi_m$=a1*RTIME+a2*DOPENA+c
H3: Decline Case: $\ln \pi_m$=a1*DECLINE+c

Case 2:	Case 3:	Case 4:
H0: Break	H0: Open	H0: Decline
H1: Constant	H1: Constant	H1: Constant
H2: Open	H2: Break	H2: Break
H3: Decline	H3: Decline	H3: Open

P TEST

(Note: Because of collinearity between H1 and H2, each hypothesis was tested in separate regressions for case 2)

T-statistics: (* indicates significance at the 95% level)

	Case 1	Case 2	Case 3	Case 4
H1	.06278	2.5821*	1.07290	1.07720
H2	.45623	2.3831*	.05634	.06300
H3	.97296	2.5174*	.96835	.45631

F-Statistics: (* indicates rejection of the null hypothesis at 5% significance)

	Case 1	Case 2	Case 3	Case 4
H1=H2=H3=0 (3,16) df	.43854		.67419	.55073
H1=0.0 (1,16) df	.00394	6.66713* (1,18) df	1.15102	1.16027
H2=0.0 (1,16) df	.20814	5.67904* (1,18) df	.00317	.00397
H3=0.0 (1,16) df	.94665	6.33743* (1,18) df	.93769	.20822

C TESTS

	Coefficient	T-Ratio		Coefficient	T-Ratio
CASE 1	.75144	2.71	CASE 1	5.29500	1.04
CASE 2	.24856	.90	CASE 4	-4.29500	.84
CASE 1	.83329	1.42	CASE 2	.26871	.98
CASE 3	.16671	.28	CASE 4	.73129	2.66
CASE 2	.37684	1.61	CASE 3	.20768	.34
CASE 3	.62316	2.66	CASE 4	.79232	1.29

Table A-3 (cont'd)

GODFREY TEST

	CASE 1	CASE 2	CASE 3	CASE 4
H1	.4383	1.5259	.38028	.41335
H2	1.5333	1.0676	.44562	.48691
H3	.2668	1.4982	.56077	1.63110

TEST METHODS:

(1) P TEST:

Following Davidson and MacKinnon (1981), the following procedure was used. Given two alternative models:

H0: Yt=ft(Xt, Beta)+e0t

H1: Yt=gt(Zt, Gamma)+e1t

The following artificial regression can be estimated for the P test:

Yt - fht = b*Xt + lambda*(ght-fht)

where fht and ght denote the fitted values based on H0 and H1. The t-ratio for lambda is the P test. If it is significant H0 is rejected and if insignificant H0 is not rejected. In cases 1 and 3 above H0 was tested against more than one alternative hypothesis at a time, with joint F-statistics reported to test whether H1 and H2 are zero.

(2) C TEST:

Again following Davidson and MacKinnon (1981), the C test involves estimating the following regression:

Yt=alpha*fht+(1-alpha)*ght

where fht and ght are the fitted values of yt from the two competing models. If alpha is greater than (1-alpha) and is significant, then fht is the dominating model.

(3) GODFREY TEST:

The statistics are derived using Godfrey's (1983) test of competing non-nested models estimated by an instrumental (IV) estimator (e.g., two stage least squares). Let the two models be:

H0: Yt=ft(Xt, Beta)+e0t

H1: Yt=gt(Zt, Gamma)+e1t

Let W be the set of exogenous variables included in the 2SLS estimation. We first estimate H0 and H1 by 2SLS and obtain the sample values of b and c (the 2SLS estimates of Beta and Gamma given W). We calculate the OLS predicted values Xht and Zht from the regression of X and Z on W. We then obtain the residual vector from the OLS regression of Xht*b on Zht and add it as an independent variable in the regression of the maintained hypothesis. The table reports the t-statistic for the variable. If it is significant it indicates that H1 adds significant explanatory power to H0 and it implies the rejection of the null hypothesis against H1.

Table A.4

Non-Nested Tests of Output Equations for the Industrial Countries

The following models of labour productivity were estimated and tested using non-nested tests of the output equations for the 19 industrial countries. For all non-break models, the constant case is used for the US. In the break case, the break model is used for US and non-US models, consistent with the hypothesis that the productivity slowdown was a feature of all the industrial countries. In the tests below, H0 denotes the maintained hypothesis, which is tested against the competing models. The output equations were estimated by Zellner seemingly unrelated regression technique with instrumental variables, using the sample period 1963-1985 for all models.

Case 1: H0: Pure Catchup case: $d\ln(\pi_m/\pi_{mus})$=a1*$\ln(\pi_{mus}/\pi_{m-1})$+a2
H1: Catchup with openness: $d\ln(\pi_m/\pi_{mus})$=a1*$\ln(\pi_{mus}/\pi_{m-1})$+a2*DOPENA+a3
H2: Constant Case: ln π_m=a1*RTIME+a2
H3: Break Case: ln π_m=a1*RTIME+a2*T74+a3

Case 2: H0: Catchup/open
H1: Pure Catchup
H2: Constant
H3: Break

Case 3: H0: Constant
H1: Catchup
H2: Catchup/open
H3: Break

Case 4: H0: Break
H1: Catchup
H2: Catchup/Open
H3: Constant

P TEST

T-statistics: (* indicates significance at the 95% level)

	Case 1	Case 2	Case 3	Case 4
H1	2.66*	4.86*	4.96*	5.09*
H2	.54	.66	2.38*	2.24*
H3	.29	.58	.78	.45

F-Statistics: (* indicates rejection of the null hypothesis at 5% significance)

	Case 1	Case 2	Case 3	Case 4
H1=H2=H3=0 (3,430) df	3.08*	8.42*	77.79*	91.44*
H1=0.0 (1,430) df	7.07*	23.58*	24.61*	25.86*
H2=0.0 (1,430) df	.29	.43	5.64*	5.04*
H3=0.0 (1,430) df	.08	.34	.60	.21

Table A-4 (cont'd)

	Coefficient	C TESTS T-Ratio
MODEL 1	.70399	5.94
MODEL 2	.29601	2.50
MODEL 1	1.08540	15.04
MODEL 3	-.08540	1.18
MODEL 1	1.06690	16.31
MODEL 4	-.06690	1.02
MODEL 2	.85986	13.80
MODEL 3	.14014	2.25
MODEL 2	.86829	15.14
MODEL 4	.13171	2.30
MODEL 3	.80523	5.33
MODEL 4	.19477	1.29

MODEL 1=PURE CATCHUP, MODEL 2=CATCHUP WITH OPENNESS,
MODEL 3=CONSTANT, MODEL 4=BREAK

TEST METHODS:

(1) P TEST:

Following Davidson and MacKinnon (1981), the following procedure was used. Given two alternative models:

H0: Yit=fit(Xt, Beta)+e0it (where i (=1,m) indexes equations and

H1: Yit=git(Zt, Gamma)+e1it t (=1,n) indexes observations)

The following artificial regression can be estimated for the P test:

Yit - fhit = b*Xit + lambda*(ghit-fhit)

where fhit and ghit denote the fitted values based on H0 and H1. The t-ratio for lambda is the P test. If it is significant, H0 is rejected and if insignificant H0 is not rejected. In the results above H0 was tested against more than one alternative hypothesis at a time, with F-statistics reported to test whether H1, H2 and H3 are zero.

(2) C TEST:

Again following Davidson and MacKinnon (1981), the C test involves estimating the following regression:

Yit=alpha*fhit+(1-alpha)*ghit

where fhit and ghit are the fitted values of yt from the two competing models. If alpha is greater than (1-alpha) and is significant, then fit is the dominating model.

Table A.5
Non-Nested Tests of Investment Equations for the Industrial Countries

The investment equations were estimated by Zellner seemingly unrelated regression technique with instrumental variables, using the sample period 1963-1985 for all models. The models of labour productivity are identical to those outlined in Table A.4.

P TEST

T-statistics: (* indicates significance at the 95% level)	Case 1	Case 2	Case 3	Case 4
H1	2.63*	2.14*	2.62*	2.60*
H2	3.89*	3.90*	3.89*	3.90*
H3	1.24	1.24	1.24	1.21

F-Statistics: (* indicates rejection of the null hypothesis at 5% significance)	Case 1	Case 2	Case 3	Case 4
H1=H2=H3=0 (4,430) df	9.35*	5.56*	9.36*	9.37*
H1=0.0 (1,430) df	6.91*	4.59*	6.88*	6.78*
H2=0.0 (1,430) df	15.14*	15.19*	15.17*	15.21*
H3=0.0 (1,430) df	1.54	1.53	1.53	1.47

C TESTS

	Coefficient	T-Ratio
MODEL 1	.15508	.66
MODEL 2	.84492	3.61
MODEL 1	-.45173	1.45
MODEL 3	1.45173	4.67
MODEL 1	.47991	1.96
MODEL 4	.52009	2.12
MODEL 2	.34159	1.59
MODEL 3	.65841	3.06
MODEL 2	.76096	3.64
MODEL 4	.23904	1.14
MODEL 3	1.25870	4.45
MODEL 4	-.25870	.91

MODEL 1=PURE CATCHUP, MODEL 2=CATCHUP WITH OPENNESS, MODEL 3=CONSTANT, MODEL 4=BREAK
See notes accompanying Table A.4 on the test method.

Table A.6

Non-Nested Tests of Employment Equations for the Industrial Countries

The employment equations were estimated by Zellner seemingly unrelated regression technique with instrumental variables, using the sample period 1963-1985 for all models. The models of labour productivity are identical to those outlined in Table A.4.

P TEST

T-statistics:	Case 1	Case 2	Case 3	Case 4
(* indicates significance at the 95% level)				
H1	3.06*	1.86	1.77	1.79
H2	1.85	1.85	3.06*	3.07*
H3	.72	0.71	.74	1.85

F-Statistics:	Case 1	Case 2	Case 3	Case 4
(* indicates rejection of the null hypothesis at 5% significance)				
H1=H2=H3=0 (3,432) df	7.95*	2.64*	3.78*	7.60*
H1=0.0 (1,432) df	9.39*	3.48*	3.16*	3.20*
H2=0.0 (1,432) df	3.42*	3.41*	9.39*	9.45*
H3=0.0 (1,432) df	.52	.51	.55	3.41*

C TESTS

	Coefficient	T-Ratio
MODEL 1	-.74296	1.84
MODEL 2	1.74296	4.32
MODEL 1	.16620	.79
MODEL 3	.83380	3.97
MODEL 1	.39331	1.83
MODEL 4	.60669	2.82
MODEL 2	.50092	2.15
MODEL 3	.49908	2.14
MODEL 2	.76455	3.40
MODEL 4	.23545	1.05
MODEL 3	1.0697	3.23
MODEL 4	-.0697	.21

MODEL 1=PURE CATCHUP, MODEL 2=CATCHUP WITH OPENNESS, MODEL 3=CONSTANT, MODEL 4=BREAK
See notes accompanying Table A.4 on the test method.

Table A.7
Output Equations for Industrial Countries
(using Catch-up Model for non-US)

	LNQS	LNCQ	LNSGAP	LNIGAP	SEE	R2	DURBIN WATSON
USA	1.0000 (***)	-0.1823 (11.93)	0.7039 (19.32)	0.0142 (4.42)	0.0085	0.9979	0.7797
JAP	1.0000 (***)	-0.0828 (8.27)	0.8035 (32.69)	0.0142 (4.42)	0.0075	0.9996	0.8851
GER	1.0000 (***)	-0.1097 (5.48)	0.6287 (23.60)	0.0142 (4.42)	0.0096	0.9978	1.1195
FRA	1.0000 (***)	-0.1764 (12.80)	0.8386 (27.50)	0.0142 (4.42)	0.0112	0.9981	0.6021
UKM	1.0000 (***)	0.0170 (0.78)	0.4606 (7.51)	0.0142 (4.42)	0.0208	0.9758	0.5232
ITA	1.0000 (***)	-0.0171 (1.43)	0.9006 (30.55)	0.0142 (4.42)	0.0143	0.9964	0.3015
CAN	1.0000 (***)	-0.2793 (11.26)	0.6624 (22.14)	0.0142 (4.42)	0.0114	0.9985	0.6969
AUS	1.0000 (***)	-0.1316 (9.76)	1.1771 (19.52)	0.0142 (4.42)	0.0128	0.9972	1.0918
OST	1.0000 (***)	-0.1009 (3.99)	0.6283 (33.44)	0.0142 (4.42)	0.0098	0.9984	0.6862
BEL	1.0000 (***)	-0.0728 (4.66)	0.5889 (26.65)	0.0142 (4.42)	0.0087	0.9986	1.0531
DEN	1.0000 (***)	-0.0877 (8.84)	0.4910 (19.55)	0.0142 (4.42)	0.0094	0.9968	1.1807
FIN	1.0000 (***)	0.0038 (0.27)	0.6342 (18.57)	0.0142 (4.42)	0.0133	0.9972	0.8017
IRE	1.0000 (***)	0.0112 (0.26)	0.5677 (9.99)	0.0142 (4.42)	0.0288	0.9903	0.8485
NET	1.0000 (***)	-0.0348 (2.26)	0.4984 (29.36)	0.0142 (4.42)	0.0102	0.9978	0.9815
NZL	1.0000 (***)	-0.0748 (5.45)	0.8826 (28.10)	0.0142 (4.42)	0.0155	0.9905	1.3872
NOR	1.0000 (***)	0.0074 (0.21)	0.2239 (4.88)	0.0142 (4.42)	0.0184	0.9954	0.8186
SPA	1.0000 (***)	-0.0155 (0.84)	0.5564 (10.34)	0.0142 (4.42)	0.0131	0.9978	0.6275
SWE	1.0000 (***)	-0.0172 (1.04)	0.5554 (15.11)	0.0142 (4.42)	0.0108	0.9959	1.6575
SWI	1.0000 (***)	-0.2651 (5.23)	0.5239 (10.28)	0.0142 (4.42)	0.0219	0.9752	0.4475

Sample 1963-1985. Estimation method by Zellner's SUR estimation technique with instruments.

Table A.8.1
Output Equations for Industrial Countries
(using Catch-up Model for non-US and Gross Private Capital Stocks)

	LNQS	LNCQ	LNSGAP	LNIGAP	SEE	R2	DURBIN WATSON
USA	1.0000	-0.2084	0.7028	0.0117	0.0086	0.9979	0.7737
	(***)	(12.28)	(19.61)	(3.68)			
JAP	1.0000	-0.0897	0.7992	0.0117	0.0074	0.9996	0.8912
	(***)	(8.75)	(32.25)	(3.68)			
GER	1.0000	-0.1419	0.6466	0.0117	0.0099	0.9976	1.0331
	(***)	(6.61)	(24.35)	(3.68)			
FRA	1.0000	-0.2057	0.8342	0.0117	0.0107	0.9983	0.6568
	(***)	(14.13)	(27.28)	(3.68)			
UKM	1.0000	0.0099	0.5031	0.0117	0.0216	0.9740	0.4584
	(***)	(0.43)	(8.29)	(3.68)			
ITA	1.0000	-0.0265	0.9024	0.0117	0.0144	0.9963	0.3011
	(***)	(2.00)	(29.82)	(3.68)			
CAN	1.0000	-0.3378	0.6715	0.0117	0.0106	0.9987	0.7494
	(***)	(11.72)	(23.25)	(3.68)			
AUS	1.0000	-0.1477	1.2043	0.0117	0.0126	0.9973	1.1462
	(***)	(10.32)	(19.89)	(3.68)			
OST	1.0000	-0.1366	0.6344	0.0117	0.0101	0.9983	0.6602
	(***)	(4.64)	(33.08)	(3.68)			
BEL	1.0000	-0.0890	0.6024	0.0117	0.0087	0.9986	1.0673
	(***)	(5.33)	(27.37)	(3.68)			
DEN	1.0000	-0.1075	0.5047	0.0117	0.0097	0.9966	1.1054
	(***)	(9.14)	(20.31)	(3.68)			
FIN	1.0000	-0.0080	0.6335	0.0117	0.0131	0.9973	0.8066
	(***)	(0.49)	(18.52)	(3.68)			
IRE	1.0000	0.0140	0.5640	0.0117	0.0286	0.9904	0.8584
	(***)	(0.32)	(9.75)	(3.68)			
NET	1.0000	-0.0465	0.5035	0.0117	0.0106	0.9976	0.9078
	(***)	(2.63)	(29.18)	(3.68)			
NZL	1.0000	-0.0797	0.8839	0.0117	0.0156	0.9903	1.3699
	(***)	(5.52)	(27.96)	(3.68)			
NOR	1.0000	-0.0300	0.2698	0.0117	0.0181	0.9956	0.8053
	(***)	(0.73)	(5.65)	(3.68)			
SPA	1.0000	-0.0244	0.5422	0.0117	0.0126	0.9979	0.6621
	(***)	(1.24)	(10.06)	(3.68)			
SWE	1.0000	-0.0352	0.5672	0.0117	0.0107	0.9959	1.6315
	(***)	(1.93)	(15.78)	(3.68)			
SWI	1.0000	-0.3771	0.5780	0.0117	0.0213	0.9766	0.5057
	(***)	(6.40)	(11.66)	(3.68)			

Sample 1963-1985. Estimation method by Zellner's SUR estimation technique with instruments.

Table A.8.2
Output Equations for Industrial Countries
(using Catch-up Model for non-US and Gross Business Capital Stocks)

	LNQS	LNCQ	LNSGAP	LNIGAP	SEE	R2	DURBIN WATSON
USA	1.0000	-0.2533	0.7146	0.0095	0.0077	0.9983	0.7630
	(***)	(13.69)	(22.22)	(3.14)			
JAP	1.0000	-0.0870	0.7929	0.0095	0.0075	0.9996	0.8607
	(***)	(8.06)	(31.33)	(3.14)			
GER	1.0000	-0.1968	0.6466	0.0095	0.0095	0.9978	1.0025
	(***)	(8.32)	(26.37)	(3.14)			
FRA	1.0000	-0.2709	0.8088	0.0095	0.0093	0.9987	0.7524
	(***)	(16.80)	(29.66)	(3.14)			
UKM	1.0000	-0.0153	0.5621	0.0095	0.0216	0.9739	0.4108
	(***)	(0.48)	(9.62)	(3.14)			
ITA	1.0000	-0.0497	0.8901	0.0095	0.0144	0.9963	0.3009
	(***)	(2.76)	(30.37)	(3.14)			
CAN	1.0000	-0.4741	0.6222	0.0095	0.0095	0.9990	0.9017
	(***)	(11.80)	(20.49)	(3.14)			
AUS	1.0000	-0.1873	1.2047	0.0095	0.0125	0.9973	1.1369
	(***)	(11.07)	(20.99)	(3.14)			
OST	1.0000	-0.1788	0.6327	0.0095	0.0097	0.9985	0.6969
	(***)	(5.76)	(32.97)	(3.14)			
BEL	1.0000	-0.0965	0.6048	0.0095	0.0083	0.9987	1.1159
	(***)	(4.81)	(27.11)	(3.14)			
DEN	1.0000	-0.1202	0.5222	0.0095	0.0095	0.9967	1.0200
	(***)	(8.07)	(21.66)	(3.14)			
FIN	1.0000	-0.0137	0.6412	0.0095	0.0130	0.9973	0.8083
	(***)	(0.63)	(18.94)	(3.14)			
IRE	1.0000	-0.0187	0.6078	0.0095	0.0286	0.9904	0.8425
	(***)	(0.32)	(10.94)	(3.14)			
NET	1.0000	-0.0275	0.4960	0.0095	0.0106	0.9977	0.9144
	(***)	(1.32)	(28.70)	(3.14)			
NZL	1.0000	-0.0881	0.8849	0.0095	0.0157	0.9902	1.3596
	(***)	(5.79)	(28.42)	(3.14)			
NOR	1.0000	-0.1595	0.3876	0.0095	0.0178	0.9957	0.7522
	(***)	(3.04)	(7.22)	(3.14)			
SPA	1.0000	-0.0354	0.5723	0.0095	0.0119	0.9982	0.7211
	(***)	(1.35)	(10.70)	(3.14)			
SWE	1.0000	-0.0608	0.5887	0.0095	0.0106	0.9960	1.5886
	(***)	(2.91)	(17.86)	(3.14)			
SWI	1.0000	-0.4938	0.7025	0.0095	0.0196	0.9803	0.6585
	(***)	(9.12)	(14.30)	(3.14)			

Sample 1963-1985. Estimation method by Zellner's SUR estimation technique with instruments.

Table A.8.3

Non-Nested Tests of:
(1) Catch-up Model A.7 (total capital)
(2) Catch-up Model A.8.1 (private capital)
(3) Catch-up Model A.8.2 (business capital)

C-TEST of Output Equations:		Coefficient	T-ratio
Test A:	Model (1)	-0.1482	0.26
	Model (2)	1.1482	2.03*
Test B:	Model (1)	-0.1840	0.81
	Model (3)	1.1840	5.22*
Test C:	Model (2)	-0.6609	2.06*
	Model (3)	1.6609	5.17*

P-TEST: Output Equation	T-Ratio		F-statistic(H=0.0)		
	H1	H2	H1,H2	H1	H2
H0: Model (1),H1=Model (2),H2=Model(3)	3.92*	6.29*	22.10*	15.34*	39.63*
H0: Model (2),H1=Model (1),H2=Model(3)	3.38*	6.24*	19.52*	11.42*	38.97*
H0: Model (3),H1=Model (1),H2=Model(2)	3.41*	3.90*	7.89*	11.65*	15.22*

Table A.8.4
Output Equations for Industrial Countries
(using Catch-up Model for non-US and with Inventory Stocks
added to Gross Business Capital Stocks)

	LNQS	LNCQ	LNSGAP	LNIGAP	SEE	R2	DURBIN WATSON
USA	1.0000 (***)	-0.2522 (13.61)	0.7037 (21.11)	0.0123 (3.98)	0.0079	0.9982	0.7559
JAP	1.0000 (***)	-0.0946 (8.23)	0.7885 (30.80)	0.0123 (3.98)	0.0071	0.9997	0.9234
GER	1.0000 (***)	-0.1646 (7.37)	0.6293 (24.49)	0.0123 (3.98)	0.0096	0.9978	0.9645
FRA	1.0000 (***)	-0.2488 (15.33)	0.8416 (28.92)	0.0123 (3.98)	0.0097	0.9986	0.7346
UKM	1.0000 (***)	0.0080 (0.27)	0.5257 (9.04)	0.0123 (3.98)	0.0214	0.9745	0.4483
ITA	1.0000 (***)	-0.0395 (2.46)	0.9017 (31.49)	0.0123 (3.98)	0.0143	0.9964	0.2991
CAN	1.0000 (***)	-0.4644 (12.07)	0.6045 (19.30)	0.0123 (3.98)	0.0100	0.9988	0.8473
AUS	1.0000 (***)	-0.1754 (10.77)	1.2060 (20.39)	0.0123 (3.98)	0.0127	0.9972	1.1114
OST	1.0000 (***)	-0.1675 (5.44)	0.6380 (33.26)	0.0123 (3.98)	0.0098	0.9984	0.6826
BEL	1.0000 (***)	-0.0875 (4.38)	0.5902 (25.53)	0.0123 (3.98)	0.0083	0.9987	1.1240
DEN	1.0000 (***)	-0.1041 (7.62)	0.5193 (21.45)	0.0123 (3.98)	0.0094	0.9968	1.0194
FIN	1.0000 (***)	-0.0056 (0.28)	0.6321 (18.68)	0.0123 (3.98)	0.0127	0.9974	0.8168
IRE	1.0000 (***)	0.0033 (0.06)	0.5975 (10.78)	0.0123 (3.98)	0.0285	0.9904	0.8528
NET	1.0000 (***)	-0.0242 (1.25)	0.4929 (28.64)	0.0123 (3.98)	0.0105	0.9977	0.9036
NZL	1.0000 (***)	-0.0849 (5.64)	0.8845 (27.74)	0.0123 (3.98)	0.0158	0.9902	1.3441
NOR	1.0000 (***)	-0.1625 (3.27)	0.3948 (7.28)	0.0123 (3.98)	0.0181	0.9956	0.7241
SPA	1.0000 (***)	-0.0247 (0.96)	0.5642 (10.15)	0.0123 (3.98)	0.0119	0.9982	0.7199
SWE	1.0000 (***)	-0.0561 (2.87)	0.5747 (17.38)	0.0123 (3.98)	0.0103	0.9962	1.6418
SWI	1.0000 (***)	-0.4162 (7.51)	0.6821 (12.46)	0.0123 (3.98)	0.0210	0.9773	0.5614

Sample 1963-1985. Estimation method by Zellner's SUR estimation technique with instruments.

Table A.8.5

Non-Nested Tests of Pure Catch-up Models
(using alternative measures of gross capital stocks)

(1) Catch-up Output Model A.7 (total capital)
(2) " " " (total capital with inventory stock)
(3) Catch-up Output Model A.8.1 (private capital)
(4) " " " (private capital with inventory stock)
(5) Catch-up Output Model A.8.2 (business capital)
(6) " " " (business capital with inventory stock)

C-TEST of Output Equations:

	(1)	(2)	(3)	(4)	(5)	(6)
(1)	-	1.8939	-0.1482	0.2942	-0.1840	-0.1809
		(1.48)	(0.26)	(.44)	(0.81)	(0.68)
(2)	-0.8939	-	-0.0766	0.0086	-0.1060	-0.1494
	(0.70)		(0.17)	(0.01)	(0.51)	(0.60)
(3)	1.4818	1.0766	-	2.2409	-0.6610	-0.6185
	(2.03)	(2.41)		(2.12)	(2.06)	(1.61)
(4)	0.7058	0.9914	-1.2409	-	-0.4671	-0.6633
	(1.06)	(1.62)	(1.18)		(1.70)	(1.87)
(5)	1.1840	1.1060	1.6610	1.4671	-	2.3429
	(5.22)	(5.35)	(5.18)	(5.36)		(3.25)
(6)	1.1809	1.1494	1.6185	1.6633	-1.3429	-
	(4.44)	(4.63)	(4.21)	(4.68)	(1.86)	

P-TEST: Output Equation		F-statistic	(H1=H2=H3=H4=H5=0.0)
H0: Model (1)	(5,428df)	18.64	versus 2.21
H0: Model (2)	"	19.05	
H0: Model (3)	"	17.65	
H0: Model (4)	"	18.38	
H0: Model (5)	"	12.75	
H0: Model (6)	"	14.26	

Table A.9.1

The Capital-Embodied Model of Technical Progress

	RTIME	CONSTANT	SEE	R2	DURBIN WATSON
USA	0.0194 (6.64)	126.8300 (596.31)	0.1116	0.6293	0.3312
JAP	0.1046 (14.50)	118.6800 (225.74)	0.2758	0.8899	0.1386
GER	0.0773 (24.58)	120.9800 (527.65)	0.1203	0.9587	0.2394
FRA	0.0982 (20.34)	119.4700 (339.70)	0.1845	0.9409	0.0882
ITA	0.0918 (14.53)	119.7900 (260.19)	0.2416	0.8903	0.1336
UKM	0.0443 (16.97)	123.1300 (647.47)	0.0998	0.9172	0.5092
CAN	0.0515 (16.40)	123.7600 (541.22)	0.1200	0.9119	0.2163
AUS	0.0433 (15.37)	123.8900 (603.47)	0.1077	0.9008	0.4947
OST	0.0881 (21.24)	119.7900 (396.32)	0.1586	0.9455	0.1340
BEL	0.0833 (26.29)	120.8200 (523.24)	0.1212	0.9637	0.2402
DEN	0.0627 (18.46)	121.7600 (491.97)	0.1298	0.9291	0.3083
FIN	0.0852 (27.41)	119.6100 (527.83)	0.1189	0.9666	0.3755
IRE	0.0953 (27.45)	118.7100 (469.19)	0.1328	0.9666	0.5319
NET	0.0786 (22.74)	121.6200 (482.57)	0.1322	0.9521	0.2594
NZL	0.0043 (1.18)	126.9800 (474.81)	0.1403	0.0506	0.4944
NOR	0.0662 (33.37)	121.6600 (841.30)	0.0759	0.9772	0.7040
SPA	0.1105 (24.39)	118.4000 (358.53)	0.1733	0.9581	0.2180
SWE	0.0455 (13.72)	123.2300 (509.64)	0.1269	0.8787	0.3147
SWI	0.0432 (11.41)	124.1200 (449.39)	0.1449	0.8335	0.1889

Note: The dependent variable is ln π_m, measured output attributable to labour. RTIME is an annual time trend equal to 60 in 1960, 61 in 1961. See the section on specification in Appendix II for a more complete description. Estimation was by SUR using sample 1960-1985.

Table A.9.2
Output Equations for Industrial Countries
(Capital-Embodied Technical Progress)

	LNQS	LNCQ	LNSGAP	LNIGAP	SEE	R2	DURBIN WATSON
USA	1.0000	-0.1736	0.7176	0.0077	0.0085	0.9980	0.7876
	(***)	(13.58)	(24.23)	(1.95)			
JAP	1.0000	-0.1653	0.8621	0.0077	0.0070	0.9997	1.1251
	(***)	(14.50)	(49.82)	(1.95)			
GER	1.0000	-0.3189	0.7525	0.0077	0.0199	0.9904	0.5244
	(***)	(12.45)	(15.37)	(1.95)			
FRA	1.0000	-0.2823	0.9381	0.0077	0.0145	0.9968	0.7504
	(***)	(15.84)	(23.12)	(1.95)			
ITA	1.0000	-0.0385	1.0526	0.0077	0.0154	0.9958	0.3175
	(***)	(2.67)	(36.77)	(1.95)			
UKM	1.0000	-0.0577	0.5923	0.0077	0.0255	0.9636	0.2725
	(***)	(2.58)	(8.54)	(1.95)			
CAN	1.0000	-0.4089	0.6550	0.0077	0.0134	0.9979	0.7919
	(***)	(13.70)	(15.72)	(1.95)			
AUS	1.0000	-0.1142	1.3167	0.0077	0.0125	0.9973	1.3172
	(***)	(9.21)	(14.10)	(1.95)			
OST	1.0000	-0.4514	0.6997	0.0077	0.0199	0.9935	0.5135
	(***)	(11.83)	(18.56)	(1.95)			
BEL	1.0000	-0.2218	0.6346	0.0077	0.0119	0.9974	0.8781
	(***)	(16.44)	(22.80)	(1.95)			
DEN	1.0000	-0.1299	0.6336	0.0077	0.0143	0.9927	0.7361
	(***)	(11.54)	(24.01)	(1.95)			
FIN	1.0000	-0.1014	0.6014	0.0077	0.0175	0.9951	0.4845
	(***)	(6.17)	(13.04)	(1.95)			
IRE	1.0000	-0.1063	0.5865	0.0077	0.0309	0.9888	0.6745
	(***)	(2.82)	(8.66)	(1.95)			
NET	1.0000	-0.2694	0.6173	0.0077	0.0230	0.9890	0.3747
	(***)	(10.18)	(20.35)	(1.95)			
NZL	1.0000	-0.0693	0.8537	0.0077	0.0152	0.9908	1.4148
	(***)	(5.27)	(22.06)	(1.95)			
NOR	1.0000	-0.1849	0.2579	0.0077	0.0150	0.9969	0.9998
	(***)	(5.94)	(5.46)	(1.95)			
SPA	1.0000	-0.1364	0.8391	0.0077	0.0131	0.9978	0.7713
	(***)	(8.14)	(21.81)	(1.95)			
SWE	1.0000	-0.1329	0.5988	0.0077	0.0117	0.9952	1.2295
	(***)	(8.36)	(14.34)	(1.95)			
SWI	1.0000	-0.4773	0.6774	0.0077	0.0274	0.9614	0.4752
	(***)	(8.34)	(9.72)	(1.95)			

Sample 1963-1985. Estimation method by Zellner's SUR estimation technique with instruments.

Table A.10
Generalized Output Equation Incorporating Technology Shocks and Factor Utilization Variables (using 'constant' case)

	LN(QS)	LN(Q/QS)-1	LNCQ	LNSGAP	LNIGAP	SEE	R2	DH
USA	1.0000	0.2471	-0.1522	0.5210	0.0196	0.0079	0.9982	1.9890
	(***)	(5.13)	(9.21)	(8.87)	(4.55)			
JAP	1.0000	-0.0074	-0.1511	0.8808	0.0196	0.0072	0.9997	2.3285
	(***)	(0.18)	(12.40)	(19.11)	(4.55)			
GER	1.0000	0.7266	-0.2343	0.2555	0.0196	0.0130	0.9959	0.2654
	(***)	(10.03)	(9.27)	(3.77)	(4.55)			
FRA	1.0000	0.8038	-0.1167	0.2347	0.0196	0.0079	0.9991	2.5554
	(***)	(9.48)	(5.98)	(2.47)	(4.55)			
UKM	1.0000	0.7698	-0.1068	0.3923	0.0196	0.0144	0.9884	-0.0429
	(***)	(10.65)	(4.23)	(4.06)	(4.55)			
ITA	1.0000	0.5837	-0.0606	0.4462	0.0196	0.0105	0.9981	0.7422
	(***)	(8.03)	(3.56)	(5.22)	(4.55)			
CAN	1.0000	0.5290	-0.3584	0.2786	0.0196	0.0100	0.9988	0.3281
	(***)	(7.76)	(11.35)	(4.33)	(4.55)			
AUS	1.0000	0.2128	-0.1062	1.0129	0.0196	0.0108	0.9980	0.2040
	(***)	(3.66)	(7.44)	(11.94)	(4.55)			
OST	1.0000	0.9196	-0.1905	0.0433	0.0196	0.0111	0.9980	-0.1522
	(***)	(14.31)	(5.72)	(0.79)	(4.55)			
BEL	1.0000	0.4556	-0.1557	0.3642	0.0196	0.0103	0.9980	0.1764
	(***)	(5.93)	(8.09)	(7.03)	(4.55)			
DEN	1.0000	0.7556	-0.0733	0.1683	0.0196	0.0140	0.9930	-1.0259
	(***)	(6.54)	(3.98)	(2.23)	(4.55)			
FIN	1.0000	0.5718	-0.0975	0.2984	0.0196	0.0129	0.9973	0.5412
	(***)	(7.50)	(4.88)	(4.55)	(4.55)			
IRE	1.0000	0.8490	-0.1171	0.1464	0.0196	0.0227	0.9939	-0.2673
	(***)	(8.76)	(2.68)	(1.56)	(4.55)			
NET	1.0000	0.8361	-0.1879	0.1886	0.0196	0.0129	0.9966	-0.3399
	(***)	(12.63)	(6.68)	(4.37)	(4.55)			
NZL	1.0000	0.3250	-0.0421	0.6681	0.0196	0.0134	0.9929	-0.8706
	(***)	(6.80)	(3.01)	(14.96)	(4.55)			
NOR	1.0000	0.4643	-0.1589	0.2360	0.0196	0.0124	0.9979	0.1516
	(***)	(6.43)	(5.37)	(4.93)	(4.55)			
SPA	1.0000	0.5897	-0.1119	0.3537	0.0196	0.0107	0.9985	0.0262
	(***)	(6.17)	(5.52)	(4.23)	(4.55)			
SWE	1.0000	0.3787	-0.1097	0.3601	0.0196	0.0109	0.9958	0.1932
	(***)	(4.19)	(5.59)	(4.85)	(4.55)			
SWI	1.0000	0.7067	-0.2539	0.2775	0.0196	0.0107	0.9940	-0.0310
	(***)	(17.55)	(7.61)	(7.07)	(4.55)			

Sample 1963-1985. Estimation method by Zellner's SUR estimation technique with instruments.

Nested Tests:	Wald Statistic (19df)		
LN(Q/QS)-1 = 0.0	1457.4678	versus	28.87
LNCQ = 0.0	835.3252	versus	28.87
LNSGAP = 0.0	1229.7174	versus	28.87
LNIGAP = 0.0	309.2629	versus	28.87
LNCQ=LNSGAP=LNIGAP=0.0	4970.1135 (57df)	versus	79.08

Table A.11
Generalized Output Equation Incorporating Technology Shocks and Factor Utilization Variables (using 'catch-up' case)

	LN(QS)	LN(Q/QS)-1	LNCQ	LNSGAP	LNIGAP	SEE	R2	DH
USA	1.0000	0.2203	-0.1543	0.5627	0.0364	0.0076	0.9984	2.4341
	(***)	(2.34)	(7.39)	(5.63)	(5.94)			
JAP	1.0000	-0.0655	-0.0854	0.8882	0.0364	0.0071	0.9997	2.8769
	(***)	(0.66)	(5.62)	(10.69)	(6.38)			
GER	1.0000	0.2105	-0.0913	0.5339	0.0364	0.0094	0.9978	2.6101
	(***)	(1.20)	(1.88)	(5.34)	(4.80)			
FRA	1.0000	0.7627	-0.1316	0.4449	0.0364	0.0088	0.9988	4.4633
	(***)	(4.79)	(4.01)	(3.69)	(5.14)			
UKM	1.0000	0.8187	-0.0871	0.3050	0.0364	0.0153	0.9869	-0.0850
	(***)	(5.03)	(1.80)	(2.92)	(2.95)			
ITA	1.0000	0.4975	-0.0168	0.5951	0.0364	0.0101	0.9982	1.7473
	(***)	(4.81)	(0.66)	(7.01)	(4.47)			
CAN	1.0000	0.4577	-0.2650	0.3421	0.0364	0.0090	0.9991	1.0238
	(***)	(3.99)	(5.37)	(4.08)	(5.01)			
AUS	1.0000	0.3565	-0.1291	0.9634	0.0364	0.0110	0.9979	-0.7240
	(***)	(3.08)	(4.72)	(6.54)	(4.12)			
OST	1.0000	0.3736	-0.1019	0.4567	0.0364	0.0084	0.9988	1.8809
	(***)	(2.59)	(2.00)	(5.28)	(5.37)			
BEL	1.0000	0.2799	-0.0784	0.4662	0.0364	0.0085	0.9986	0.6158
	(***)	(2.23)	(2.66)	(6.91)	(5.31)			
DEN	1.0000	0.4026	-0.0671	0.3264	0.0364	0.0102	0.9963	-0.3117
	(***)	(2.01)	(3.28)	(3.46)	(4.45)			
FIN	1.0000	0.4500	-0.0271	0.4372	0.0364	0.0110	0.9981	1.1566
	(***)	(3.52)	(0.82)	(5.91)	(4.11)			
IRE	1.0000	0.7255	-0.1070	0.3157	0.0364	0.0215	0.9946	-0.5270
	(***)	(4.81)	(1.54)	(3.16)	(2.10)			
NET	1.0000	0.3017	-0.0470	0.3769	0.0364	0.0096	0.9981	1.4076
	(***)	(1.91)	(0.95)	(5.31)	(4.73)			
NZL	1.0000	0.3760	-0.0557	0.6558	0.0364	0.0133	0.9930	-1.2668
	(***)	(3.93)	(2.92)	(7.02)	(3.39)			
NOR	1.0000	0.6307	-0.1159	0.2402	0.0364	0.0133	0.9976	-0.0711
	(***)	(4.05)	(2.06)	(2.65)	(3.41)			
SPA	1.0000	0.6154	-0.0153	0.3483	0.0364	0.0104	0.9986	-0.4573
	(***)	(4.32)	(0.38)	(2.77)	(4.33)			
SWE	1.0000	0.2186	-0.0207	0.4593	0.0364	0.0104	0.9962	0.3650
	(***)	(1.42)	(0.75)	(5.10)	(4.36)			
SWI	1.0000	0.7700	-0.2138	0.3187	0.0364	0.0105	0.9944	-0.2246
	(***)	(8.90)	(3.39)	(5.18)	(4.32)			

Sample 1963-1985. Estimation method by Zellner's SUR estimation technique with instruments.

Nested Tests:	Wald Statistic (19df)		
LN(Q/QS)-1 = 0.0	289.8689	versus	28.87
LNCQ = 0.0	184.1547	versus	28.87
LNSGAP = 0.0	586.9489	versus	28.87
LNIGAP = 0.0	63.8332	versus	28.87
LNCQ=LNSGAP=LNIGAP=0.0	803.8724 (57df)	versus	79.08