A technology gap approach to why growth rates differ

by

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Abstract: This paper contains a discussion and test of the technology gap approach to development and growth. The basic hypotheses of the theory are tested on pooled cross-sectional and time-series data for 25 industrial countries for the period 1960-1983. The sample includes, in addition to 19 OECD countries, 6 of the most important industrial economies from the non-OECD area. The findings of the paper confirm that there exists a close correlation between the level of economic development, measured as GDP per capita, and the level of technological development, measured through R&D or patent statistics. Furthermore, for the group of 25 countries as a whole, technology gap models of economic growth are found to explain a large part of the actual differences in growth rates, both between countries and periods. As expected, both the scope for imitation, growth in innovative activity and "efforts" to narrow the gap (investment) appear as powerful explanatory factors of economic growth. However, when the non-OECD countries, and later USA and Japan, are removed from the sample, the explanatory power of the technology variables, especially growth in innovative activity, diminishes.

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1. Introduction

Why do growth rates differ? When students of economic growth nearly thirty years ago started to study this question, they expected differences in the supply of capital and labour to be of utmost importance. Much to their surprise, differences in the growth of capital and labour explained[1] only a small part of the actual differences in growth between nations (Abramowitz 1956, Solow 1957, Denison 1967). One of the consequences of these paradoxical findings was to put technology in the forefront of theoretical and empirical studies of growth. Solow (1957) and others extended the neoclassical theory of growth by including technology as a third factor of production in addition to capital and labour. According to this approach, technology should be regarded as a free good, growing at a constant, exponential rate.

The technology gap approach, developed by Posner (1961), Gomulka (1971), Cornwall (1976, 1977) and others, also emphasizes the crucial role of technology in the process of economic growth, but from a radically different perspective. According to this approach, the international economic system is characterized by marked differences in technological levels and trends, differences which can only be overcome through radical changes in technological, economic and social structures. The main hypotheses of the technology gap approach to economic growth may be summarized as follows:

(1) There is a close relation between a country's economic and technological level of development.
(2) The rate of economic growth of a country is positively influenced by the rate of growth in the technological level of the country.
(3) It is possible for a country facing a technological gap, i.e., a country on a lower technological level than the countries on "the world innovation frontier", to increase its rate of economic growth through imitation ("catching up").
(4) The rate at which a country exploits the possibilities offered by the technological gap depends on its ability to mobilize resources for transforming social, institutional and economic structures.

Hypotheses 1 and 2, laid down in the seminal contributions by Posner (1961) and Gomulka (1971), may be regarded as the basic hypotheses of the technology gap theory. Curiously enough, with one notable exception (Pavitt and Soete 1982), very little empirical research has been done in order to test these hypotheses. In contrast to this, the "catching up" hypothesis (3) has been tested extensively, using the level of economic development as a proxy for technological development (Gomulka 1971, Singer and Reynolds 1975, Cornwall 1976, 1977) and others).[2]

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[1] The term "explain" in the present context refers primarily to the fit of a regression. Obviously, neither the models in " the growth accounting" literature, nor "the technology gap" models to be developed later, can claim to be "explanations" in the sense that all relevant functional relationships and variables are included. While economic development is shaped by a large number of interrelated factors, of which many cannot be easily quantified, the models discussed and developed in this paper include only a few variables, all on a very high level of aggregation. Therefore, the tests presented in this paper cannot be expected to explain all the observed differences in growth between countries. What they can do is to test the explanatory power of a few vital variables and in this way increase our understanding of economic processes and give directions for future research. The "growth accounting" debate is in my view an excellent example of this.

[2] For an overview, see Choi (1983).

The results seem generally to support this hypothesis. Regarding the last hypothesis, the research process is still in an early phase, but the results so far seem to support this hypothesis also (Parvin 1975, Cornwall 1976, 1977, Abramowitz 1979).

The purpose of this paper is to test the basic hypotheses of the technology gap theory and analyse the differing growth performance of the industrial countries during the last twenty years. For this purpose it was found necessary to include in the sample, in addition to 19 OECD countries, 6 of the most important industrial economies from the non-OECD area: Brazil, Argentina, Mexico, Korea (South), Hong Kong and Taiwan. In the next section the relation between levels of economic and technological development is discussed and tested. With the results in mind, the third section presents a test of a technology gap approach to "why growth rates differ".

2. Economic and technological levels of development

Most people, economists or not, would probably agree with the proposition that economic and technological levels of development are closely related. But they would probably disagree on how levels of technological development should be defined and measured. Following traditional neoclassical theory, the level of technological development of a country depends primarily on the relation between capital and labour. The technology gap theorists on the other hand relate the technological level of a country to its *level of innovative activity*. A high level of innovative activity means a high share of "new" goods in output and an extensive use of "new" techniques in production. Since "new" goods command high prices and "new" techniques imply high productivity, it follows that countries with a comparatively higher level of innovative activities also tend to have a higher level of value-added per worker, or GDP per capita, than other countries.[3] Of course, a country may increase its level of economic development by mainly imitating activities, but it cannot, according to the way of reasoning sketched above, surpass the most advanced countries economically without passing them in innovative activities as well.

Measures of technological level and or innovative activity may be divided into "technology input" measures and "technology output" measures (Soete 1981). Of the former type, expenditures on education, research and development and employment of scientists and engineers may be mentioned, of the latter, patenting activity. Regarding the former type, these measures may be said to be related to the innovative capacity of a country as well as its capacity for imitation, since a certain scientific base is a precondition for successful imitation in most areas.[4] This study confines itself to one "technology input" measure, R&D. Patenting activity, on the other hand, is more directly related to inventive activity and process and product innovation than to imitation.

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[3] This is the argument with runs through the whole "neotechnological" tradition, from Kravis (1956) to Posner (1961), Vernon (1966) and Hirsch (1967). For a more recent formulation, see Krugman (1979).

[4] The role of R&D as a necessary precondition for imitation is emphasized by, among others, Freeman (1982, p. 185) and Mansfield et al. (1982, p. 209).

The main problem concerning R&D as an indicator of technological level is that the data generally are of poor quality, especially for years earlier than 1970, and for non-OECD countries. Yearly time-series dating back to the early 1960s exist for a few countries only. Another problem is whether or not military R&D should be included.[5] Patent statistics, on the other hand, are available for a lot of countries and for long time-spans. Furthermore, studies on the relation between patenting activity and R&D on the firm or industry level seem to indicate a close relation between patenting activity and R&D.[6] Differences in national patenting regulations have made it more difficult to compare patenting activities across countries.[7] But, as pointed out by Soete (1981), this problem may be significantly reduced by limiting the analysis to patenting activities of different countries in one common (foreign) market. Contrary to Soete who used foreign patenting in USA as indicator, this paper uses foreign patenting on the world market.[8] This has several advantages.[9] First, it gives data for USA, which is of great importance in an analysis of technological gaps and trends. Second, the propensity to patent in the US market probably varies more than the propensity to patent in foreign markets in general.

Figure 1 compares the development of average civil R&D as percentage of GDP, patenting activity (less domestic patents) and average GDP per capita in constant 1980 prices for the OECD countries between 1963 and 1982.[10] All variables are expressed relative to average 1963-82 to facilitate comparison. Before 1973 the R&D and patent indicators show a relatively similar pattern. During the 1960s both show a strong upward trend, strongest for patents, with peaks in 1968/69, followed by a slowdown in the early-mid 1970s. It is an interesting fact that both indicators peak several years before GDP per capita, indicating that innovative

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[5] I have chosen to exclude military R&D. The main reason for this is that if included, the size of the military sector of a country, relative to the military sectors of other countries, would have influenced the rank of the country relative to other countries in terms of technological level. For instance, a country like Japan, which for political reasons does not have a military sector, would have obtained a lower rank in terms of technological level if military R&D had been included.

[6] This was pointed out already by Schmookler (1966, pp. 44-55) in a case study of USA for the year 1953. More recent evidence pointing in the same direction may be found in Griliches (1984), especially ch. 1 and 3.

[7] Nevertheless Soete (1981) found a quite close correlation between levels of domestic patenting and R&D expenses in a cross-country study covering the business enterprise sector in 19 OECD countries.

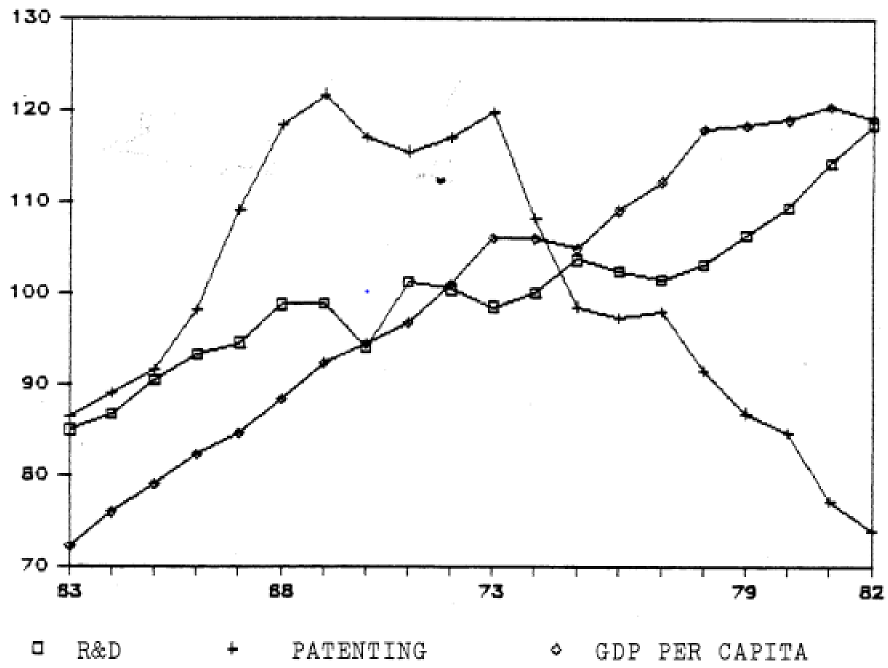
[8] That is: Total patent applications of residents in country x in all countries which report patent applications to WIPO (World Intellectual Property Organisation) less patent applications by residents of x in country x.

[9] A possible disadvantage is that since patent regulations differ between countries, and several studies show that the level of external patent applications of a country is correlated with the level of its exports, external patent applications of a country may be influenced by the geographical breakdown of its export. However, case studies show that external patenting is not significantly affected by differences in patent regulations between countries. Thus, this problem is probably not of major importance. Differences in "attractiveness" between countries in relation to patenting from abroad seem mainly to depend on the size and level of economic development in the recipient country. Also the level of exports and subsidiaries of MNEs of the patenting country in the recipient country seem to be of importance, but here the direction of causation is not at all clear. For discussion and tests of the relation between external patenting and characteristics of the patenting and the recipient country the reader is referred to Schiffel and Kitti (1978), Bosworth (1980,1984) and Basberg (1983).

[10] The reader is referred to the appendix for further information regarding sources and methods.

activity cannot be seen as a mere reflection of economic activity. After 1973, however, patenting activity continues to decline, while the growth in R&D picks up again from 1979 onwards. This general slowdown in patenting activity affects most countries except Japan, Finland and the Asian NICs. However, in general the diverging trends in the two technology indicators in the last years (after 1978) should be interpreted with great care because new international patenting channels may have influenced the general propensity to patent through the established national channels.[11]

Fig. 1. Technology indicators 1963-82 (OECD).



Tables 1 and 2 present indexes of technological level for 25 countries in the periods 1960/63-68, 1969-73, 1974-79 and 1980-82/83. The first index is based on patent statistics, while the second is based on R&D data. In both cases the sources and methods are the same as in fig. 1 above. Both indexes are expressed relative to average in the period (average level= 1). To construct an index of technological development based on patent statistics, it was necessary to normalize the levels of patenting activity according to the size of the country and the propensity to patent in foreign markets. This was done by dividing the number of patent applications filed by residents of a country in foreign markets by the number of inhabitants and the share of exports in GDP in the country. The reason for including the degree of openness of the economy in the index is that the propensity to patent in foreign markets is assumed to be dependent on the importance of the home market relative to export markets.

[11] Since 1 June 1978 national channels for filing applications for patents have been supplemented by a European channel (EPC) and an international channel (PCT). If the applications filed through these channels are added to the data supplied through the WIPO member countries, the measure of patenting activity would show an upward trend (OECD 1984).

Table 1. Index of technological level (patent data)[a]

	1960-68	1969-73	1974-79	1980-83
USA	5.091	4.701	3.342	3.391
Japan	0.509	1.113	1.430	2.053
FRG	2.561	2.502	2.542	2.228
France	1.527	1.459	1.347	1.276
UK	1.460	1.218	0.987	1.081
Italy	0.534	0.502	0.486	0.593
Canada	0.536	0.486	0.545	0.561
Austria	0.765	0.769	0.844	0.802
Belgium	0.477	0.379	0.351	0.285
Denmark	0.734	0.853	1.037	0.837
Netherlands	1.045	0.952	0.956	0.850
Norway	0.305	0.326	0.463	0.396
Sweden	2.517	2.216	2.457	2.222
Switzerland	5.601	5.820	5.796	5.152
Finland	0.313	0.500	0.786	1.178
Ireland	0.090	0.110	0.118	0.143
Australia	0.403	0.516	0.691	0.925
New Zealand	0.251	0.284	0.440	0.563
Spain	0.172	0.158	0.200	0.184
Brazil	0.011	0.013	0.022	0.026
Argentina	0.045	0.070	0.068	0.068
Hong Kong	0.015	0.015	0.036	0.067
Taiwan	0.011	0.010	0.028	0.075
Korea	0.001	0.003	0.007	0.016
Mexico	0.025	0.027	0.031	0.027
Standard dev	1.461	1.423	1.296	1.193

a The index is defined as follows: Index = [PAT/(POP • X/GDP)]. relative to average of the sample. where PAT= Patent applications filed in other countries; POP= Population; X = Exports in constant prices; GDP= Gross national product in constant prices.

Table 2 Index of technological level (R&D data)[a]

	1963-68	1969-73	1974-79	1980-82
USA	1.821	1.558	1.413	1.407
Japan	1.636	1.576	1.584	1.711
FRG	1.581	1.681	1.689	1.740
France	1.690	1.338	1.218	1.211
UK	1.745	1.505	1.340	1.400
Italy	0.774	0.775	0.707	0.703
Canada	1.254	1.004	0.869	0.914
Austria	0.436	0.537	0.747	0.841
Belgium	1.200	1.206	1.113	
Denmark	0.654	0.836	0.788	0.776
Netherlands	1.963	1.840	1.624	1.363
Norway	0.818	1.030	1.096	0.928
Sweden	0.971	1.100	1.316	1.472
Switzerland	2.595	2.025	1.933	1.661
Finland	0.414	0.740	0.820	0.885
Ireland	0.589	0.651	0.658	0.573
Australia	1.091	1.056	0.812	0.725
New Zealand	0.523	0.669	0.682	
Spain	0.174	0.229	0.284	0.290
Brazil			0.528	0.435
Argentina	0.218	0.176	0.284	0.363
Hong Kong				
Taiwan	0.425			
Korea	0.305	0.291	0.495	0.602
Mexico	0.120	0.176		
Standard	0.665	0.537	0.454	0.450

a Civil R&D in percentage of GDP relative to average in the sample.

The indexes of technological level reveal several interesting facts. Firstly, as can be seen from the standard deviations, the absolute differences in technological levels between countries are greater on the patent-based index than on the index based on R & D data. This is consistent with the assumption that patent statistics measure innovative activities, while R&D data measure both innovative and imitating activities. Secondly, the ranking of the countries is very similar on the two indexes. For instance, the seven technologically most advanced countries in the early 1960s, according to patent statistics, were Switzerland, USA, FRG, Sweden, France, UK, and the Netherlands. With one exception these countries also were the technologically most advanced according to R&D statistics. A similar relation holds for later periods. Thirdly, the two indexes give broadly the same picture of the changes in relative technological position through time. Both indexes show an increase in the technological levels relative to other countries for countries like Japan, Finland and Korea, and a similar decrease for "old super-powers" like US, UK and the Netherlands. Furthermore, it may be noted that both indexes show a decreasing technological gap (measured in terms of standard deviation) from the early 1960s to the early 1980s. But this process seems to have slowed down in the late

1970s.

Table 3 presents a formal test of the relation between the two measures of technological level. Since the relation between them is non-linear, and the ranking is what interests most, the test is performed by calculating the Spearman rank correlation separately for each period. The test shows a strong positive correlation between the two rankings, significant at a 1 percent level at a one-tailed test. Table 3 also presents similar tests of the relation between the technological level on the one hand, and the level of economic development measured as GDP per capita in fixed prices on the other hand. In both cases a positive correlation existed between the two rankings, significant at a 1 percent level at a one-tailed test.

Table 3 Rank correlations – economic and technological level

	1960/63-68	1969-73	1974-79	1980-82/83
R&D index/ Patent index[a]	0.784	0.829	0.839	0.827
R&D index/ GDP per capita[a,b]	0.642	0.677	0.709	0.701
Patent index/ GDP per capita[b,c]	0.837	0.826	0.838	0.795

a Sample = 20.
b Fixed prices, at the price levels and exchange rates of 1980.
c Sample= 25.

In summary, the results of this section support the general hypothesis of the technology gap theory of a strong positive relation between the level of technological and economic development.[12] However, this is only a first step in testing the theory. Of particular interest is whether or not the technology gap theory may explain the differing growth performance of industrial countries in the post-war period. This will be discussed in the next section.

3. Technology gaps, innovation and economic growth

The technology gap approach, following Schumpeter (1934, 1939,1947) , analyses economic growth as the combined result of two conflicting forces; innovation which tends to increase technological gaps, and imitation or diffusion which tends to reduce them. Countries on a comparatively low economic and technological level may realize higher growth rates than other countries by exploiting the potential for imitation. But this is certainly no "law". It depends both on their own efforts and the innovative efforts of the more advanced countries in increasing the "gap".

Attempts to test models which explain economic growth (or productivity growth) as

[12] This confirms the results obtained earlier by Pavitt and Soete (1982). They tested the correlation between GDP per capita. US patents per capita and R&D expenditure per capita in selected years up to 1977 for a sample of 14-15 OECD countries. The results indicated a positive and significant correlation between economic and technological level, especially after 1963.

a function of both technology gaps and efforts or "capacity" for exploiting the gap have been made by Parvin (1975), Cornwall (1976, 1977), Marris (1982) and Lindbeck (1983). In general, these studies show that both technology gaps, measured (in different ways) by GDP per capita, and efforts in exploiting it, measured by investment ratios, have significant influences on growth. However, a common omission in all these models and tests is that they do not include any variable measuring differing trends in innovativeness between countries, as pointed out by Pavitt (1979/1980). According to Pavitt this is a major weakness, because innovation plays an increasingly important role in the process of growth.

Pavitt and Soete (1982) have tried to extend the models developed by Cornwall (1976, 1977) and others by including US patents per capita and growth in US patents. The model was tested for seven different time periods using cross-sectional data for the period 1890-77 covering 14 OECD countries. The results do not seem to indicate any stable relations between the variables involved for the period as a whole. Surprisingly, the "gap" variable (relative GDP per capita) does not seem to influence economic growth, except for the period 1970-77, and then with an opposite sign of what could be expected. A significant positive effect of patent growth on economic growth between 1950 and 1970 turns to a significant negative effect in the period 1970-77. The level of patents does not seem to matter much, except for the last period, and then with a negative sign. Pavitt and Soete also tested alternative models, replacing either economic growth with productivity growth as the dependent variable, or patent statistics with R&D statistics, as independent variables. The results were not qualitatively different, with the exception that the "gap" variable performed better when productivity growth was taken as the dependent variable.

Generally, the results obtained by Pavitt and Soete cannot be interpreted as fully supporting the technology gap approach. Pavitt's assumption of the increasing importance of innovativeness for growth does not seem to get any support at all. One possible reason for this somewhat disappointing result may be the inclusion of both a technological level variable and an economic level variable in the same model. These variables reflect to a high degree the same basic relationship and are – as shown by Pavitt and Soete themselves – closely correlated. By including both types of variables in the same model, and by estimating on cross-sectional data only, a problem of multicollinearity appears.

Although, the general approach of this paper is quite close to that of Pavitt and Soete, the test presented in the following differs from their test in several respects. Firstly, in terms of model specification, the model does not include more than one "gap" variable; GDP per capita. This variable was preferred for two reasons: (1) As shown in the previous section, the ranking according to GDP per capita and patent- or R&D-based indexes of technological development was quite close. (2) The other two indexes have some disadvantages compared with the GDP index. The patent index clearly overestimates the absolute differences in technological level between countries, and R&D data do not exist for several countries and periods.

A second difference between this test and that of Pavitt and Soete is that the sample in this test is not limited to OECD countries, but includes some of the more important industrial countries of the non-OECD area as well. The importance of including these countries in testing a technology gap theory can hardly be questioned. Thirdly, the present test differs from that of Pavitt and Soete in the method of estimation. While Pavitt and Soete estimated on cross-country data from different periods, this test uses a pooled time-series cross- country data set. Both methods, of course, have their advantages and problems, but in the present context the latter method should be more efficient because it uses more information.[13]

In general, the model tested contains three variables; the potential for imitation, the efforts mobilized in exploiting this potential and the growth of innovating activity. For reasons mentioned above, GDP per capita (TG) was chosen as a measure of the potential for imitation. As in most other studies the investment share (INV) was chosen as an indicator of the efforts in exploiting the potential for imitation. This is, of course, a simplification since institutional factors obviously are very important for imitation and the associated structural changes to take place. But the share of investment may also be seen as the outcome of a process in which institutional factors take part; i.e. differences in the size of the investment share reflect differences in institutional systems as well. To measure growth in innovative activity, growth in patent applications abroad (PAT) was chosen. In theory, growth in R&D could have been used instead, but since R&D data are lacking for several countries and periods, this was not possible.

The following variables were used:

GDP_i = growth of gross domestic product in country *i* in constant prices

TG_i = gross domestic product per capita in country *i* in constant 1980 market prices (1000 USD)

PAT_i = growth of patent applications from residents of country *i* in other countries

INV_i = gross fixed investment in country *i* as percentage of GDP in constant prices

W = growth of world trade in constant prices

Since annual observations are heavily affected by short-run fluctuations, average values of the variables covering whole business cycles were calculated, using the "peak" years 1968, 1973, 1979 and 1983 (final year) to separate one cycle from the next. As mentioned above, this gives a pooled cross-country time-series data set with a maximum of 100 observations for each variable. Further information regarding the data is given in a separate appendix to this paper.

Two different versions of the model were tested:

(1) GDP = *f*(TG, PAT, INV)
(2) GDP = *f*(Tga, PATa, INVa, W)

[13] Cross-country estimates are confined to the relation between variables at a specific point of time. Pooled data sets combine this information with information on the overall changes in, for instance, growth, technology gaps and growth of innovative activity through time.

The first model may be regarded as a pure "supply-side" model where economic growth is supposed to be a function of the level of economic development TG (negative), the growth of patenting activity PAT (positive) and the investment share INV (positive). However, it can be argued that this model overlooks that differences in the overall growth rate between periods also are heavily affected by other factors, especially differences in economic policies. According to Maddison (1982), who generally favours a technology gap approach to economic growth, the economic slowdown in the 1970s could partly be explained by too "cautious" economic policies. The second model takes this into account by assuming that the average growth rate of all countries is determined by the growth of world demand, but that the deviations from this average growth rate are determined by the three technology gap variables mentioned above. It may be regarded, then, as an extreme "Keynesian" version of the general technology gap model. In this version, all variables (except the growth rates of GDP and world demand) are expressed as the difference between the value of the variable for country *i* and the average value of the variable for all countries in the sample.[14]

To test the sensitivity of the results for changes in sample and periods, each model was tested for three different samples: (1) all countries, (2) OECD countries and (3) small and medium-sized OECD countries (SMD = OECD countries less USA and Japan), and three periods: (a) 1960-83, (b) 1960-73 and (c) 1974-83. To test for serial correlation in the residuals of the cross-sectional units, we used the Durbin-Watson statistics adjusted for gaps (DW(g)).[15]

The results are given in table 4.

[14] This implies that the average value of each of the variables TGa, PATa, INVa in each period in this transformed data set is defined as zero. Thus, the growth rate (GDP) of an "average" country, defined as having average values of these three variables, would be determined exclusively by the growth in world demand (W) (and the constant term).

[15] This test was suggested to me by Professor Ron Smith of Birkbeck College. London. What it implies is that we leave out the differences between the residuals of different cross-sectional units, and the corresponding residuals, from both the numerator and the denominator, thereby reducing the number of observations by one per cross-sectional unit. Given the short time series, this test was applicable to the 1960-83 period only.

Table 4 The technology gap approach tested

All countries, 1960-83 (N = 99)

```
GDP  = 2.04-0.19TG+0.18PAT+0.13INV,                R2  = 0.67
       (1.99) (-3.90)  (7.79)       (3.21)          SER = 1.56,   DW(g) = 1.56
        **      *        *            *

GDP  = 0.29-0.19TGa+0.13PATa+0.14INVa+0.55W,       R2   = 0.75
        (0.97) (- 4.64)  (5.47)     (3.70)    (12.62)      SER =1.35,   DW(g) =1.56
                  *        *          *          *
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OECD countries, 1960-83 (N = 76)

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GDP  = 1.02-0.14TG+0.18PAT +0.16INV,               R2  = 0.68
         (1.03) (- 2.46)  (6.62)     (4.07)         SER =1.21,   DW(g) = 1.81
                   *        *          *

GDP  = 0.51-0.13TGa+0.09PATa+0.16INVa+0.51W,       R2   = 0.79
       (2.20) (- 2.72)      (2.86)  (4.87)     (14.35)      SER = 0.98,   DW(g) = 2.36
        **      *             *       *           *
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SMD countries, 1960-83 (N = 68)

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GDP  = 0.44-0.17TG+0.16PAT+O.19INV,                R2   = 0.60
        (0.38) (- 2.74)  (5.26)   (3.82)            SER =1.22,   DW(g) =1.81
                  *        *        *

GDP  = 0.46-0.14TGa+0.03PATa+0.15INVa+0.50W,       R2   = 0.78
       (2.04) (-3.04)  (1.02)       (3.76)   (14.55)       SER = 0.90,   DW(g) = 2.26
        **      *                     *         *
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All countries, 1960-73 (N = 49)

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GDP  = 3.02- 0.32TG + 0.10PAT +0.17INV,            R2   = 0.54
       (2.26) (- 4.00)   (2.41)     (2.80)          SER = 1.47
        **       *         *          *

GDP  = 5.78-0.31TGa+0.13PATa+0.14INVa-0.09W        R2   = 0.60
       (2.10) ( -4.11)  (3.09)       (2.43)   ( -0.30)      SER = 1.39
        **       *        *            *
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OECD countries, 1960-1973 (N = 38)

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GDP  = 1.91-0.18TG+0.09PAT+0.17INV,                R2    = 0.50
       (1.54) (- 2.17)  (2.06)    (3.16)            SER  = 1.10
        ***     **       **         *

GDP  = 5.10-0.21TGa+0.12PATa+0.15INVa-0.02W,       R2    = 0.59
        (2.26) (-2.62)+ (2.95)       (2.91)   (-0.07)       SER  = 1.02
         **       *       *            *
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SMD countries, 1960-73 (N = 34)

```
GDP  = 4.01-0.14TG+0.02PAT+0.081NV,                R2     = 0.12
        (2.72) ( -1.61)  (0.46)   (1.07)            SER   = 1.00
         *       ***             ****

GDP  = 3.01-0.18TGa+0.05PATa+0.08INVa+0.21W,       R2     = 0.26
      (1.33) (- 2.13)  (1.16)       (1.25)    (0.80)        SER   = 0.94
       ***      **      ****          ****
```

All countries, 1974-83 (N =50)

GDP = -1.82-0.10TG+0.12PAT+0.24INV, R2 = 0.70
(-1.27) (- 2.01) (4.13) (4.48) SER = 1.29
**** ** * *

GDP = 0.32-0.11TGa+0.11PATa+0.22INVa+0.59W, R2 = 0.75
(0.81) (-2.22) (4.26) (4.43) (4.63) SER = 1.19
** * * *

OECD countries, 1974-83 (N = 38)

GDP = -1.74-0.08TG+0.03PAT+0.21INV, R2 = 0.51
(-1.51) (-1.43) (0.65) (5.01) SER = 0.91
*** *** *

GDP = 0.72-0.07TGa+0.03PATa+0.19INVa+0.43W, R2 = 0.59
(2.35) (-1.29) (0.62) (4.76) (4.18) SER = 0.84
** **** * *

SMD countries, 1974-83 (N = 34)

GDP =- 2.34-0.10TG+0.03PAT+0.24INV, R2 = 0.51
(-1.90) (-1.72) (0.71) (4.93) SER = 0.89
** ** *

GDP = 0.64-0.09TGa+0.02PATa+0.21INVa+0.44W, R2 = 0.58
(1.94) (-1.60) (0.55) (4.44) (4.07) SER = 0.84
** *** * *

Method of estimation: Ordinary least squares
* = significant at a 1% level (one-tailed test); **=significant at a 5% level (one tailed test);
***=significant at a 10% level (one-tailed test); * * * * =significant at a 15% level (one-tailed test).
SER =Standard error of regression; DW(g) =Durbin-Watson statistics adjusted for gaps.

For the period as a whole, the technology gap models explain a large part of the actual differences in growth rates, both between countries and between periods. As expected, both GDP per capita, patent growth and the investment ratio appear as powerful explanatory factors of economic growth, even if the effect of GDP per capita decreases somewhat when the non-OECD countries are removed from the sample. Both models give essentially the same picture, but the effect of growth in patenting activity is somewhat smaller in the "Keynesian" model than in the "supply-side" model. This is not surprising since in the "Keynesian" model the general slowdown in economic growth in the 1970s is explained by the slowdown in world demand, while in the "supply-side" model this is taken care of mainly (but not exclusively) by the slowdown in patenting activity. Both models go a long way in explaining the differences in economic growth, both between countries and periods, but in terms of fit the "Keynesian" is in general the most successful one.[16]

When the models are estimated on data before and after 1973, some interesting results emerge. Notably, for all three groups of countries, the effect of GDP per capita

[16] This may be interpreted in support of Maddison's view, i.e., that differences in demand policies between periods have significant effects for economic growth, and that a large part of the economic slowdown in the 1970s may be explained in this way.

decreases from 1960-73 to 1974-83, while the effect of the investment ratio increases. Keeping in mind that the technology gaps were significantly reduced from the 1960s to the 1970s, one possible explanation is that the cost of imitation has increased as the distance to the world innovation frontier has decreased. Another interesting result is that when the non- OECD countries, and later USA and Japan, are removed from the sample, the "technology variables" become gradually less important, even if the signs of the coefficients do not change. For the group of OECD countries, patent growth ceases to influence growth after 1973, and for the group of small and medium-sized developed countries this variable does not seem to have significant effects on economic growth, neither before, nor after 1973. In general, for this group of countries, the patent growth variable may explain some of the slowdown in the 1970s, but it does not explain "why growth rates *differ"* between countries.

The last result calls for some reflection. Obviously, it is not very surprising that technology gap models are better suited for a sample of industrial countries on different levels of development than for a sample of countries on approximately the same level of development. But it is surprising to find that differences in the growth of innovative activities seem to have strong effects on the differing growth performance of industrial countries in general, but much less so for the developed countries, especially the small and medium-sized ones. In terms of data, it is not difficult to see why. For the period as a whole, only a few countries have trends in innovative activities that differ much from other countries; Japan, Finland, Korea, Taiwan, Hong Kong and to some extent Brazil. When the majority of these countries is excluded from the sample, it is not surprising that the importance of the variable is reduced.

To test the sensitivity of this result for the way data were handled, two additional tests were carried out. First, for the OECD countries as well as the SMD countries, a three-year lag was introduced for the patent growth variable. This did not alter the result significantly. Second, a cross-country regression was carried out for the period 1979-83, replacing the patent growth variable based on WIPO statistics with the growth of total external patent applications *including patent applications through international channels (EPC / PCT).* Because of data limitations, only 11 countries were included in the regression. The result was that when USA and Japan were included, the patent growth variable was significant, otherwise not.

Many of the countries included in the test, among them the non-OECD countries, had a very low level of patenting activity in the early 1960s (and still have) compared to other countries. It may be dangerous to draw conclusions from high growth rates when the initial levels were very low. However, in terms of R&D, where the initial levels were higher, the tendencies seem to be the same for countries where data exist. Japan had a very high share of civil R&D in GOP in the early 1960s compared to other countries. Nevertheless, its share has grown very rapidly and currently enjoys the highest level in the world. Finland and Korea both had rather low shares compared to other countries in the 1960s, but they grew very rapidly throughout the 1970s, and both countries have now (1982/83) shares close to the average of the sample. Thus, the available evidence seems to support that these countries have followed a separate way of development characterized by rapid imitation, high growth in innovative activities and rapid economic growth.

4. Conclusions

The main findings of this paper are the following:

(1) There exists a close correlation between the level of economic development measured as GDP per capita, and the level of technological development, measured through R&D or patent statistics.

(2) Technology gap models of economic growth explain rather well the differences in growth between the industrialized countries as a whole in the post-war period. Both the scope for imitation, growth in innovative activity and "efforts" to narrow the "gap" (investment) seem to be powerful explanatory factors of economic growth. This has not changed qualitatively after 1973, but the scope for imitation seems to have decreased and the costs of imitation increased, compared with the 1960s.

(3) The models are less well suited in explaining the (much smaller) differences in growth between developed countries, especially the small and medium-sized ones, most of which are on approximately the same level of development.

The findings of this paper confirm that many of the small and medium-sized European countries have attained very high levels of GDP per capita with moderate levels of innovative activity. Thus, to explain the differences in growth between these countries in the post-war period, a much more detailed analysis of economic, social and institutional structures should be carried out. The prospects for this group of countries will partly depend on whether or not competition through innovation will be the dominant form of competition in international markets in the future. The decreased scope for imitation which is revealed in this study and the general upturn in R & D efforts during the last years may be taken as an indication of a growing importance of technological competition on the international level. If correct, this implies that the future growth of the small and medium-sized European countries in part depends on their ability to change the trend towards a stagnating innovative level compared to other countries.

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Appendix

Methods

Growth rates are calculated as geometric averages for the periods 1960-68, 1968-73, 1973-79 and 1979-83, or the nearest period for which data exist. Levels and shares are calculated as arithmetic averages for the periods 1960-67, 1968-73, 1974-79 and 1980-83, or the nearest period for which data exist.

Sources

Real GDP per capita, 1980market prices in US$:
Taiwan: *Statistical Yearbook of the Republic of China 1984*.
Other countries: *IMF Supplement on Output Statistics*

Growth of gross domestic product in constant prices:

OECD countries: *OECD Historical Statistics 1960-1983*
Hong Kong, Taiwan and Korea 1960-73: E.K. Chen. *Hyper-growth in Asian Economies* (MacMillan, London. 1979)
Taiwan 1973-83: *Statistical Yearbook of the Republic of China 1984*
Hong Kong and Korea 1973-83 and Mexico, Argentina and Brazil: *IMF Supplement on Output Statistics*

Gross fixed capital formation as percentage of GDP:

OECD countries: *OECD Historical Statistics 1960-1983*
Taiwan: *Statistical Yearbook of the Republic of China 1984*
Other countries: *IMF Supplement on Output Statistics*

External patent applications:

OECD countries: *OECD / STIIU DATA BANK*
Other countries: World International Property Organisation (WIPO): *Industrial Property Statistics*, various editions and unpublished data.

The OECD data are adjusted WIPO data. Data for the non-OECD countries are compiled from published WIPO statistics except for Hong Kong, Korea and Taiwan 1975-83, where data are compiled by WIPO from unpublished sources. Unfortunately, the quality of the data for some of the non-OECD countries prior to 1975 is far from perfect. To avoid year-to-year fluctuations, caused mainly by bad statistics, from influencing the calculated growth rates, some efforts were made to adjust the growth rates accordingly (see table A3 for details).

R&D as percentage of GDP:

The R&D data are estimates based on the following sources:

OECD countries: *OECD Science and Technology Indicators. Basic Statistical Series (vol B (1982)* and *Recent Results (1984)).* Other countries: *UNESCO Statistical Yearbook* (various editions) and various *UNESCO surveys on resources devoted to R & D*

Military R & D expenditures were, following OECD, assumed to be negligible in all countries except US, France, FRG, Sweden and UK. The R&D data for these countries were adjusted downward according to OECD estimates. The estimates were taken from OECD, Directorate for Science, Technology and Industry: *The problems of estimating defence and civil GERD in selected OECD member countries* (unpublished). For other countries, civil and total R&D as percentage of GDP were assumed to be identical.

Population and export shares in GDP:

Data on population and export shares in GDP were taken from: *OECD Historical Statistics 1960-83, OECD National Accounts* (various editions), *IMF Supplement on Output Statistics, UN Monthly Bulletin of Statistics* (various editions) and *Statistical Yearbook of the Republic of China 1984.*

Growth of world trade at constant prices:

The growth of total OECD imports was used as proxy (8.1, 9.4, 4.0, 1.3). The data were taken from: *OECD Historical Statistics 1960-1983.*

Table A1. Growth of real GDP

	1960-68	1968-73	1973-79	1979-83
USA	4.5	3.3	2.6	0.7
Japan	10.5	8.8	3.6	3.9
FRG	4.2	4.9	2.4	0.5
France	5.4	5.9	3.1	1.1
UK	3.1	3.2	1.4	0.4
Italy	5.7	4.6	2.6	0.6
Canada	5.6	5.6	3.4	0.8
Austria	4.2	5.9	2.9	1.5
Belgium	4.5	5.6	2.2	0.9
Denmark	4.6	4.0	1.9	0.9
Netherlands	4.8	5.3	2.6	-0.3
Norway	4.4	4.1	4.9	2.3
Sweden	4.4	3.7	1.8	1.2
Switzerland	4.4	4.5	-0.4	1.4
Finland	3.9	6.7	2.4	3.3
Ireland	4.2	4.8	4.6	2.2
Australia	5.0	5.5	2.6	1.7
New Zealand	3.1	5.1	0.6	2.1
Spain	7.5	6.8	2.5	1.2
Brazil [a]	8.5	9.3	6.8	0.8
Argentina	2.8	3.2	2.3	-1.9
Hong Kong	8.5	8.4	8.3	6.7
Taiwan	9.0	10.6	8.0	5.6
Korea	7.6	10.7	9.0	4.5
Mexico	6.7	6.6	5.9	2.6

a 1962-82

Table A2 Real GDP per capita (1980 market prices in US$)

	1962-67	1968-73	1973-79	1979-82
USA	9419	10746	11905	12706
Japan	4018	6365	7827	9063
FRG	7374	9132	10618	11806
France	6530	8311	10004	11000
UK	6836	7788	8726	9054
Italy	3972	5075	5864	6486
Canada	7310	8961	10624	11157
Austria	5139	6624	8180	9198
Belgium	6133	7823	9516	10186
Denmark	8264	9889	10975	11571
Netherlands	7070	8857	10214	10586
Norway	7993	9550	11668	13385
Sweden	9638	11399	12797	13368
Switzerland	12177	14317	15010	15855
Finland	5848	7485	8891	10004
Ireland	3285	4059	4718	5024
Australia	7796	9429	10262	10775
New Zealand	6135	6890	7495	7249
Spain	3056	4047	4935	5054
Brazil	1024	1366	1954	2217
Argentina	2166	2583	2786	2652
Hong Kong	1676	2389	3436	4710
Taiwan	0490	0780	1448	2037
Korea	0592	0871	1337	1613
Mexico	1227	1546	1844	2133

Table A3. Growth in external patent applications

	1960-68	1968-73	1973-79	1979-83
USA	6.7	-1.7	-6.1	-4.3
Japan	22.8	10.9	0.9	1.0
FRG	5.2	0.7	-6.7	-8.7
France	6.3	0.5	-6.1	-4.8
UK	3.1	-2.4	-9.5	-2.2
Italy	5.9	0.6	-0.3	-8.7
Canada	5.7	2.9	-5.7	-3.2
Austria	4.5	3.0	-5.0	-6.5
Belgium	5.9	-5.8	-8.7	-4.4
Denmark	8.6	-3.0	-5.8	-2.9
Netherlands	2.2	-1.4	-4.6	-9.2
Norway	1.2	5.9	-6.2	-7.3
Sweden	5.3	0.0	-4.5	-4.9
Switzerland	5.2	0.6	-7.3	-9.1
Finland	10.0	8.1	4.0	4.2
Ireland	10.4[a]	7.9	-2.7	-6.6
Australia	5.1	9.4	-1.7	-2.7
New Zealand	-0.7	10.3	1.7	-2.4
Spain	8.8[a]	2.0	-2.7	-9.0
Brazil	7.5[a]	16.0	3.4	-19.2
Argentina	16.3[a]	1.4	-3.8	-15.9
Hong Kong	8.8[a]	4.2	14.8	0.0
Taiwan	22.2[a]	17.9[b]	21.0[d]	12.7
Korea	n.a.	13.5[c]	16.3[d]	18.9
Mexico	-0.6[a]	4.8	-9.5	1.1

a 1969/70-1964/65, b 1968-75, c 1969-75, d 1975-79.

Table A 4. Gross fixed capital formation as percentage of GDP

	1960-67	1968-73	1974-79	1980-83
USA	18.0	18.3	18.3	17.4
Japan	31.3	34.7	32.0	30.4
FRG	25.2	24.4	20.9	21.5
France	22.3	23.3	22.7	20.9
UK	17.8	19.2	19.4	16.9
Italy	21.7	20.6	20.0	19.2
Canada	22.1	21.6	22.9	21.8
Austria	26.4	27.2	26.4	24.0
Belgium	21.6	21.7	21.9	18.3
Denmark	23.4	24.4	22.1	16.7
Netherlands	25.0	25.0	20.9	19.2
Norway	29.0	27.4	32.9	25.8
Sweden	23.9	22.6	20.6	19.2
Switzerland	28.0	27.9	22.7	23.6
Finland	26.6	26.2	27.2	24.9
Ireland	18.7	23.3	26.1	26.7
Australia	25.8	25.3	22.7	23.1
New Zealand	21.1	20.8	23.2	21.4
Spain	20.2	22.7	21.6	19.5
Brazil	18.6[a]	25.3	27.2	21.7[b]
Argentina	18.6[a]	24.6	25.1	19.5[b]
Hong Kong	26.7[a]	21.7	28.1	32.8
Taiwan	15.4	23.1	27.8	28.3
Korea	17.4[a]	25.6	30.3	28.2
Mexico	18.5[a]	21.1	23.6	26.1[b]

a 1962-67, b 1980-82.