A
CROSS-COUNTRY, CROSS-INDUSTRY COMPARISON OF THE BEHAVIOR OF SOLOW RESIDUALS

Donna M. Costello†

Department of Economics
University of Rochester
Rochester, NY 14627

July 1989

†I would like to thank Mark Bils and Alan Stockman for their advice. I would also like to thank Tom Cooley, Linda Tesar and participants at the International Workshop at the University of Rochester for helpful comments on an earlier draft. All errors, of course, remain my own.

1. Introduction

The pioneering work by Kydland and Prescott (1980,1982) and prominent papers by, among others, Long and Plosser (1983), Hansen (1985), and King, Plosser and Rebelo (1988) emphasize productivity shifts as important sources of fluctuations in output. The propagation mechanism of these shocks across time, and recently across countries (Backus and Kehoe (1988), Baxter and Crucini(1989)), plays an important role in real business cycle models. A central measurement issue is whether the variance of the technology shock needed to generate fluctuations that mimic the data corresponds in size to actual technology shocks. Prescott (1986) and Hall (1987) have calculated measures of technology growth for the United States, but less is known about the properties of technology shocks that arise from different industries within a nation or about technology shocks in nations other than the United States.

Scepticism of real business cycle models has centered on the nature of these technology shocks. If these shocks refer to changes in the technical relationship between inputs and outputs then any specific innovation should affect the production of only a few goods. The technology shocks across industries within a country should be independent, so the average innovation across industries would be low relative to a shock in any specific industry. At the international level, an industry's productivity growth would be correlated across countries but, not across industries within any one country. This criticism applies to the subset of real business cycle models in which industry-specific shocks play a major role as in Long and Plosser (1983). However, if technology shocks are country-specific, and not industry-specific the proponents of real business cycle theories will need to specify what these "technology shocks" represent.

A stylized fact is that fluctuations in detrended output are correlated across countries (see e.g. Dellas (1985), Baxter and Stockman (1988)). We also know that output is correlated across industries in the United States. There are alternative explanations for these facts. According to real business cycle theory outputs move together because the underlying Solow residuals are highly correlated. Other competing theories argue that if countries interact in international markets, changes in output in one country are transmitted to other countries.

Stockman (1988) examines cross-country output data to test these hypotheses. Using an errors components model he isolates changes in output that are due to nation-specific shocks from changes in aggregate output that are associated with industry-specific disturbances. He finds evidence that both nation and industry shocks are important. Norrbin and Slagenhauff(1989) extend Stockman's work by employing dynamic factor analysis and also find evidence of both nation and industry effects. Hall (1988) makes use of Solow's (1957) measurement of technology change to investigate the relationship between productivity growth and output growth in industries and the aggregate productivity growth for the U.S. economy. He finds evidence that suggests that productivity shifts may be a major driving force for output fluctuations.

In this paper I study the nature of productivity growth, as measured by Solow residuals, in five manufacturing industries, in six countries. Some of the questions I address are the following: Are aggregate technology shocks correlated across countries? Are industry shocks correlated with national shocks and/or are industry shocks correlated across countries? How important are nation-specific versus industry-specific disturbances for productivity growth variation?

I consider three complementary methods to investigate the stochastic properties of productivity growth. In section three I present cross-correlations and autocorrelation functions of Solow residuals for five two-digit manufacturing industries in seven countries. In section four I decompose total world productivity into the variation due to each industry and nation, where the world is defined as the weighted sum of the countries in the sample. In section five I employ an errors-components model to estimate industry-specific and nation-specific disturbances and the fraction of technology growth attributed to each.

I find that output growth and productivity growth have strikingly different behavior. Output growth is correlated across both countries and industries, but aggregate productivity growth is only weakly correlated across countries. At the industry level, productivity growth is significantly correlated across industries within a country but is only weakly correlated across countries for any individual industry. The results suggest that nation-effects are as important, if not more important than industry-effects. The general conclusions are robust to the type of filter employed and the method of measuring the capital input.

2. Productivity measurement and data

Throughout the paper I make use of the method of productivity measurement introduced by Solow (1957). This common method of measuring technological change is defined as the change in output less the sum of the changes in labor's input times labor share and the change in the capital input times capital share. The formula for productivity growth λ is:

$$\lambda = \Delta y - \alpha\Delta\ell - (1-\alpha)\Delta k$$

where Δ y, $\Delta\ell$, and Δk are the growth rates of output, labor, and capital. I assume competitive conditions and constant returns to scale so that α is equal to labor's share in total revenue and $(1-\alpha)$ is capital's share in total revenue. Measuring the variables in logs, this is the percentage change in the technology parameter of the Cobb-Douglas production function.

I study productivity residuals for 1957-1985 in five manufacturing industries; food, beverages and tobacco (31), textiles (32), chemicals (35) basic metals (37), and metal manufacturing (38), in six countries; the United States, Canada, Japan, the United Kingdom, Germany, and Italy. In section four I study world productivity growth, where the world is defined as these six countries. The industries are classified according to the International Standard Industrial Code.

The questions addressed in this paper deal with the common element of productivity growth across countries for a given industry, the common element across industries for a given country, as well as aggregate productivity across countries. The residual for industry i in country j is denoted by:

$$u_j^i = \Delta y_j^i - \alpha_j^i \Delta \ell_j^i - (1 - \alpha_j^i) \Delta k_j^i$$

Labor's share α, and therefore capital's share $(1 - \alpha)$, will be allowed to vary across both countries and industries.

Since the most important aspect of this study is the behavior of the Solow residual, great care was taken in constructing each of the variables. The labor input variable is measured as total hours worked. The data are total hours for the five two-digit manufacturing industries, and total hours for total (aggregate) industry for the six countries. The variable total hours was constructed by multiplying employment times average hours. The data come from various international and country sources. All data are described in full in the data appendix. Ideally aggregate hours for total industry should include hours worked by all workers, not just those in manufacturing. Unfortunately, other than the United States, the data available for non-manufacturing sectors is either not available for any length of time or there were other severe problems with the published numbers. Hall(1988) finds that three-fourths of the productivity variation for the United States comes from manufacturing industries. This suggests that by including only manufacturing industries we will systematically overestimate the volatility of the aggregate Solow residuals. Given these constraints, I proceeded by considering the best measure of total hours available for all industries in the country, henceforth referred to as total industry, and measured aggregate output as industrial production.

It is often argued that the measurement of the capital input is less important than the measurement of labor since the net capital stock does not move much over the business cycle. However, it is possible that capital utilization is more volatile than the capital stock over the cycle. If so, then measuring the capital input as simply the net capital stock will underestimate the volatility of capital and the measurement of the capital input should incorporate the utilization of capital. There are many possible ways to measure the usage of capital. In this study I use electricity consumption as an indicator of the capital input. One advantages of using electricity consumption is that it is a perfectly homogeneous input of invariant quality and hence presents no measurement problems that are common to other methods of capital measurement. Secondly, electricity cannot easily be stored; hence the electricity flow into a process corresponds exactly to the amount used in the process. There remains, however, the problem that the relationships between capital services and electricity consumption may change with time. Ideally electricity consumption should be adjusted by some independent measure of the quantity of electricity necessary to operate the capital stock. I assume that the relationship between capital services and electricity consumption has remained constant and use electricity consumption measured in kilowatts per hour as a proxy for the capital input. Heathfield (1972) calculates capital usage for six manufacturing industries in the U.K. for the years 1955-1965 using electricity consumption and compares them to other measures of capital usage. Electricity use compares favorably to the other measures. Since the measurement of capital is controversial, I also consider the fixed capital stock as a measure of the capital input. The results are somewhat sensitive to the method of capital measurement. I report the results from both measures.

Labor's share in total output, α, is measured as total compensation divided by gross domestic product net of indirect taxes. Labor compensation is measured gross of fringe, social security, and other costs incurred by the employer. The value of the labor shares for the different countries and industries are presented in Table 1. The value varies across both countries and industries. The food industry has a relatively low labor share and the basic metal industry has a relatively high labor share for all countries.

Output is measured by the index of industrial production. All data are logged and detrended by first differencing. I also employ the Hodrick-Prescott filter. Many general conclusions hold regardless of the detrending method. However, the cross-correlations and standard deviations of the Solow residuals are sensitive to the method of detrending. [1] When appropriate I report the results from both detrend-

[1] This method involves choosing smoothed values ${s_t}_{t=1}^T$ for the series ${x_t}_{t=1}^T$ which solve the fol-

ing procedures.

3. Simple Descriptive Techniques

Figures 1-6 show the behavior of aggregate output growth and productivity growth for the United States, Canada, Germany, Italy, Japan and the United Kingdom over the past thirty years. At the aggregate level output growth and productivity growth appear to move together in most countries. Table 2 presents sample statistics for the, aggregate and industry, Solow residuals and the output series. The mean annual growth rates of output range from a minus one percent for the basic metal industry in the United Kingdom to twelve percent for the basic metal industry in Japan. The standard deviations of change for output growth are low for total industry relative to any individual manufacturing industry (with the exception of the food industry). There is a lot of variation across industries and nations. Standard deviations of change in output growth range from approximately two percent for the food industry in Canada to eleven percent for the Basic Metal industry in Japan.

The mean annual productivity growth rates range from minus 5 percent per year for the metal manufacturing industry in the United Kingdom, to six percent per year in the basic metal industry in Japan. The standard deviations of change in productivity growth in individual industries are not on the whole larger than the standard deviations for aggregate productivity growth. If correlated outputs are being driven by innovations which are independent across industries as in Long and Plosser (1983), we would expect to see the standard deviation for the aggregate Solow residual to be smaller than the standard deviation for any particular industry

lowing problem: $min[(1/T)\sum_{t=1}^{T}(x_t - s_t)^2 + (\lambda/T)\sum_{t=2}^{T-1}(s_{t+1} - s_t) - (s_t - s_{t-1})^2]$ where $\lambda > 0$ is the penalty on variation, where variation is measured as the averaged squared second difference. I choose $\lambda = 400$ rather than 1600 because I use annual data.

Solow residual. This suggests that innovations may not be independent across industries and that innovations at the country level are important.

In the U.S., the standard deviation of change in aggregate output growth is larger than the standard deviation of productivity growth. This is consistent with what Prescott finds using quarterly data. Interestingly, although this is true for all of the other countries in the sample, it is not true for most industries. Often the standard deviation of change for the Solow residuals at the industry-level are larger than the standard deviations for output growth of the industry.

Table 3 presents correlation coefficients for aggregate growth rates of output and productivity for all country pairs. Output growth and productivity growth have very different patterns of correlations. Output growth is significantly positively correlated across all country pairs, whereas productivity growth is significantly correlated for only four country pairs. For these four country pairs the correlation is in the range of .39-.80. The correlation between the U.K. and Germany is .39, .46 between Italy and Japan and .80 between the U.S. and Canada. The lack of correlation between underlying productivity disturbances poses a challenge for many real business cycle models. This evidence suggests that correlated Solow residuals alone are not responsible for correlated outputs and that other market interactions may be important in an explanation of correlated output growth across countries.

Interestingly, U.S. productivity growth is significantly positively correlated only with Canadian productivity growth. It also does not appear that countries within Europe are more closely related to each other than they are with the U.S. or Japan.

Table 4a presents cross-correlations for productivity growth between different industries within each country. Several of the correlation coefficients are significant. Productivity growth is positively correlated across manufacturing industries within the United States and Canada. Manufacturing industries are less correlated in Germany, Italy and Japan. Their are three significant positive correlation in Germany, two in Italy, and one in Japan. In only ten out of thirty cases is individual industry productivity growth correlated with aggregate productivity growth.

There does not appear to be much correlation across countries for a given industry. Table 4b presents cross-correlations for productivity growth across countries for each industry. There are only five cases where an industry's productivity growth is correlated (either positively or negatively) across a country pair. Productivity growth in the food industry is negatively correlated for the United States with Japan. Productivity growth in the textile industry in Canada is strongly positively correlated with the textile industry in Germany. If an industry has similar technological processes in all countries then any specific innovation should affect the production of that industry in all countries. However, if technology differs more across countries than across industries within a country then productivity could be more correlated across industries within a country than for any given industry across countries.

However, there are only eight instances where an industry's productivity growth is correlated with aggregate productivity growth. For example, none of the five manufacturing industries in Canada is correlated with aggregate productivity growth in Canada. If technology growth were nation specific any specific innovation should affect all industries. On the other hand, if technology growth is industry specific an innovation should affect similar industries across countries. The cross-correlations suggest that both nation-specific and, to a lesser extent, industry-specific shocks are present.

In this paper, I study only five two-digit manufacturing industries and it is possible that I am missing important information about the transmission mechanism for these technology shocks. It would be interesting to consider the properties of technology growth in other industries. However, Hall(1987) calculates residuals for one-digit SIC industries and finds that most of the productivity growth occurs in manufacturing and trade industries. This suggests that although I consider only manufacturing industries I should be picking up at least some of the main effects.

Table 5 presents cross-correlations of output growth with productivity growth. At both the aggregate level and industry level productivity growth and output growth are positively correlated. Aggregate productivity and aggregate output are highly correlated. The U.S. has the highest correlation (.95) and the U.K. has the lowest (.77). This is a bit of good news for real business cycle proponents. These models have the feature of strong correlations between output and productivity. If productivity shocks are driving output then we should see a positive correlation. However, it is puzzling that although output growth and productivity growth are correlated, correlated productivity growth is not driving correlated output growth across either countries or industries. Output growth and productivity growth are less correlated at the industry level. The correlations are significantly negative in two cases.

Table 6 presents autocorrelation functions for productivity growth by nation. In the majority of cases no lags are significant.

3.1 Lag Effects of Productivity

One possible explanation for the low contemporaneous correlations across countries at the industry level may be that the transmission of technology occurs with a lag. For example, the U.S. may have a positive technology shock today in the chemical industry but the information may not be received in the German chemical industry until next period. If this is true then productivity growth in the chemical industry in Germany should be correlated with the lag of productivity growth in the U.S.. Table 7 presents the cross-correlations between productivity growth in industry i in nation n at time t and time t-1. There is no evidence in support of the idea that technology growth is highly correlated across countries but the transmission of technology takes more than four quarters.

3.2 Differences due to capital measurement and filter employed

Tables 2.a1-5.a1 present the results when the capital input is measured as the gross capital stock. The cross-correlations are sensitive to the method of capital measurement. The main difference between the results based on electricity consumption and capital stock is that at the industry-level productivity growth is more correlated across countries when capital is measured using the capital stock. However, the correlations are still only in the .4 to .8 range. The general conclusions concerning the industry level hold although which industries and which countries are correlated differ substantially. Tables 4aC - 5C present these results.

One possible explanation for why the residuals are more positively correlated when the capital input is measured by the capital stock is that the capital stock is less volatile than electricity consumption. If so, then the Solow residual could be picking up some of the variance in output. Since we know that output growth is positively correlated across industries and countries, we would expect the residuals to be more correlated when the capital input is measured as the capital stock.

The importance of which method of filtering is chosen is illustrated in the results presented in 2.a2-5.a2. Aggregate productivity is much more correlated across countries. Surprisingly, the cross-correlation between productivity in the U.S. and Canada is not significantly different from zero. Except for in the United States productivity growth is even more correlated across industries within a country, In the U.S. the Solow residuals are no longer significantly correlated across industries. There continues to be little correlation across countries for a given industry.

3.3 Conclusions

In summary, simple descriptive techniques suggest that productivity shocks are not correlated across countries for most industries and are weakly correlated across industries within countries. Output growth is positively correlated across all industries and countries. Aggregate output growth and productivity growth are positively correlated. Industry productivity growth and output growth are less correlated. The results are sensitive to filtering and the method of measurement of capital but the general conclusions remain intact.

4. The Decomposition of Total Productivity

In this section I investigate the relationship between world industry productivity growth and national industry productivity growth. I also consider the relationship between world and national productivity growth. The world is defined as the six countries: the United States, the United Kingdom, Japan, Canada, Germany, and Italy.

Since we are interested in the common element of productivity growth within an industry throughout the world it is useful to define world industry output. Define β_j^i as the share of output in industry i in country j relative to world output. Similarly define β^i as the share of output in industry i (over all countries) relative to world output and let β_j denote the share of output in country j (over all industries) relative to world output. Then world output growth in industry i is approximately:

$$\Delta y^i = \sum_{j=1}^{6} \frac{\beta_j^i}{\beta^j} \Delta y_j^i$$

We can define similar measures for aggregate national output, Δy_j and aggregate world manufacturing output, Δy.

$$\Delta y_j = \sum_{i=31}^{38} \frac{\beta_j^i}{\beta^j} \Delta y_j^i$$

$$\Delta y = \sum_{j=1}^{6} \beta_j \Delta y_j = \sum_{i=31}^{38} \beta^i \Delta y^i$$

I assume that all of the β's are constant over time and take them to be equal to their mean over the sample.

We can now define productivity growth for the world (u), each industry in the world (u^i), and for each country's manufacturing industry (u_j). Then

$$u = \sum_{j=1}^{6} \beta_j u_j = \sum_{i=31}^{38} \beta^i u^i$$

$$u^i = \sum_{j=1}^{6} \frac{\beta_j^i}{\beta^i} u_j^i$$

$$u_j = \sum_{i=31}^{38} \frac{\beta_j^i}{\beta_j} u_j^i$$

It is interesting to look at the relationships between these productivity measures. The cross-correlation of total world productivity growth with national and total world industry productivity growth are included in Tables 4a and 4b. World food productivity growth is positively correlated with World metal manufacturing productivity. World textile productivity is positively correlated with World productivity in the basic metal industry. The total World Productivity is correlated only with the basic metal industry world productivity.

World Productivity in the food industry is negatively correlated with Canada's productivity growth in the food industry. Productivity growth in the textile industry in Italy is correlated with World productivity growth. National Productivity growth is correlated with world productivity growth for the U.S. and Canada.

An alternative way of considering the relationship between different industry's productivity growth rates and aggregate productivity growth is to decompose total productivity into the variation due to each industry and nation. To measure the association of industry i's residual with world productivity growth I define δ^i as the coefficient of the regression of u_j^i on Δu^i. Then δ^i is the elasticity of an industry's productivity growth with respect to world productivity growth in the industry. Similarly, let δ_j denote the elasticity of a country's productivity growth with respect to world productivity growth.

The first panel in Table 8 decomposes world productivity growth. Column one gives the elasticity of national productivity to world productivity (δ_j), for both total industry and individual industry. For example, if there is a one percent increase in world productivity growth, productivity in the U.S. increases by 1.16 percent. The second column shows the value share for each country, β_j. The third column is the elasticity multiplied by the value share. This measures the contribution of nation j to fluctuations in world productivity. If technology shocks were strictly industry-specific then a country's contribution to world productivity growth should be equal to its value share in that industry . In general this does not appear to be the case. We see that the values for the contributions are both larger and smaller than the county share in world output.

The elasticities are high for the United States and low for Italy and the U.K.. The United States is by far the largest contributor to fluctuations in world output

(.65). This can be explained by noticing that the U.S. has both the largest elasticity and the largest share in world output. Germany is a distant second with its contribution at only .13.

Table 8 presents the decomposition of world industry productivity growth for each industry. The elasticities are relatively high for industries in the U.S.. For instance, a one-percent increase in productivity in the food industry in the world is associated with a 1.25 percent increase in productivity in the food industry in the U.S.. The elasticities are significantly negative in some cases. A one percent increase in world productivity in the metal industry is associated with a 1.81 percent decrease in productivity in the Italian metal industry. The information presented in Table 8 is consistent with the earlier results. The evidence suggest that if worldwide industry-specific shocks are present there are also other nation or nation-industry specific innovations occurring simultaneously.

5. Error-Components Model

The results presented in sections two and three suggest that nation effects may be as important if not more important than industry effects. In this section I investigate the source of the disturbances to technology growth for the six countries over the past thirty years. I use an error-components model to determine what fraction of the variations of technology growth can be attributed to industry-specific shocks and what fraction can be attributed to nation-specific shocks. Industry-specific shocks are defined as changes in technology growth that are unique to an industry but are common to all nations in the sample. Nation-specific shocks are defined as the changes in technology growth that are unique to a particular nation but common to all industries in the nation.

Stockman (1988) investigates the source of disturbances to fluctuations in the growth rate of industrial production in seven European countries and the U.S.. He estimates industry-specific and nation-specific disturbances and the fractions of the variation in the growth of output attributable to each. In his study, both industry and nation effects are found to be empirically important. Norrbin and Schlagenhauff (1989) employ dynamic factor analysis to also investigate the source of disturbances to output. They also find strong nation effects.

If shocks to productivity are assumed to vary across industries but not systematically across nations then Stockman's results casts doubt on the hypothesis that most macroeconomic fluctuations can be ascribed to technology shocks alone. We have just seen that technology growth (as measured by Solow residuals) and output growth have considerably different time series behavior so the issue of what these residuals represent remains open. If the residuals are associated with industries, then the interpretation of the residuals as technology shocks seems natural. If they are associated with countries then we may want to consider the changes in national economic policies.

I employ the same methodology as Stockman (1988) to estimate industry-specific and nation-specific disturbances and the fractions of technology growth attributed to each. I find nation effects to be important regardless of which measure of the capital input or detrending method that is employed.

5.1 The Model

The statistical model employed is,

$$dlnPG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)$$

where PG(i,n,t) represents productivity growth in industry i in nation n at time t and (d ln PG) represents its growth rate. The term m(i,t) term is a constant term specific to industry i in nation n. The term f(i,t) represents the interaction of a fixed effect for industry i with a fixed time effect. Precisely f(i,t) is a vector of coefficients of dummy variables multiplied by a vector of dummy variables specific to industry i and to time t but common to all nations. This term will capture the variation in technology that is due solely to changes in the technical relationship between inputs and outputs in a particular industry that is located in all nations. The term g(n,t) on the other hand, captures the variation in technology growth that comes from the difference in technology across nations relative to the common technology growth across industries within any given nation. That is g(n,t) is the interaction of a fixed effect for nation n with a fixed time effect. The last term u(i,n,t) is an idiosyncratic disturbance to industry i in nation n at time t, assumed to be an i.i.d random variable.

The model is unidentified because some combinations of the dummy variables are perfectly colinear, but by a normalization a combination of the parameters can be identified. The normalizations imposed here are the same as those in Stockman (1988). That is the nation effects g(n,t) are set equal to zero for one nation. For the results that included the United States, the United States is this nation. For the results that exclude the United States, Italy is this nation. This normalization gives the estimated coefficients the interpretation that g(n) measures the difference between the nation-specific components of productivity growth in nation n and the United States. The time varying industry effects must also be interpreted relative to this normalization. The vector f(i) estimates the industry-specific components of productivity growth in the United States. The second normalization imposed is f(i,T)=g(n,T)=0 for T=1985 for all industries and nations. This normalization implies that the estimated industry and nation effects must also be interpreted relative to the last year in the sample (1985).

The nation and industry effects are correlated so in order to decompose the variation in productivity growth into fractions explained by either the nation effects or industry effects we need to consider separately the fractions explained by the orthogonal components and the fraction contributable to the covariation of the two. [2]

5.2 Results

Table 9 reports summary statistics from estimation of the model including all

[2] If there was only one time period, m(i,n) was defined to be equal to zero, and the data were balanced, then this correlation would vanish.

six nations. [3] The model explains seventy percent of the variation in productivity growth rates. Both the nation effects and industry-effects are significantly nonzero. The F-statistic for testing the null hypothesis that all of the g(n,t) terms are zero is 1.58, with a marginal significance level of 0.0035. The F-statistic for testing the null hypothesis that all of the f(i,t) terms are significantly different from zero is 1.24 with a marginal significant level of 0.0257. This indicates the presence of nation-specific disturbances that are common to industries within a nation as well as industry-specific disturbances that are common to nations.

The total sum of squares attributable to the industry effects and the nation effects is .71. This is about forty-two percent of the total sum of squares. Since the industry effect and the nation effect are correlated Table 9 reports the variance decomposition of these two effects. The sum of squares attributable to the orthogonal part of f(i,t) is .31, which is 44 percent of .71. The sum of squares attributable to the orthogonal part of g(n,t), is .28 (that is the part of g(n,t) that is orthogonal to f(i,t)), which is 39 percent of .604. The remaining 17 percent of the .71 is attributable to the covariation between f(i,t) and g(n,t). The time series of the residuals show no evidence of being autocorrelated.

Since the nation terms were all normalized such that g(US,t)=0, the joint significance of the nation effects indicates that the other nations jointly experienced nation-specific shocks, common to all industries in each nation that differed from nation-specific disturbances in the United States. Table 10 reports results for the model when the United States is excluded. This was done to determine whether there were significant nation or industry effects within all the other countries. The nation effects are normalized on Italy. Both the nation-effects and industry-effects continue to be important. These results hold regardless of which of the other nations is chosen for the normalization. The results do not indicate that the main difference between countries is between the United States and other countries.

The model assumes that a nation-specific disturbance has the same effect on the growth rate of technology in all industries in the sample. This is unlikely to be

[3] Estimation was performed using Proc GLM in SAS.

true since the industries have different standard deviations of technology growth. In fact the standard deviations of technology growth differ not only by industry but by nation. To relax this assumption I could estimate a modified version of the model,

$$dlnTS(i,n,t) = m(i,n) + \beta^n f(i,t) + \beta^i g(n,t) + u(i,n,t)$$

where β^n is a coefficient unique to nation n but common across industries, and β^i is a coefficient unique to industry i but common to nations. The model contains a very large number of parameters, making estimation infeasible. Instead I make an adjustment similar to the one Stockman (1988) employs. I adjust the data prior to estimation by dividing technology growth in each nation in each industry by the standard deviation of technology growth of that industry in the nation. [4]

Table 11 reports the results using the adjusted data with the US included in the sample. The results are somewhat different from the results in Table 9 which are based on unadjusted data. The fraction of the variance attributable to the industry specific disturbance falls somewhat but remains important. The conclusion that nation effects are important is even stronger. Table 12 reports the results using the adjusted data excluding the United States. The conclusion that both industry and nation effects are important remains intact although again the fraction attributable to industry effects falls.

5.3 Capital Measurement and Filtering

The results remain intact if capital is measured by the gross capital stock. Tables 13 and 14 present these results. Both industry and nation-effects are significant, although the sum of squares attributable to the orthogonal part of g(n,t) declines from 39 percent to 27 percent.

The results are sensitive to the method of detrending. Table 15 presents the results when the data are filtered by the Hodrick-Prescott procedure. The model explains sixty-five percent of the variation in productivity growth rates. Only the

[4] This is similar to imposing estimates of β^i that are proportional to standard errors.

nation effects are significantly nonzero. The F-statistic for testing the null hypothesis that all of the g(n,t) terms are zero is 2.38, with a marginal significant level of 0.0001. The F-statistic for testing the null hypothesis that all of the f(i,t) terms are significantly different from zero is 1.04 with a marginal significant level of 0.3941. This indicates the presence of nation-specific disturbances that are common to industries within a nation but industry-specific disturbances that are common to nations are not important.

The total sum of squares attributable to the industry effects and the nation effects is .93. This is about sixty-two percent of the total sum of squares. Since the industry effect and the nation effect are correlated Tables 15 reports the variance decomposition. The sum of squares attributable to the orthogonal part of g(n,t), is .49 (that is the part of g(n,t) that is orthogonal to f(i,t)), which is 53 percent of .93. The time series of the residuals show no evidence of being autocorrelated.

5.4 Industrial Production and Detrending

Tables 16- 19 present the results for the variance decomposition of output growth. The sample of countries I consider differs from the sample Stockman considers. He considers the U.S. and five European countries. The results in Tables 16-19 are consistent with Stockman's results. Both industry-effects and nation-effects are significant. I also used the H-P filter to see if the results for output growth were sensitive to the detrending procedure employed. Both industry-effects and nation-effects remain important.

6. Conclusions

This paper presents evidence on the nature of productivity growth, as measured by Solow residuals. Output growth and productivity growth have strikingly different properties. Output growth is positively correlated across countries and industries, whereas productivity growth is not correlated across countries for most industries and is only weakly correlated across industries within countries.

I consider the decomposition of world productivity growth into the variation due to each industry and nation. The United States makes the largest contribution to world productivity with Germany a weak second. Metal Manufacturing is the largest industry contributor to world manufacturing productivity. I employ an error-components model to estimate the fraction of technology growth attributed to industry-specific and nation-specific disturbances. I find Nation-effects are always important regardless of the method of detrending or capital measurement.

The evidence strongly suggests that nation-specific technology shocks or demand shocks are as important, if not more important, than industry-specific technology shocks.

References

[1] **Dellas, Harris,** "Cyclical Comovements in Real Economic Activity and Prices in the World Economy," *University of Rochester, Dissertation,* 1985.

[2] **Backus, David, Patrick Kehoe and Finn Kydland,** "Is the Trade Balance too Smooth? Notes from the Lab," *manuscript, Minneapolis, MN,* 1988.

[3] **Baxter, Marianne, Alan Stockman,** "Business Cycles and the Exchange Rate System: some international evidence," *National Bureau of Economic Research Working Paper,* 1988; No. 2689.

[4] **Baxter, Marianne, and Mario Crucini,** "Explaining Savings-Investment Correlations," *University of Rochester, manuscript,* 1989.

[5] **Hall, Robert E.,** "Invariance Properties of Solow's Product Residual," *Stanford University, manuscript,* 1987.

[6] **Hall, Robert E.,** "The Relation between Price and Marginal Cost in U.S. Industry," *Journal of Political Economy,* October 1988; vol 96, pp. 921-947.

[7] **Hansen, Gary D.,** "Indivisible Labor and the Business Cycle," *Journal of Monetary Economics,* November 1985; vol 16, pp.309-327.

[8] **Heathfield David F.,** "The Measurement of Capital Usage Using Electricity Consumption Data for the U.K.," *Journal of Review of Statistics Soc* , 1972; vol 135 part 2, pp.208-220.

[9] **Hodrick, Robert J. and Edward C. Prescott,** "Postwar Business Cycles: An Empirical Investigation," *mimeograph Carnegie-Mellon University,* 1980.

[10] **King, Robert G., Charles I. Plosser, and Sergio T. Rebelo,** "Production Growth and Business Cycles," *Journal of Monetary Economics,* May 1988; vol 21, No 2, March 1988.

[11] **Kydland, Finn E., and Edward C. Prescott,** "Time to Build and Aggregate Fluctuations," *Econometrica,* November 1982; Vol 50, pp.1345-1370.

[12] **Long, John B., and Charles I. Plosser,** "Real Business Cycles," *Journal of Political Economy,* February 1983; Vol 91, pp. 39-69.

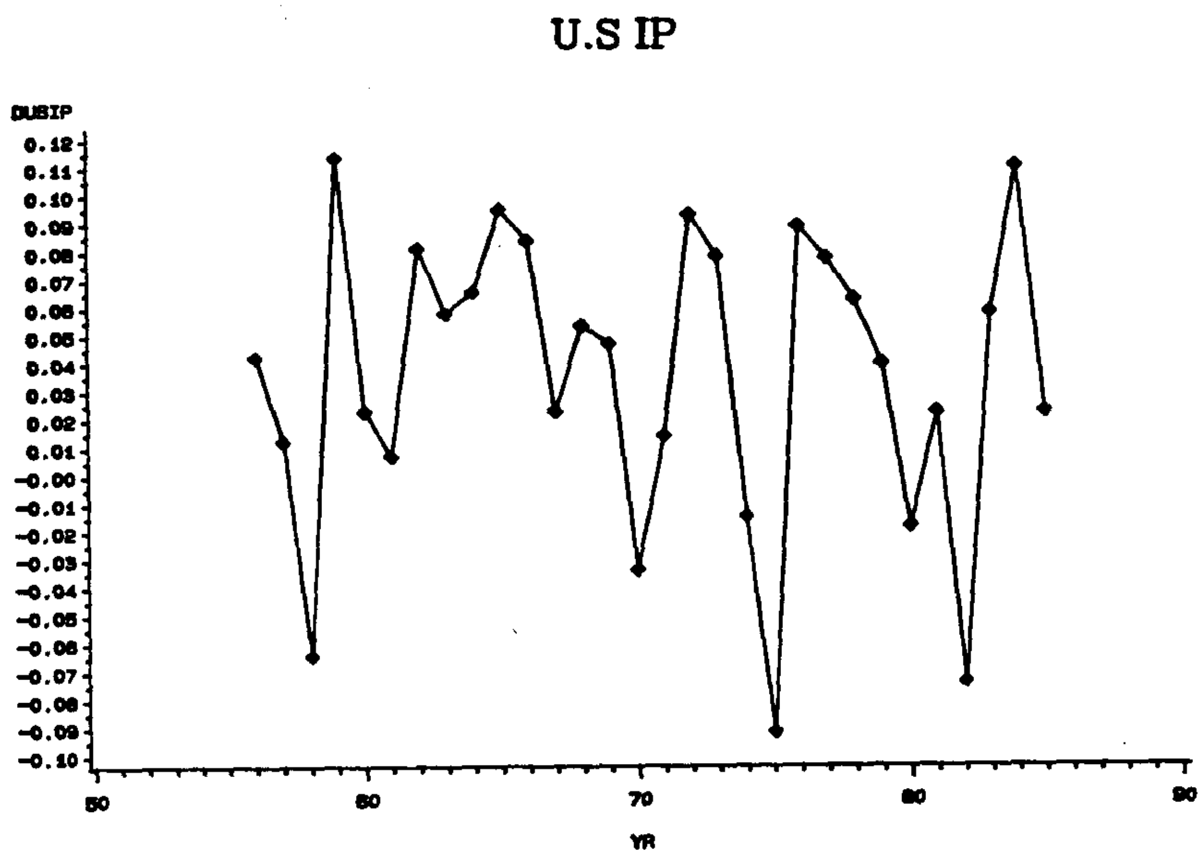
[13] **Norrbin, Stefan and Donald Schlagenhauff,** "The Role of International Factors in the Business Cycles: A Multicountry Study," *Arizona State University, manuscript,* 1989.

[14] **Prescott, Edward C.,** "Theory Ahead of Business Cycle Measurement," *Carnegie-Rochester Conference Series on Public Policy,* Autumn 1987; Vol 27.

[15] **Solow, Robert M.,** "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics,* May 1957; Vol 39, pp. 312-320.

[16] **Stockman, Alan C.,** "Sectorial and National Aggregate Disturbances to Industrial Output in Seven European Countries," *Journal of Monetary Economics,* May 1988; Vol 21, pp. 387-409.

Figure 1


U.S IP
DUSIP
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
-0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
50
60
70
80
90
YR

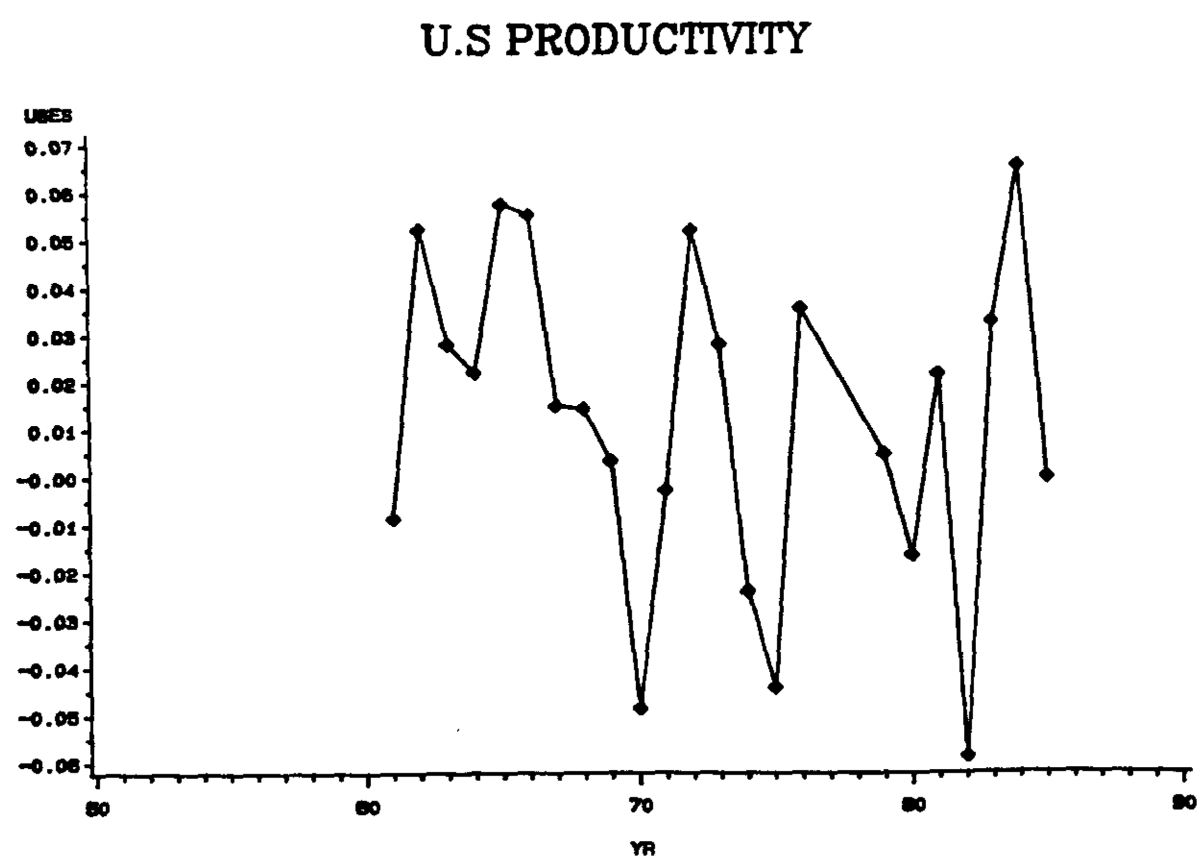
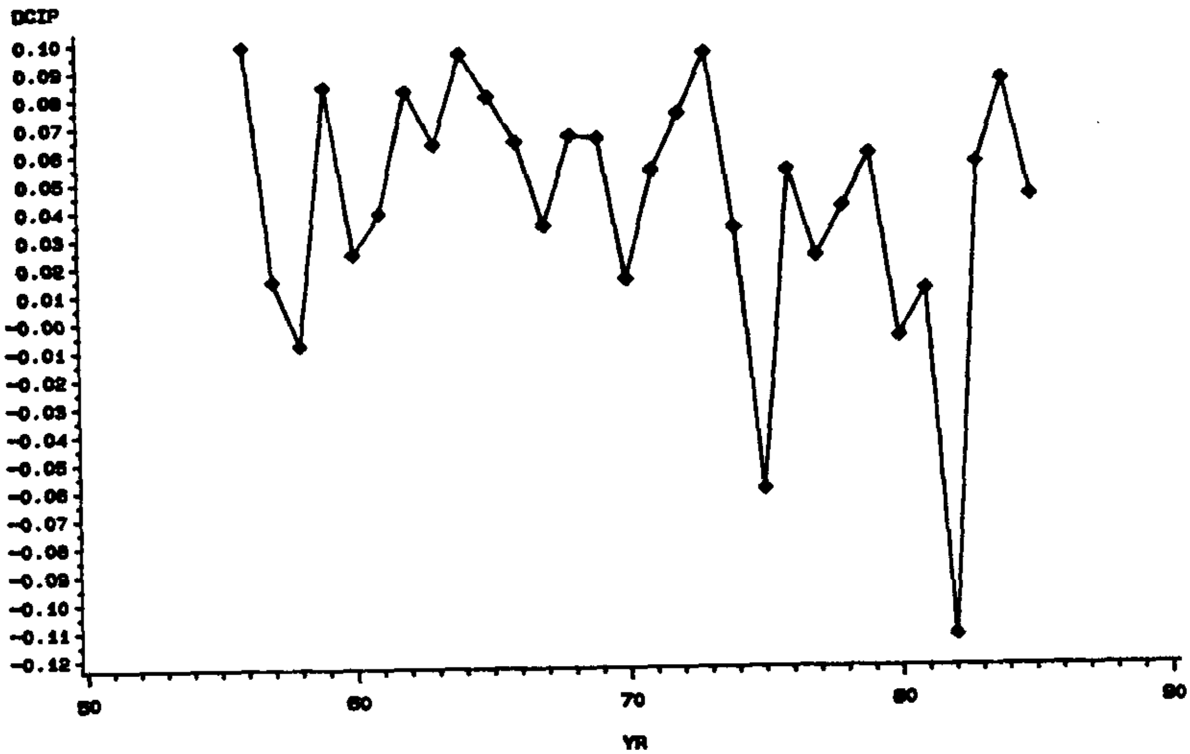

U.S PRODUCTIVITY
USES
0.07
0.06
0.05
0.04
0.03
0.02
0.01
-0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
50
60
70
80
90
YR

Figure 2

CANADA IP



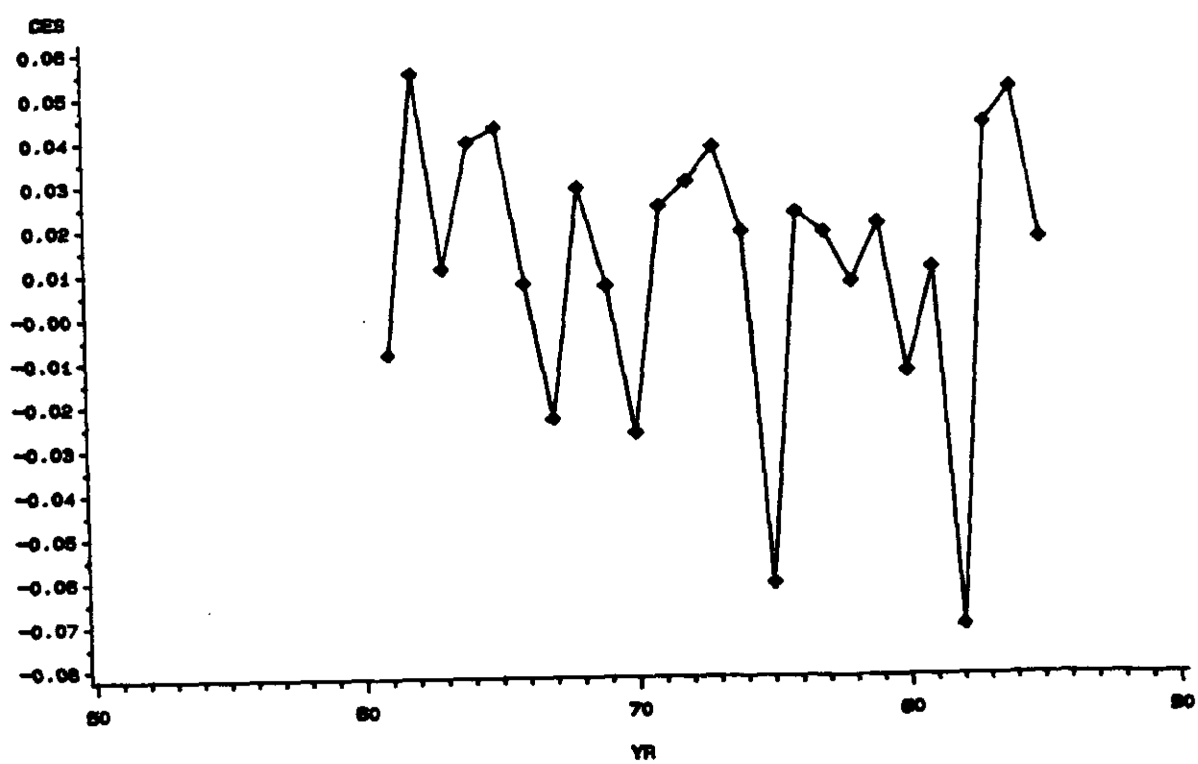
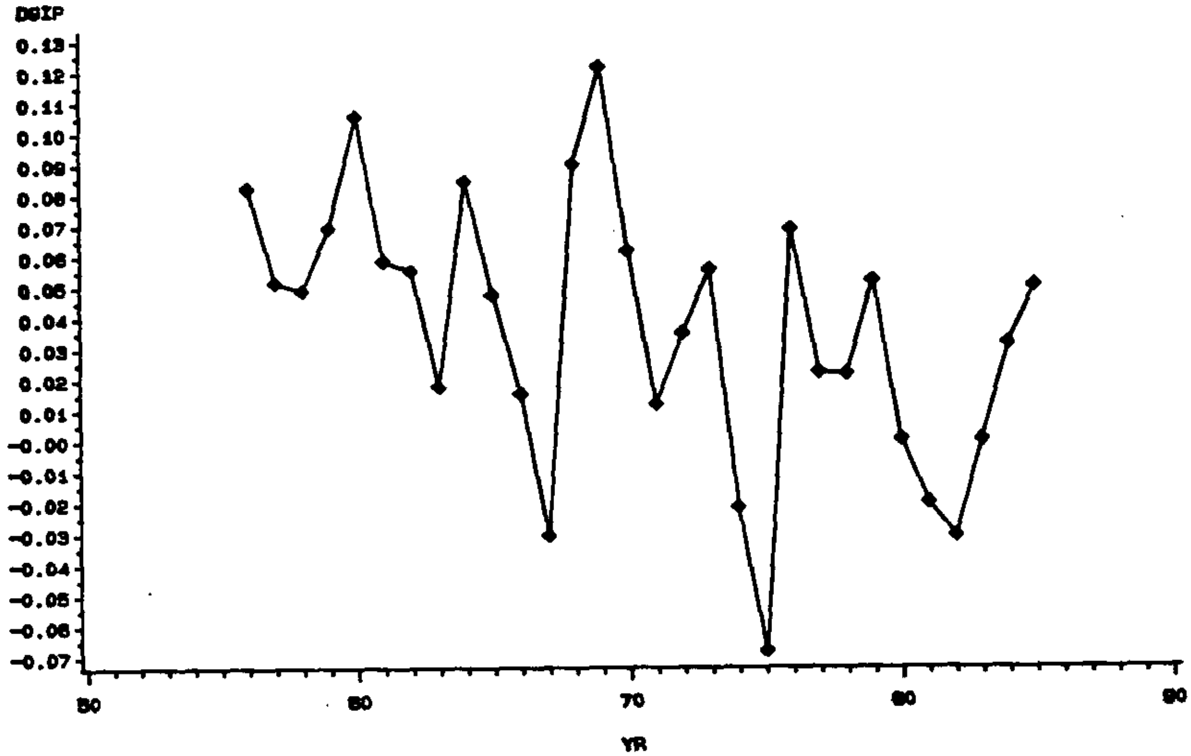


Figure 3

GERMANY IP



GERMANY PRODUCTIVITY

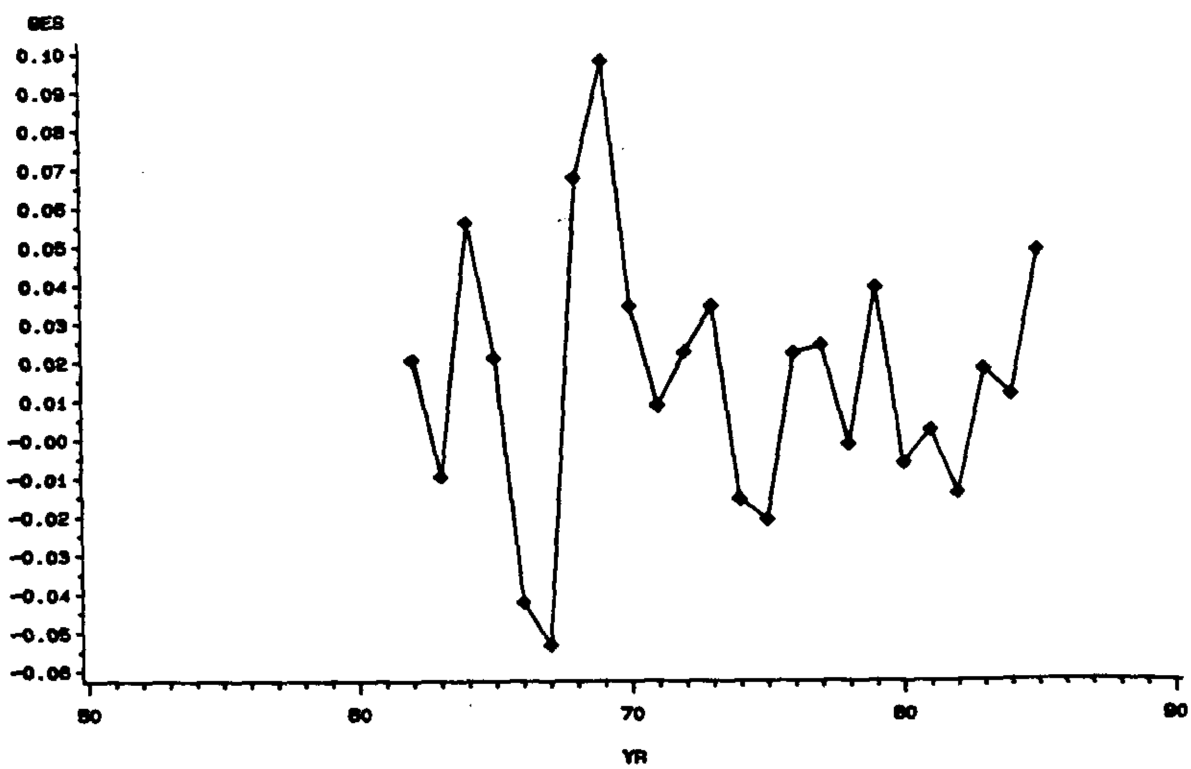
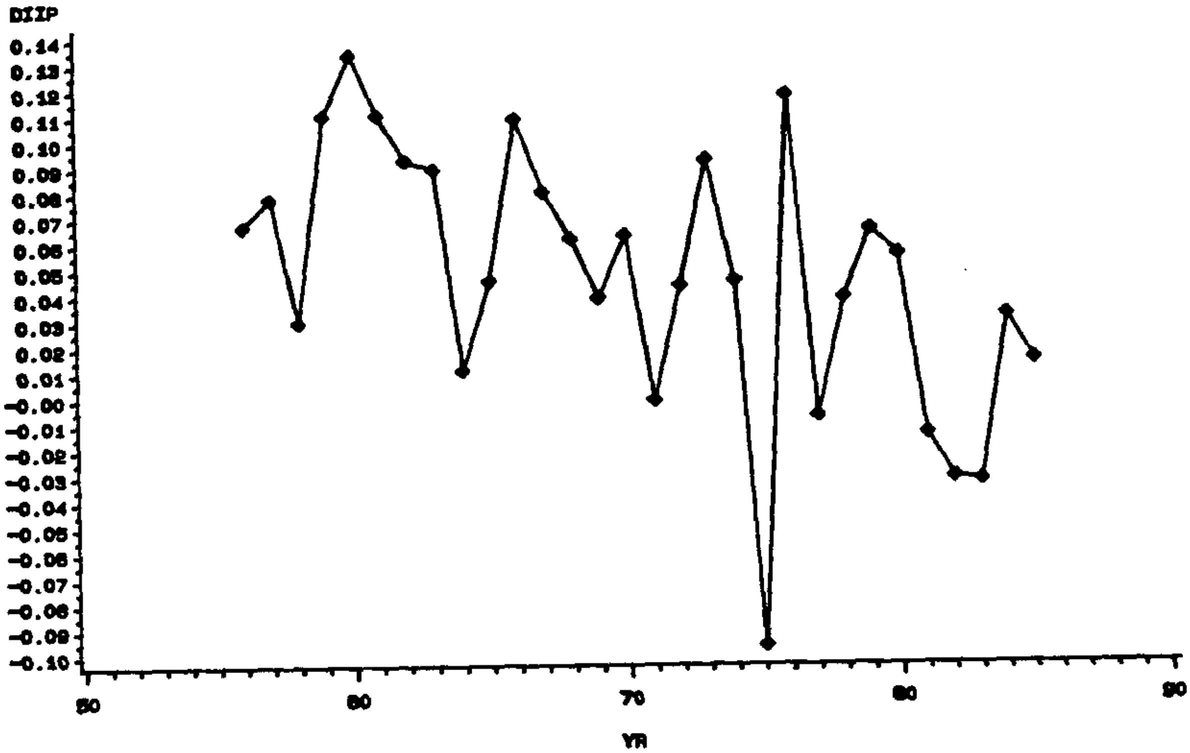


Figure 4

ITALY IP



ITALY PRODUCTIVITY

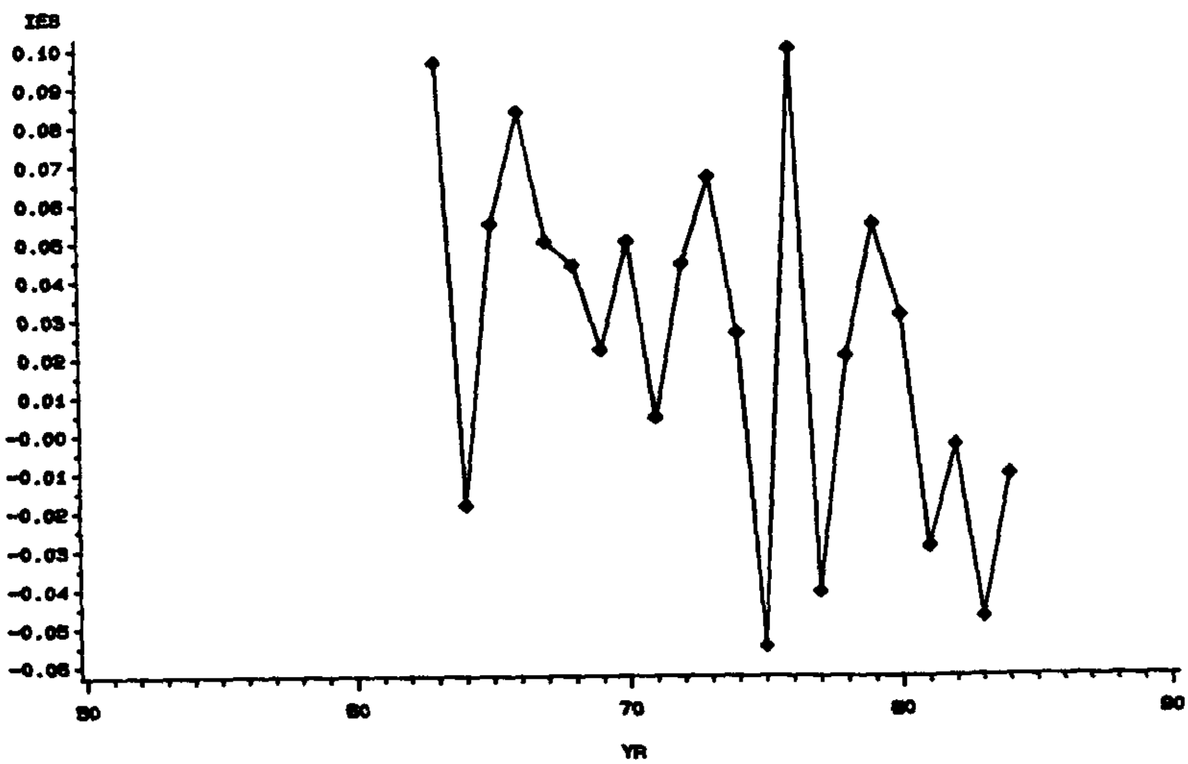
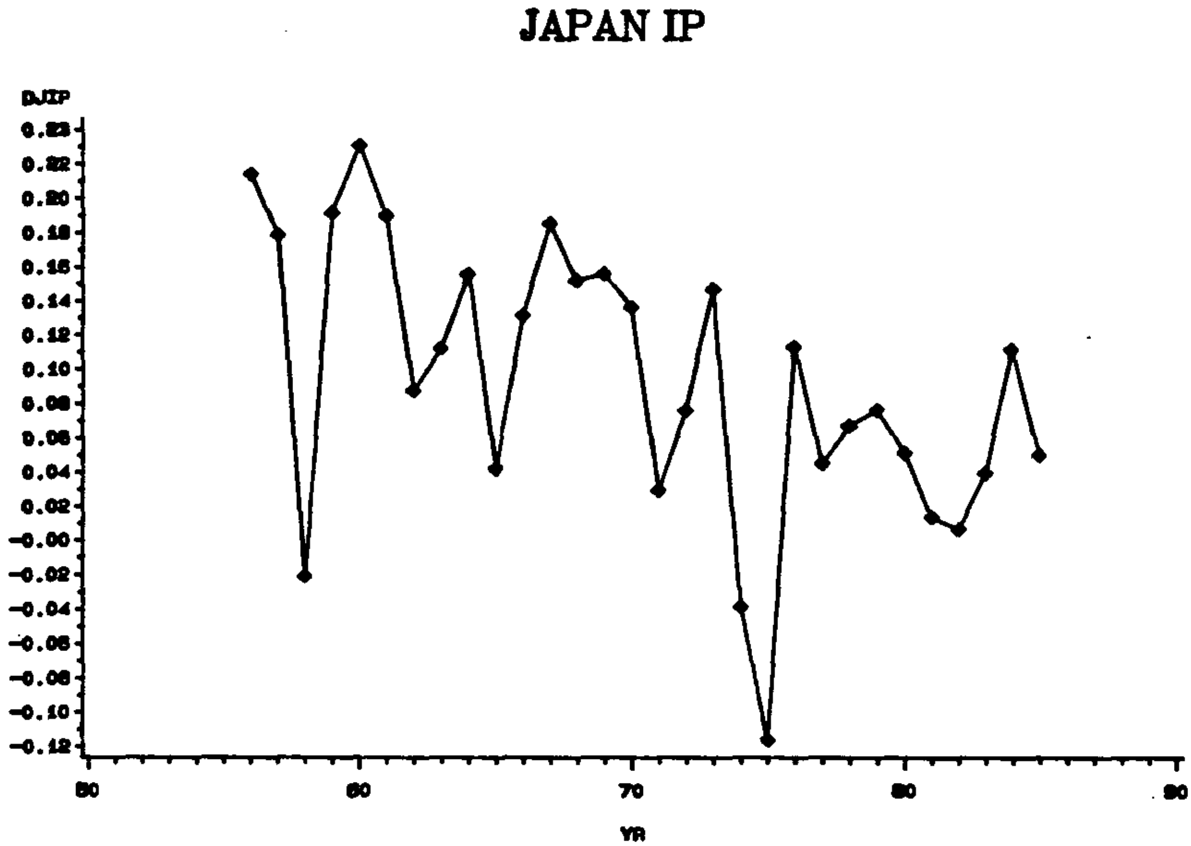


Figure 5


JAPAN IP
DJIP
0.23
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
-0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
50
60
70
80
90
YR

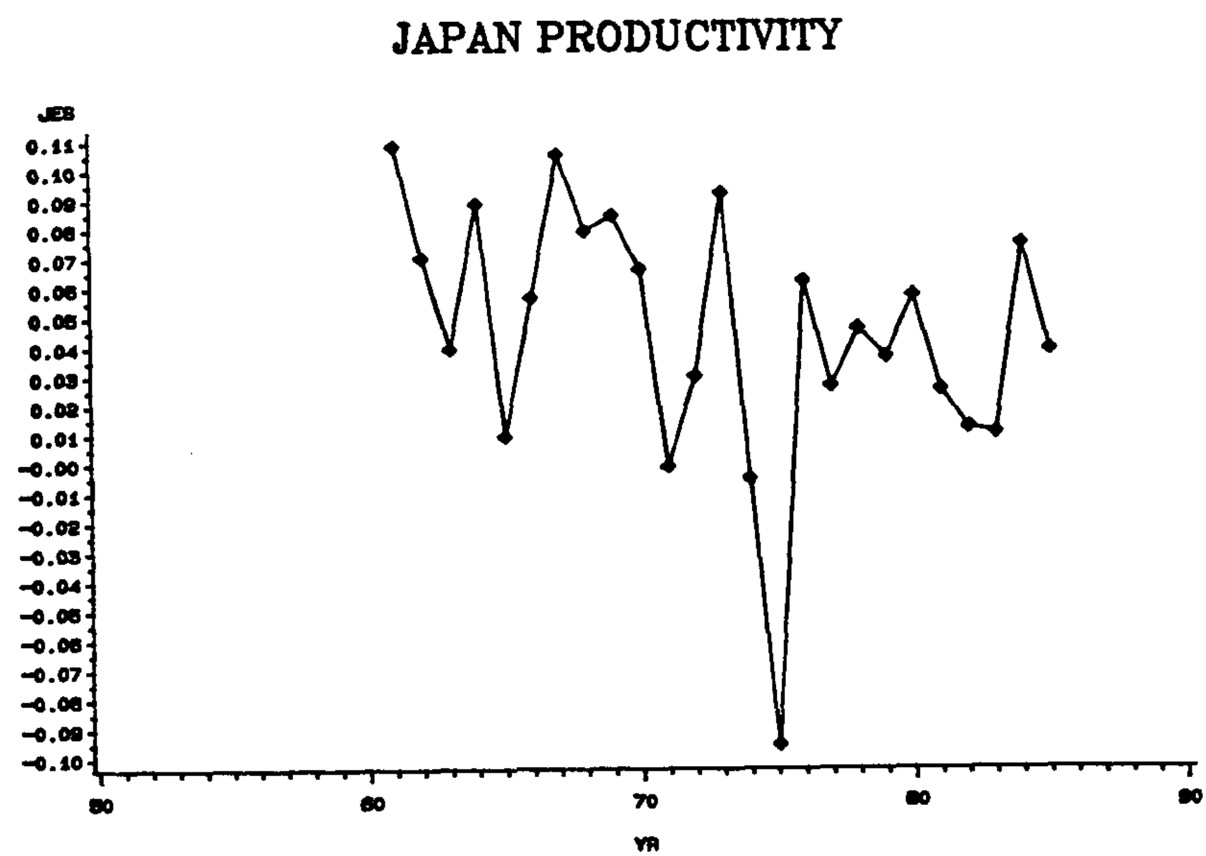
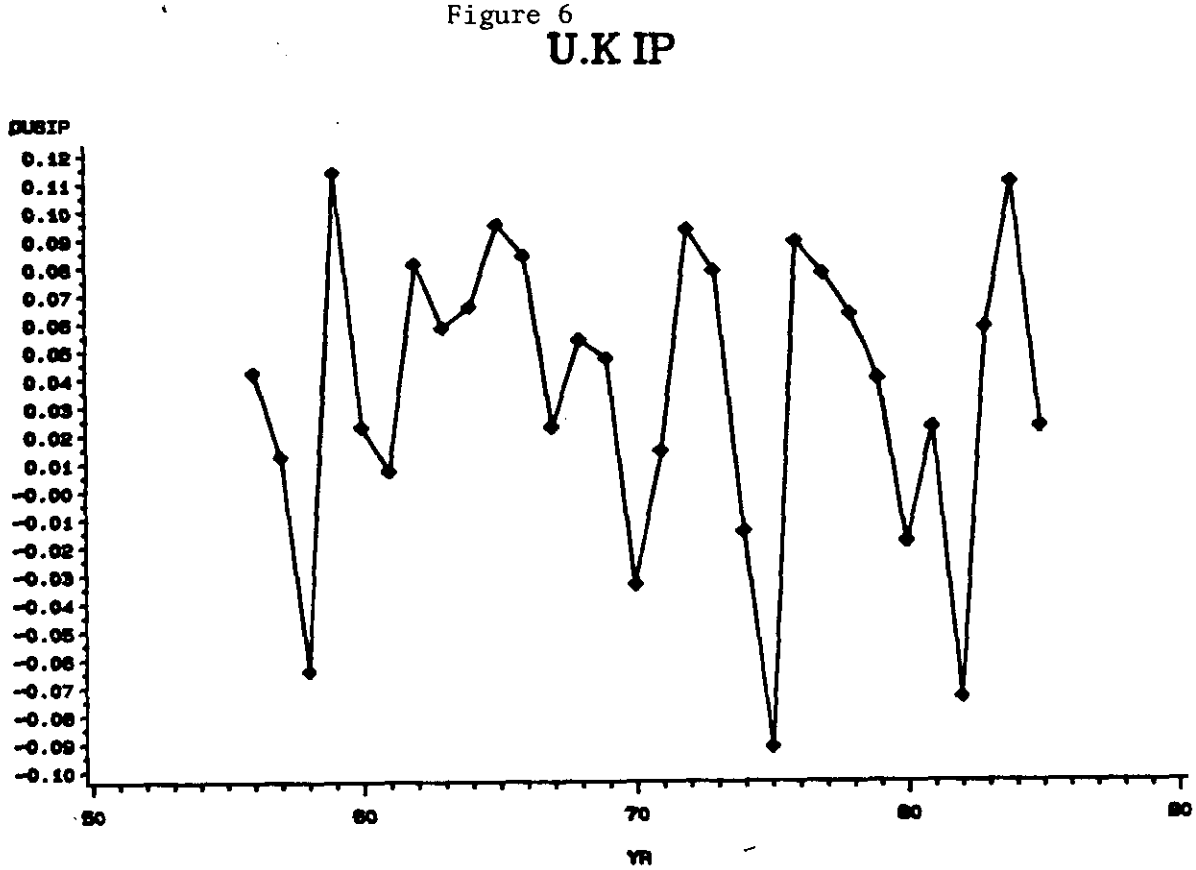

JAPAN PRODUCTIVITY
JES
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
-0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
50
60
70
80
90
YR

Figure 6


U.K IP
DUSIP
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
-0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
50
60
70
80
90
YR

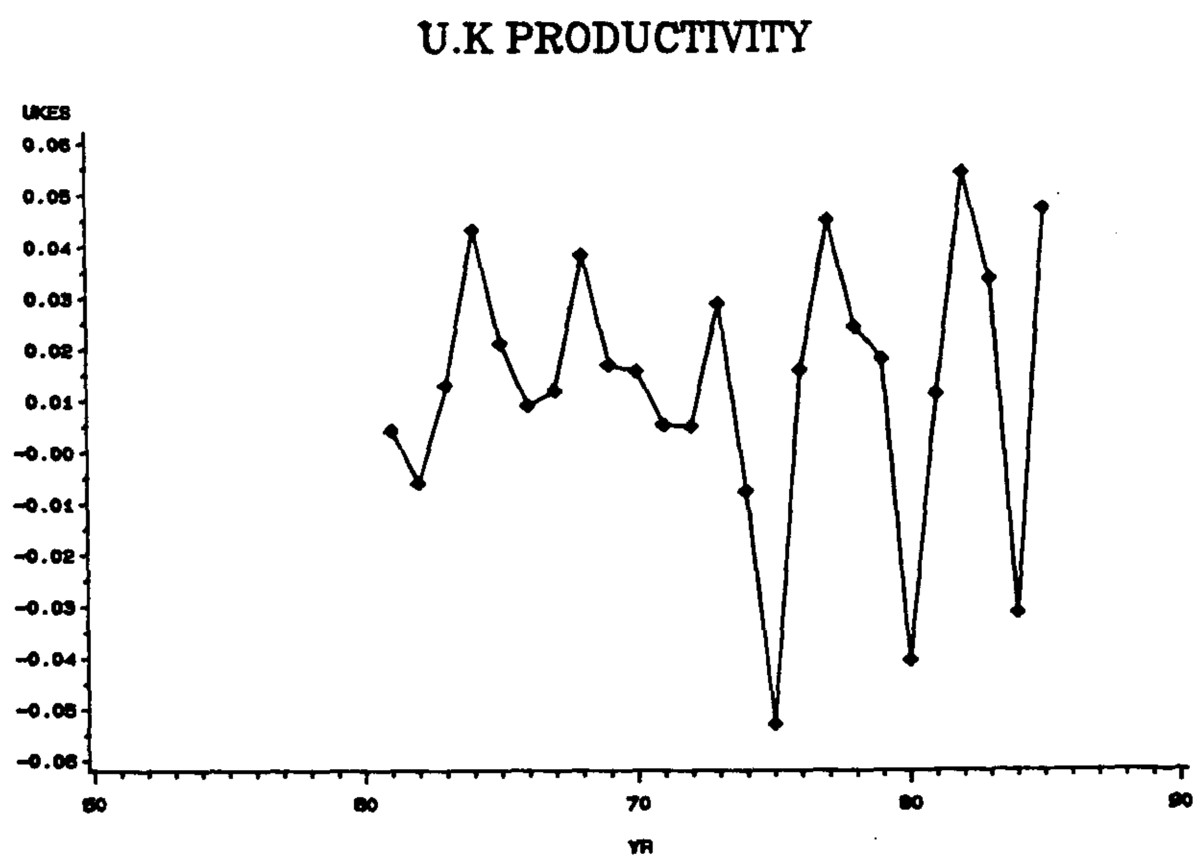

U.K PRODUCTIVITY
UKES
0.06
0.05
0.04
0.03
0.02
0.01
-0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
50
60
70
80
90
YR

Table 1
LABOR SHARES

	FOOD	TEX	CHEMICAL	BASIC	MET MFG	TOT MFG
Italy	0.47	0.63	0.67	0.72	0.74	0.63
Canada	0.77	0.74	0.76	0.74	0.74	0.62
Germany	0.40	0.72	0.49	0.75	0.75	0.61
U.K.	0.73	0.70	0.72	0.74	0.74	0.69
U.S.	0.79	0.58	0.76	0.78	0.78	0.65
Japan	0.57	0.40	0.42	0.58	0.63	0.52
World	0.69	0.62	0.66	0.74	0.76	0.62

Table 2
Sample Statistics
(percent)

	Solow Res	mean	std dev	Output	mean	std de
	Italy	2.46	4.51	Italy	4.75	5.21
	Canada	1.12	3.15	Canada	4.16	4.62
	Germany	1.51	3.40	Germany	3.59	4.35
	U.K.	1.28	2.62	U.K.	2.01	3.54
	U.S.	1.23	3.47	U.S.	3.54	5.35
	Japan	4.48	4.38	Japan	8.76	7.89
Food	Italy	2.73	5.09	Italy	3.02	4.60
	Canada	1.90	2.76	Canada	2.37	2.95
	Germany	2.46	2.72	Germany	2.82	2.57
	U.K.	5.34	3.64	U.K.	1.29	2.90
	U.S.	2.31	3.08	U.S.	2.36	2.86
	Japan	2.85	4.23	Japan	4.48	5.69
Textiles	Italy	1.29	6.84	Italy	4.17	8.45
	Canada	0.18	3.47	Canada	2.65	3.32
	Germany	2.66	3.80	Germany	2.87	7.20
	U.K.	0.70	10.88	U.K.	1.70	9.68
	U.S.	0.17	3.31	U.S.	2.17	5.49
	Japan	na	na	Japan	na	na
Chemical	Italy	4.21	4.64	Italy	4.83	6.53
	Canada	1.34	2.99	Canada	3.69	4.09
	Germany	3.09	3.95	Germany	4.19	6.99
	U.K.	5.52	4.27	U.K.	2.39	6.60
	U.S.	3.25	6.36	U.S.	4.76	6.91
	Japan	3.16	2.75	Japan	8.87	7.78
Basic	Italy	na	na	Italy	na	na
	Canada	0.92	3.58	Canada	3.10	5.64
	Germany	3.63	6.64	Germany	2.55	7.71
	U.K.	0.63	9.72	U.K.	-0.58	8.49
	U.S.	-0.01	3.11	U.S.	0.59	9.10
	Japan	6.45	5.51	Japan	12.50	11.40
Metal	Italy	3.56	5.40	Italy	4.41	7.72
	Canada	na	na	Canada	na	na
	Germany	3.02	2.26	Germany	3.95	5.54
	U.K.	-5.89	9.31	U.K.	1.34	3.89
	U.S.	2.63	2.96	U.S.	4.30	5.50
	Japan	na	na	Japan	na	na

Table 3
Output Correlations
(* indicates significant at 10% level)

	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.48*	0.57*	0.34*	0.44*	0.75*
Canada		1.00	0.58*	0.50*	0.84*	0.53*
Germany			1.00	0.62*	0.43*	0.70*
U.K.				1.00	0.57*	0.56*
U.S.					1.00	0.47*
Japan						1.00

Productivity Growth
Correlations
(* indicates significant at 10% level)

	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.14	-0.04	0.08	0.29	0.46*
Canada		1.00	0.42*	0.14	0.80*	0.30
Germany			1.00	0.39*	0.07	0.31
U.K.				1.00	0.03	0.28
U.S.					1.00	0.32
Japan						1.00

Table 4a
Productivity Growth
Correlations (industry)

Italy	Food	Textiles	Chemicals	Basic	Metal Mfg	Total	World
Food	1.00	-0.07	0.38	na	0.40*	0.28	-0.59*
Textiles		1.00	0.29	na	0.27	0.38	0.54*
Chemicals			1.00	na	0.42*	0.53*	0.42*
Basic				1.00	na	na	na
Metal Mfg					1.00	0.06	-0.12

Canada	Food	Textiles	Chemicals	Basic	Metal Mfg	Total	World
Food	1.00	-0.36	0.49*	-0.05	na	0.13	0.30
Textiles		1.00	0.48*	0.52*	na	0.25	0.00
Chemicals			1.00	0.52*	na	0.18	0.32
Basic				1.00	na	0.08	-0.03
Metal Mfg					1.00	na	na

Germany	Food	Textiles	Chemicals	Basic	Metal Mfg	Total	World
Food	1.00	-0.40*	-0.20	0.00	-0.49*	-0.65*	-0.49*
Textiles		1.00	0.27	-0.13	0.50*	0.34*	-0.04
Chemicals			1.00	0.11	0.09	-0.14	0.34
Basic				1.00	0.04	0.22	0.74*
Metal Mfg					1.00	0.70*	0.14

U.K.	Food	Textiles	Chemicals	Basic	Metal Mfg	Total	World
Food	1.00	-0.15	0.14	-0.14	0.50*	-0.46*	-0.30
Textiles		1.00	0.01	0.16	0.13	0.11	0.14
Chemicals			1.00	0.62*	-0.03	0.60*	0.47
Basic				1.00	0.29	0.62*	0.48*
Metal Mfg					1.00	-0.26	-0.19

U.S.	Food	Textiles	Chemicals	Basic	Metal Mfg	Total	World
Food	1.00	0.11	0.41*	0.07	0.64*	-0.10	-0.20
Textiles		1.00	-0.08	0.31	0.37*	0.40*	0.29
Chemicals			1.00	-0.08	0.44*	-0.25	-0.29
Basic				1.00	0.27	0.54*	0.65*
Metal Mfg					1.00	0.26	0.16

Japan	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	na	-0.25	0.01	na	0.12
Textiles		1.00	na	na	na	
Chemicals			1.00	0.48*	na	0.21
Basic				1.00	na	0.65*
Metal Mfg					1.00	

World	Food	Textiles	Chemicals	Basic	Metal Mfg	Total	World
Food	1.00	0.20	-0.05	0.30	0.45*	-0.02	
Textiles		1.00	-0.19	0.16	0.76*	0.21	
Chemicals			1.00	0.04	0.12	-0.27	
Basic				1.00	-0.10	0.89*	
Metal Mfg					1.00		

Note: Total denotes the total industry in each nation. World is defined in section 2 and includes only countries in the sample.

Table 4b
Productivity Growth
Correlations (industry)

Food	Italy	Canada	Germany	U.K.	U.S.	Japan	World
Italy	1.00	-0.18	0.04	0.16	0.30	-0.21	0.23
Canada		1.00	-0.21	0.03	-0.32	0.20	-0.12
Germany			1.00	0.32	-0.25	0.36	0.20
U.K.				1.00	0.06	0.12	0.36
U.S.					1.00	-0.53*	0.91*
Japan						1.00	0.52*
World							1.00

Textiles	Italy	Canada	Germany	U.K.	U.S.	Japan	World
Italy	1.00	0.07	-0.13	0.36	0.34	na	0.58*
Canada		1.00	0.80*	0.23	-0.16	na	0.34
Germany			1.00	0.27	0.02	na	0.34
U.K.				1.00	0.05	na	0.67
U.S.					1.00	na	0.66
Japan						1.00	na
World							1.00

Chemicals	Italy	Canada	Germany	U.K.	U.S.	Japan	World
Italy	1.00	-0.12	0.07	0.25	-0.15	-0.06	-0.15
Canada		1.00	0.45	0.21	0.22	0.50*	0.24
Germany			1.00	0.18	0.20	0.18	0.47
U.K.				1.00	-0.01	0.02	0.83
U.S.					1.00	0.02	0.99
Japan						1.00	-0.07
World							1.00

Basic	Italy	Canada	Germany	U.K.	U.S.	Japan	World
Italy	1.00	na	na	na	na	na	na
Canada		1.00	0.08	0.41	-0.15	0.25	0.23
Germany			1.00	0.41	0.46*	0.12	0.80
U.K.				1.00	0.23	0.06	0.68
U.S.					1.00	-0.15	0.77
Japan						1.00	0.20
World							1.00

Metal Mfg	Italy	Canada	Germany	U.K.	U.S.	Japan	World
Italy	1.00	0.23	0.52*	0.23	0.01	na	-0.92*
Canada		1.00	0.05	0.23	-0.41	na	-0.04
Germany			1.00	0.17	0.46*	na	0.42*
U.K.				1.00	0.37	na	-0.10
U.S.					1.00	na	0.93*
Japan						1.00	na
World							1.00

Note: Total denotes the total industry in each nation. World is defined in section 2 and includes only countries in the sample.

Table 5
Correlations
Output Growth and Productivity Growth

	Total Industry	Food	Textiles	Chemicals	Basic	Metal Mfg
Italy	0.92*	0.63*	0.75*	0.65*	na	0.54*
Canada	0.89*	0.12	0.63*	0.64*	0.49*	-0.71
Germany	0.88*	-0.21	0.78*	0.57*	0.83*	0.67*
U.K.	0.77*	-0.65*	0.94*	0.53*	0.87*	-0.28
U.S.	0.95*	0.79*	0.67*	0.61*	0.76*	0.38*
Japan	0.94*	0.16	na	0.43*	0.89*	na

Table 6
Autocorrelation Functions
Standard error is below correlation

Country		lag 1	lag 2	lag 3
U.S.	corr	0.23	-0.26	-0.05
	SE	0.25	0.26	0.28
U.K.	corr	-0.01	-0.47	-0.14
	SE	0.20	0.20	0.23
Germany	corr	0.18	-0.43	-0.28
	SE	0.20	0.21	0.24
Italy	corr	-0.13	0.10	0.21
	SE	0.21	0.22	0.22
Canada	Corr	0.05	-0.43	-0.11
	SE	0.20	0.20	0.23
Japan	Corr	0.11	-0.13	0.19
	SE	0.20	0.21	0.21

Table 7
Productivity Growth
Corr(t,t-1)
(* indicates significant at 10% level)

TOT IND	Italy(t)	Canada	Germany	U.K.	U.S.	Japan
Italy(t-1	-0.14	-0.02	0.13	0.02	-0.17	0.15
Canada	0.20	-0.11	-0.02	-0.15	0.00	0.02
Germany	0.34*	-0.07	-0.06	-0.25	-0.03	0.09
U.K.	-0.19	0.15	0.18	-0.01	0.06	0.03
U.S.	0.37*	-0.04	-0.01	0.24	0.09	0.40*
Japan	-0.06	0.13	0.19	0.18	-0.14	0.12

FOOD	Italy(t)	Canada	Germany	U.K.	U.S.	Japan
Italy(t-1	-0.24	0.26	0.46*	0.45*	-0.24	0.27
Canada	-0.15	-0.04	0.06	-0.04	-0.20	-0.21
Germany	-0.15	-0.39*	0.14	0.11	0.25	-0.12
U.K.	-0.31	0.15	0.00	0.41*	0.47	-0.19
U.S.	0.11	0.50*	0.04	0.26	-0.13	0.59*
Japan	0.09	-0.37	0.56	0.13	-0.07	-0.18

TEXTILE	Italy(t)	Canada	Germany	U.K.	U.S.	Japan
Italy(t-1	0.08	-0.51*	-0.77*	-0.21	-0.01	na
Canada	0.48	-0.04	-0.17	-0.23	0.23	na
Germany	0.48	0.02	-0.14	-0.08	0.25	na
U.K.	-0.02	0.02	-0.21	-0.60	0.17	na
U.S.	-0.18	-0.61*	-0.50	-0.34	0.11	na
Japan	na	na	na	na	na	na

CHEMICAL	Italy(t)	Canada	Germany	U.K.	U.S.	Japan
Italy(t-1	-0.53*	0.10	-0.31	0.01	-0.02	-0.48*
Canada	0.19	0.48*	0.17	0.22	0.04	0.19
Germany	-0.06	0.39	0.46*	0.32	-0.22	0.11
U.K.	-0.11	0.20	-0.26	-0.08	0.07	0.17
U.S.	-0.12	0.13	0.03	0.38	-0.09	-0.35
Japan	0.19	0.41*	0.39	0.56	0.13	0.23

BASIC	Italy(t)	Canada	Germany	U.K.	U.S.	Japan
Italy(t-1	na	na	na	na	na	na
Canada	na	0.06	-0.07	0.12	-0.19	na
Germany	na	-0.03	-0.05	-0.25	-0.17	na
U.K.	na	0.15	0.18	-0.01	0.06	na
U.S.	na	-0.32	-0.04	0.09	-0.10	na
Japan	na	na	na	na	na	na

METAL	Italy(t)	Canada	Germany	U.K.	U.S.	Japan
Italy(t-1	-0.02	-0.99*	-0.57*	-0.03	-0.47*	na
Canada	0.02	-0.83*	-0.07	0.54	0.18	na
Germany	na	0.61	-0.52*	0.06	-0.25	na
U.K.	na	0.01	-0.42	0.13	0.23	na
U.S.	na	0.28	-0.34	-0.30	-0.33	na
Japan	na	na	na	na	na	na

Table 8
Contributions To Productivity Growth

World	Elasticity	Share	Contribut Elas*Shar
US	1.16	0.56	0.65
Germany	1.03	0.13	0.13
Canada	0.98	0.04	0.04
Japan	0.93	0.14	0.13
Italy	0.61	0.04	0.02
UK	0.22	0.08	0.02
World Food			
US	1.25	0.57	0.71
Germany	0.78	0.15	0.12
Canada	-0.03	0.05	0.00
Japan	0.67	0.10	0.07
Italy	0.55	0.03	0.02
UK	0.87	0.09	0.08
World Textile			
US	0.65	0.57	0.37
Germany	0.89	0.16	0.14
Canada	0.51	0.06	0.03
Japan			0.00
Italy	1.28	0.08	0.10
UK	2.23	0.12	0.27
World Chemical			
US	1.59	0.60	0.95
Germany	0.39	0.15	0.06
Canada	-0.16	0.03	0.00
Japan	-0.03	0.15	0.00
Italy	-0.14	0.05	-0.01
UK	na	na	0.00
World Basic			
US	0.89	0.50	0.45
Germany	1.70	0.18	0.31
Canada	0.26	0.04	0.01
Japan	0.58	0.18	0.10
Italy		na	0.00
UK	1.79	0.09	0.16
World Metal			
US	1.45	0.72	1.04
Germany	0.50	0.13	0.07
Canada	-0.45	0.03	-0.01
Japan		na	0.00
Italy	-1.81	0.05	-0.09
UK	na	na	0.00

Table 9
Annual Data for 1955-1985

All six countries included

Model: d ln PG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)

Total SS = 1.71 R = .69 F = 2.26
Model SS = 1.18
Total SS attributable to f(i,t) + g (n,t) = 0.71

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	0.31	44	1.24	0.0257
Orthogonal nation*Time, g(n,t)	0.28	39	1.58	0.0035

Table 10
Annual Data for 1955-1985
United States excluded

Model: d ln PG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)

Total SS = 1.43 R = 0.74 F = 2.58
Model SS = 1.05
Total SS attributable to f(i,t) + g(n,t) = .64

Effect	SS	%	F	P
hogonal industry*Time, f(i,t)	0.32	50	1.69	0.0025
Orthogonal nation*Time, g(n,t)	0.22	34	1.57	0.0125

Table 11
Annual Data for 1955-1985
All six countries included
(adjusted data)

Model: $d \ln PG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + \dot{u}(i,n,t)$

Total SS = 167.42 R = .77 F =3.19
Model SS = 129.64
Total SS attributable to f(i,t) + g(n,t) = 118.93

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	47.29	40	1.55	0.0029
Orthogonal nation*Time, g(n,t)	50.34	42	2.11	0.0001

Table 12
Annual Data for 1955-1985

United States excluded
(adjusted data)

Model: $d \ln PG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)$

Total SS =265.08 R = 0.77 F = 2.91
Model SS = 194.31
Total SS attributable to f(i,t) + g(n,t) = 59.88

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	26.49	44	1.57	0.0091
Orthogonal nation*Time, g(n,t)	22.11	37	1.67	0.0061

Table 13

Annual Data for 1955-1985
All six countries included
(K = Capital Stock)

Model: d ln PG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)

Total SS = 1.59 R = .74 F = 2.68
Model SS = 1.17
Total SS attributable to f(i,t) + g (n,t) = 0.75

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	0.28	45	1.24	0.0196
Orthogonal nation*Time, g(n,t)	0.25	27	1.58	0.0005

Table 14
Annual Data for 1955-1985
United States excluded
(K = Capital Stock)

Model: d ln PG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)

Total SS = 1.32 R =.78 F = 2.53
Model SS = 1.02
Total SS attributable to f(i,t) + g(n,t) = .67

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	0.3	45	1.45	0.0198
Orthogonal nation*Time, g(n,t)	0.18	27	1.63	0.0113

Table 15
Annual Data for 1955-1985
All six countries included
(Filter = HP)

Model: d ln PG(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)

Total SS = 1.5 R = .66 F = 1.70
Model SS =.98
Total SS attributable to f(i,t) + g (n,t) = 0.93

	SS	%	F	P
Orthogonal industry*Time, f(i,t)	0.26	28	1.04	0.3941
Orthogonal nation*Time, g(n,t)	0.49	53	2.38	0.0001

Table 16
Annual Data for 1955-1985 (IP)
All six countries included

Model: $d \ln IP(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)$

Total SS = 4.32 R= 0.84 F = 7.07
Model SS = 3.63
Total SS attributable to $f(i,t) + g(n,t)$ = 2.33

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	0.405	17	2.09	0.0001
Orthogonal nation*Time, g(n,t)	0.765	33	3.34	0.0001

Table 17
Annual Data for 1955-1985
United States excluded (IP)

Model: $d \ln IP(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)$

Total SS = 3.60 R = 0.87 F = 7.12
Model SS = 3.12
Total SS attributable to $f(i,t) + g(n,t)$ = 1.95

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	0.37	19	2.01	0.0001
Orthogonal nation*Time, g(n,t)	0.49	25	2.83	0.0001

Table 18
Annual Data for 1955-1985
All six countries included (IP)
(adjusted data)

Model: d ln IP(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)

Total SS = 933.17 R = 0.84 F = 6.18
Model SS = 784.93
Total SS attributable to f(i,t) + g(n,t) = 493.30

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	72.22	15	1.51	0.0028
Orthogonal nation*Time, g(n,t)	143.77	29	2.52	0.0001

Table 19
Annual Data for 1955-1985
United States excluded (IP)
(adjusted data)

Model: d ln IP(i,n,t) = m(i,n) + f(i,t) + g(n,t) + u(i,n,t)

Total SS = 728.71 R = 0.87 F = 6.03
Model SS = 632.80
Total SS attributable to f(i,t) + g(n,t) = 399.67

Effect	SS	%	F	P
Orthogonal industry*Time, f(i,t)	66.48	17	1.52	0.0046
Orthogonal nation*Time, g(n,t)	88.07	22	2.08	0.0001

Table 2.A1
Sample Statistics
(K = Capital Stock)

	Solow Res	mean	std dev	Output	mean	std de
	Italy	3.18	4.86	Italy	4.75	5.21
	Canada	3.55	3.33	Canada	4.16	4.62
	Germany	1.40	3.94	Germany	3.59	4.35
	U.K.	1.67	2.76	U.K.	2.01	3.54
	U.S.	3.19	3.77	U.S.	3.54	5.35
	Japan	na	na	Japan	8.76	7.89
Food	Italy	4.32	4.69	Italy	3.02	4.60
	Canada	0.97	3.57	Canada	2.37	2.95
	Germany	4.10	6.58	Germany	2.82	2.57
	U.K.	4.52	2.30	U.K.	1.29	2.90
	U.S.	2.62	3.17	U.S.	2.36	2.86
	Japan	na	na	Japan	4.48	5.69
Textiles	Italy	3.63	7.77	Italy	4.17	8.45
	Canada	-1.12	3.80	Canada	2.65	3.32
	Germany	0.26	10.50	Germany	2.87	7.20
	U.K.	0.60	10.38	U.K.	1.70	9.68
	U.S.	1.45	3.40	U.S.	2.17	5.49
	Japan	na	na	Japan	na	na
Chemical	Italy	3.51	5.24	Italy	4.83	6.53
	Canada	0.16	3.87	Canada	3.69	4.09
	Germany	4.20	5.45	Germany	4.19	6.99
	U.K.	5.19	4.60	U.K.	2.39	6.60
	U.S.	3.37	5.94	U.S.	4.76	6.91
	Japan	na	na	Japan	8.87	7.78
Basic	Italy	na	na	Italy	na	na
	Canada	0.34	4.30	Canada	3.10	5.64
	Germany	7.90	20.60	Germany	2.55	7.71
	U.K.	0.43	0.90	U.K.	-0.58	8.49
	U.S.	0.11	3.35	U.S.	0.59	9.10
	Japan	na	na	Japan	12.50	11.40
Metal	Italy	3.47	5.30	Italy	4.41	7.72
	Canada	na	na	Canada	na	na
	Germany	6.57	14.65	Germany	3.95	5.54
	U.K.	-5.94	8.78	U.K.	1.34	3.89
	U.S.	1.65	2.40	U.S.	4.30	5.50
	Japan	na	na	Japan	na	na

Table 3.A1
Productivity Growth
(K = Capital Stock)
Correlations
(* indicates significant at 10% level)

	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.54	0.55	0.18	0.52	na
Canada		1.00	0.67	0.54	0.84	na
Germany			1.00	0.55	0.56	na
U.K.				1.00	0.60	na
U.S.					1.00	na
Japan						1.00

Table 5.A1
Correlations
(K = Capital Stock)
Output Growth and Productivity Growth

	Total Industry	Food	Textiles	Chemicals	Basic	Metal Mfg
Italy	0.97*	0.87*	0.90*	0.77*	na	0.72*
Canada	0.96*	0.28	0.71*	0.80*	0.75*	~~0.86*~~
Germany	0.97*	0.07	0.86*	0.89*	0.89*	0.79*
U.K.	0.87*	-0.50*	0.97*	0.74*	0.91*	-0.14
U.S.	0.99*	0.82*	0.88*	0.83*	0.85*	0.47*

Table 4a.A1
Productivity Growth
(K = Capital Stock)
Correlations (industry)

Italy	Food	Textiles	Chemicals	Basic	Metal Mfg	Total Ind
Food	1.00	0.11	0.39	na	0.31	0.46*
Textiles		1.00	0.05	na	0.01	0.46*
Chemicals			1.00	na	0.49*	0.54*
Basic				1.00	na	na
Metal Mfg					1.00	0.42

Canada	Food	Textiles	Chemicals	Basic	Metal Mfg	Total Ind
Food	1.00	0.37*	0.41*	0.30	na	0.09
Textiles		1.00	0.68*	0.82*	na	0.59*
Chemicals			1.00	0.59*	na	0.57*
Basic				1.00	na	0.47*
Metal Mfg					1.00	na

Germany	Food	Textiles	Chemicals	Basic	Metal Mfg	Total Ind
Food	1.00	-0.29	-0.24	0.16	-0.38*	0.01
Textiles		1.00	0.32	0.17	0.53*	0.16
Chemicals			1.00	0.57*	0.39*	0.62*
Basic				1.00	0.44*	0.70*
Metal Mfg					1.00	0.24

U.K.	Food	Textiles	Chemicals	Basic	Metal Mfg	Total Ind
Food	1.00	-0.22	-0.02	0.02	0.57*	-0.34
Textiles		1.00	0.13	0.20	0.16	0.30
Chemicals			1.00	0.77*	-0.02	0.68*
Basic				1.00	0.33	0.70*
Metal Mfg					1.00	-0.03

U.S.	Food	Textiles	Chemicals	Basic	Metal Mfg	Total US
Food	1.00	0.34*	0.35*	0.06	0.65*	-0.05
Textiles		1.00	0.38*	0.42*	0.67*	0.57*
Chemicals			1.00	0.19	0.47*	0.03
Basic				1.00	0.38*	0.73*
Metal Mfg					1.00	0.32*

Table 4b.A1
Producivity Growth

(K = Capital Stock)
Correlations (industry)

Food	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.03	0.03	0.04	0.32	na
Canada		1.00	-0.37	-0.23	-0.20	na
Germany			1.00	0.14	-0.30	na
U.K.				1.00	0.29	na
U.S.					1.00	na
Japan						1.00

Textiles	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.10	0.09	0.44*	0.30	na
Canada		1.00	0.64*	0.21	0.38*	na
Germany			1.00	0.34*	0.40*	na
U.K.				1.00	0.25	na
U.S.					1.00	na
Japan						1.00

Chemicals	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	-0.26	0.46*	0.29	-0.26	na
Canada		1.00	0.60*	0.54*	0.19	na
Germany			1.00	0.55*	0.19	na
U.K.				1.00	0.14	na
U.S.					1.00	na
Japan						1.00

Basic	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	na	na	na	na	na
Canada		1.00	0.45*	0.51*	0.33	na
Germany			1.00	0.48*	0.59*	na
U.K.				1.00	0.37	na
U.S.					1.00	na
Japan						1.00

Metal Mfg	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	-0.31	0.34	0.13	-0.10	na
Canada		1.00	-0.57	-0.52	-0.34	na
Germany			1.00	0.25	0.49*	na
U.K.				1.00	0.40*	na
U.S.					1.00	na
Japan						1.00

Table 2.A2

Sample Statistics
(Filter = HP)

	Solow Res.	std dev	Output	std de
	Italy	4.04	Italy	5.10
	Canada	3.88	Canada	3.97
	Germany	6.34	Germany	7.33
	U.K.	4.63	U.K.	4.21
	U.S.	3.55	U.S.	3.13
	Japan	3.43	Japan	4.30
Food	Italy	na	Italy	5.17
	Canada	5.80	Canada	5.61
	Germany	2.49	Germany	6.01
	U.K.	7.12	U.K.	7.12
	U.S.	3.48	U.S.	3.48
	Japan	5.01	Japan	5.02
Textiles	Italy	2.39	Italy	5.73
	Canada	3.80	Canada	5.65
	Germany	5.51	Germany	7.95
	U.K.	5.74	U.K.	5.74
	U.S.	5.09	U.S.	5.01
	Japan	na	Japan	na
Chemical	Italy	5.05	Italy	7.93
	Canada	7.10	Canada	7.84
	Germany	3.59	Germany	7.68
	U.K.	8.48	U.K.	8.48
	U.S.	2.62	U.S.	2.62
	Japan	4.31	Japan	9.05
Basic	Italy	na	Italy	na
	Canada	5.14	Canada	6.66
	Germany	5.79	Germany	6.65
	U.K.	13.40	U.K.	13.40
	U.S.	3.17	U.S.	3.17
	Japan	6.24	Japan	10.25
Metal	Italy	4.85	Italy	6.68
	Canada	4.39	Canada	6.66
	Germany	3.82	Germany	1.75
	U.K.	4.85	U.K.	4.84
	U.S.	6.14	U.S.	6.13
	Japan	na	Japan	na

Table 3.A2
Output Correlations
(* indicates significant at 10% level)
Filter = HP

	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.22	0.37*	0.76*	0.72*	0.34*
Canada		1.00	0.70*	0.51*	0.50*	0.49*
Germany			1.00	0.69*	0.54*	0.39*
U.K.				1.00	0.54*	0.40*
U.S.					1.00	0.30*
Japan						1.00

Productivity Growth
Correlations
(* indicates significant at 10% level)
Filter = HP

	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.08	0.36*	0.64*	0.57*	0.05
Canada		1.00	0.62*	0.26	0.03	0.21
Germany			1.00	0.64*	0.29	0.39*
U.K.				1.00	0.53*	0.00
U.S.					1.00	-0.13
Japan						1.00

Table 4a.A2
Productivity Growth
Correlations (industry)
Filter = HP

Italy	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	na	na	na	na	na
Textiles		1.00	0.48*	na	0.01	-0.01
Chemicals			1.00	na	0.47*	0.31
Basic				1.00	na	na
Metal Mfg					1.00	0.06

Canada	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	0.58*	0.53*	0.39	-0.29	0.58*
Textiles		1.00	0.46*	0.46*	0.14	0.44*
Chemicals			1.00	0.48*	0.27	0.05
Basic				1.00	0.84*	0.17
Metal Mfg					1.00	-0.09

Germany	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	0.23	0.06	0.11	-0.57*	-0.43*
Textiles		1.00	0.55*	0.35	-0.61*	0.52*
Chemicals			1.00	-0.24	-0.28*	0.67*
Basic				1.00	-0.18	-0.23
Metal Mfg					1.00	0.13

U.K.	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	0.25	0.28	0.40*	0.19	-0.05
Textiles		1.00	0.89*	0.61*	0.18	0.08
Chemicals			1.00	0.76*	0.09	0.02
Basic				1.00	0.14	-0.19
Metal Mfg					1.00	-0.02

U.S.	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	-0.10	0.28	0.17	-0.22	0.25
Textiles		1.00	0.05	0.17	0.18	0.14
Chemicals			1.00	0.56*	-0.33	-0.07
Basic				1.00	-0.21	-0.24
Metal Mfg					1.00	-0.17

Japan	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	na	0.00	-0.36	na	0.20
Textiles		1.00	na	na	na	na
Chemicals			1.00	0.50	na	0.28
Basic				1.00	na	0.36
Metal Mfg					1.00	na

World	Food	Textiles	Chemicals	Basic	Metal Mfg	Total
Food	1.00	-0.36*	-0.15	-0.35*	-0.40	0.31
Textiles		1.00	0.30	0.22	0.40	0.46*
Chemicals			1.00	0.42	-0.53*	0.62*
Basic				1.00	-0.11	0.11
Metal Mfg					1.00	-0.25

Note: Total denotes the total industry in each nation. World is defined in section 2 and includes only countries in the sample.

Table 4b.A2
Productivity Growth
Correlations (industry)
Filter = HP

Food	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	na	na	na	na	na
Canada		1.00	0.05	0.30	-0.15	-0.55*
Germany			1.00	0.04	0.01	0.06
U.K.				1.00	-0.29	-0.41*
U.S.					1.00	0.77*
Japan						1.00

Textiles	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	-0.16	0.18	0.37	0.01	na
Canada		1.00	0.51*	-0.07	-0.07	na
Germany			1.00	0.12	-0.04	na
U.K.				1.00	0.01	na
U.S.					1.00	na
Japan						1.00

Chemicals	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	0.01	0.11	0.00	0.54*	-0.24
Canada		1.00	0.15	0.36	-0.09	0.21
Germany			1.00	0.27	-0.13	0.56*
U.K.				1.00	0.14	0.45*
U.S.					1.00	0.20
Japan						1.00

Basic	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	na	na	na	na	na
Canada		0.33	0.00	-0.10	0.04	0.00
Germany			1.00	0.08	-0.16	-0.20
U.K.				1.00	0.18	0.22
U.S.					1.00	-0.12
Japan						1.00

Metal Mfg	Italy	Canada	Germany	U.K.	U.S.	Japan
Italy	1.00	-0.05	0.26	0.54*	-0.20	na
Canada		1.00	-0.12	0.03	-0.22	na
Germany			1.00	0.17	0.02	na
U.K.				1.00	-0.25	na
U.S.					1.00	na
Japan						1.00

Note: Total denotes the total industry in each nation.

Table 5.A2
Correlations
Output Growth and Productivity Growth
Filter = HP

	Total Industry	Food	Textiles	Chemicals	Basic	Metal Mfg
Italy	0.91*	na	0.48	0.69*	na	0.66*
Canada	0.96*	0.73*	0.83*	0.72*	0.91*	0.80*
Germany	0.96*	0.41*	0.93*	0.84*	0.66*	-0.69*
U.K.	0.76*	0.80*	0.51*	0.69*	0.60*	0.59*
U.S.	0.86*	0.59*	0.71*	0.40	0.37*	0.81*
Japan	0.68*	0.31	na	0.53*	0.84*	na