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22.5.1989

16/89

AGGREGATE VERSUS INDUSTRY-SPECIFIC SOURCES OF
ECONOMIC GROWTH AND BUSINESS CYCLE FLUCTUATIONS

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Helsinki 1989
ISBN 951-686-202-2
ISSN 0785-3572

ABSTRACT

This paper evaluates the power of aggregate and sector-specific disturbances to output growth in the Finnish economy using annual data on the growth of value added in 31 industries over the period 1961-87. The uniform power distribution assumptions implicit in the standard random and fixed effects models are considered and tested by analyzing the power of disturbances by frequency band.

In the 'representative' industry, the growth rate fluctuates quite randomly around its mean and growth fluctuations with different frequencies have roughly the same power. However, long-run trend changes and especially short-run fluctuations are weaker than medium-term fluctuations. Aggregate effects are a significant source of sectoral growth fluctuations, especially at the medium term frequencies. In a simple analysis of variance, they explain about 25 per cent of all medium-term variation in output growth.

Real business cycle models or other theories stressing the role of sector-specific factors do not provide a satisfactory explanation for fluctuations in aggregate output growth. Aggregate growth and business cycle fluctuations are driven mainly by aggregate disturbances. Sectoral disturbances are a particularly poor explanation for the strong aggregate fluctuations with a duration of 5-10 years, which are a characteristic of the Finnish economy.

Aggregate growth disturbances in the medium-term frequency group are twice as powerful as shorter or longer disturbances. However, one cannot reject at conventional significance levels the hypothesis that the power distribution is uniform, i.e. that aggregate disturbances to output are a random walk.

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1. INTRODUCTION

Macroeconomic analysis is largely concerned with economy-wide changes in variables such as output, employment or prices. Much of the effort is directed towards accounting for the causes of these changes. Some authors like Altonji and Ham (1987) and Stockman (1988) have focused on the distinction between nation-wide and sector-specific disturbances. They have tried to assess the relative importance of these two proximate sources of fluctuations with the help of simple variance-component type models, asking questions like: What fraction of all variations in employment or output growth can be attributed to specific shocks, restricted to particular regions or to particular industries, and what fraction can be attributed to nation-wide shocks, shared by all regions and industries? Are aggregate shocks, taken together, a dominant cause of variation in different branches, or is it that aggregate fluctuations arise merely from the summation of small independent sectoral disturbances?

This paper extends earlier discussion by considering, in the variance components framework, the persistence of aggregate and sector specific disturbances to output growth. The analysis is conducted using frequency domain methods initiated by Engle (1974). Frequency domain methods fit rather nicely into the analysis-of-variance framework. The role of aggregate and sector-specific disturbances can be considered separately for long-run and short-run movements in output growth and frequency decompositions also make it possible to test some of the assumptions of the standard variance component model. Can the evolution of both aggregate and sectoral effects be accurately described as unpredictable and permanent deviations from constant trends, as apparently implied by the assumptions of the model? Is the 'pure' aggregate shock to total output a random walk, or can we distinguish cyclical features in it, masked perhaps in other analyses by sectoral disturbances?

The paper is organized as follows. The basic variance-component model and its extensions are introduced in the next section. The data and

the conventional estimates are presented in Section 3. In Section 4, variations in output growth are grouped into three frequency classes or bands, depending on the duration of fluctuations, and the power of aggregate and sector-specific shocks is investigated separately in each band. We also discuss whether the grouping is redundant, i.e. whether the extended model reduces to the standard variance component model. The analysis is mainly conducted in the context of the 'representative' sector of the economy, as defined in Section 2. The limitations of this concept are dealt with in Section 5. The concluding section includes a summary of the results.

2. MODELS OF OUTPUT GROWTH

Let $g_{j,t}$ denote the growth of output in sector j in year t . The conventional variance component model can be written as

$$(1) \quad g_{j,t} = g + \alpha_t + \beta_j + u_{j,t}$$

for $j=1, \dots, J$ and $t=1, \dots, T$. Here g is a constant which indicates the (unconditional) expected growth rate of output for all industries and all years. The α -, β - and u -effects are considered as impulses from different sources to sectoral output growth, measured in such a way that one unit of the impulse induces one unit of output growth. The model recognizes two systematic sources of deviations from the common growth trend, namely sector-invariant time variations captured by the α_t 's and time-invariant sectoral variations captured by the β_j 's. Beyond them, output growth is governed by idiosyncratic sector-specific forces described by the term $u_{j,t}$. The effects are treated relatively to the trend, and it is assumed that

$$E \alpha_t = E \beta_j = E u_{j,t} = 0.$$

Assuming furthermore that the effects are independent, identically distributed normal random variables, we are led to the standard random effects model with g and the variance components

$$\sigma_\alpha^2 = E \alpha_t^2$$

$$\sigma_\beta^2 = E \beta_j^2$$

and

$$\sigma_u^2 = E u_{j,t}^2$$

as the parameters.

There is not very much in this paper about the overall average growth rate or about growth differences between sectors. Rather, we focus on a hypothetical or constructed sector defined by the condition that the

value of β is equal to its expected value 0. Let σ^2 denote the variance or power of the growth of output in the representative sector. The main features of the model can be restated for the representative sector as the decomposition

$$(2) \sigma^2 = \sigma^2_{\alpha} + \sigma^2_u.$$

The power of the average growth rate is $\sigma^2_{\alpha} + \sigma^2_u/J$. If all sectors are of equal size, this is also the power of the aggregate output growth.

Viewed as a description of the whole economy's growth dynamics the variance-component model is exceedingly simple. The simplicity is derived from strong assumptions, and one might be interested in checking whether the assumptions are reasonable or not. This paper pays particular attention to the time-series properties of the error components α and u . If there exists an unobserved aggregate effect governing output fluctuations in all sectors of the economy, does its evolution in time really follow the imposed random walk? And is the economy's production structure amorphous in the sense that sectoral output levels fluctuate in a random manner around the aggregate level, without returning to normal positions after disturbances or showing any other form of persistence in growth, except for constant sector-specific trends?

The specification of variance components has attracted much discussion in the panel data literature. The main alternative to the random effects specification in modelling the aggregate effect is known as the 'fixed effects' specification. It conditions on the aggregate effect, as if accepting each year on its own. In this specification, each α_t is a parameter to be estimated.

Although there are close links between fixed and random effects specifications, it is convenient to contrast the two models. In a sense, the random effects model is a fully specified, testable growth model whereas the fixed effects model is consistent with any theory of the aggregate effect, including not only non-normal distributions or variable stochastic or deterministic trends, partial adjustment towards normal levels and other forms of autocorrelation in growth rates but also a complete rejection of the assumption that the aggregate effect follows a stochastic process with well-defined transition probabilities.

The contrast between the models has been highlighted recently in a slightly different context by Blanchard and Watson (1986, pp. 123-124). They summarize existing research on (aggregate) impulses "as centered on two independent but related questions. The first question concerns the number of sources of impulses: Is there only one source of shocks to the economy, or are there many? Monetarists often single out monetary shocks as the main source of fluctuations; this theme has been echoed recently by Lucas (1977) and examined empirically by the estimation of index or dynamic factor analysis models. The alternative view, that there are many, equally important, sources of shocks, seems to dominate most of the day-to-day discussions of economic fluctuations.

The second question concerns the way the shocks lead to large fluctuations. Are fluctuations in economic activity caused by an accumulation of small shocks, where each shock is unimportant if viewed in isolation, or are fluctuations due to infrequent large shocks. The first view derives theoretical support from Slutsky, who demonstrates that the accumulation of small shocks could generate data that mimicked the behavior of macroeconomic time series. It has been forcefully restated by Lucas (1977). The alternative view is less often articulated but clearly underlies many descriptions and policy discussions - that there are infrequent, large, identifiable shocks that dominate all others. Particular economic fluctuations can be ascribed to particular large shocks followed by periods during which the economy returns to equilibrium. Such a view is implicit in the description of specific periods such as the Vietnam War expansion, the oil price recession, or the Volcker disinflation." The "small shocks" view leads to the random effects specification; the fixed effects specification corresponds to the "ad hoc" or "large shocks" view.

The panel data literature has devoted much attention to the choice between the two models, usually in the context of individual (sector-specific) rather than time effects. The crucial consideration in the literature appears to be whether the effects are correlated with the explanatory variables or not (see, for example, Mundlak (1978) and Hausman (1978)). This consideration is not of much help here because there are no explanatory variables proper in the model. However, one can ask whether the random walk hypothesis describes sufficiently well the evolution of aggregate forces, or do we have to adopt a more

complicated model for that purpose, losing not only in the simplicity of the analysis but also in the power of tests in deciding between competitive hypotheses.

In the analyses of panel data the relative shortness of the time span usually excludes complicated stochastic specifications for the aggregate effect and, in practice, the choice often has to be done between random and fixed effects specifications.

The assumptions of the variance component model for the representative sector can be highlighted from the frequency domain perspective as follows.¹ The power of output growth is distributed uniformly over all frequencies, and the model takes for granted that the same decomposition applies across all frequencies in the sense that the power of both disturbance sources is constant across the frequencies. In the complete variance component model (1) the very longest of time horizons considered, the zero frequency, provides an exception to these assumptions. At the zero frequency, the power of the aggregate disturbance source is zero. All variation in output growth arises from differences in sectoral trends.

A natural extension of the standard variance component model is to allow for different variance decompositions at different frequencies. Let the subscript v refer to the frequency considered. For the representative sector, a generalization of the variance decomposition (2) can be presented as

$$(3) \sigma_v^2 = \sigma_{\alpha,v}^2 + \sigma_{u,v}^2.$$

σ_v^2 is the power of the sector's output growth at frequency v . It is given by the sum of the power of the aggregate shock and the power of the idiosyncratic shock, but the model allows for different decompositions at different frequencies. (2) is obtained from (3) as the special case

$$\sigma_{\alpha,v}^2 = \sigma_{\alpha}^2$$

$$\sigma_{u,v}^2 = \sigma_u^2$$

for all frequencies $v \neq 0$.

Instead of specific frequency values, we can consider frequency ranges or bands. By virtue of the uncorrelatedness of the spectral measures,

the power of a band is obtained simply by summing the power of frequencies within the band. The differences in band power averages reflect the true power distribution of the process, but in a somewhat rough fashion. There are two good empirical reasons for focusing on frequency bands rather than on specific frequency values. First, the duration of cycles varies from one cycle to another and from one sector to another. The observed durations and corresponding power estimates are averages over cycles rather than genuine durations. Secondly, especially in small-sized samples, even a genuine cycle with cycle length n tends to show spikes at frequencies $n/2$, $n/3$, $n/4$, etc. in addition to n .

We analyze variance decompositions by frequency bands in order to investigate empirically the importance of aggregate and sectoral forces in explaining temporary and persistent shocks to output, the dynamics of idiosyncratic sectoral forces and the choice between the random versus fixed effects specification for the aggregate effect. The issues are related and can be considered in a fairly similar manner in the same simple framework.

3. ESTIMATES OF THE VARIANCE COMPONENTS

In the error component models, both aggregate and sectoral shocks are treated as latent variables. The purpose of the analysis is to estimate the relative strengths of these unobservables, given some set of more or less plausible assumptions about their effects.

The overall sample mean

$$g_{..} = \Sigma_j \Sigma_t g_{j,t} / J * T,$$

the yearly mean deviations from the overall mean

$$g_{t.} = \Sigma_j g_{j,t} / J - g_{..}$$

and the deviations of the sectoral averages from the overall mean

$$g_{.j} = \Sigma_t g_{j,t} / T - g_{..}$$

provide the conventional fixed effects estimators for g , the α_t 's and the β_j 's, respectively. The variance component σ_u^2 can be estimated using the standard error of the estimate,

$$s_u^2 = \Sigma_{j,t} (g_{j,t} - g_{t.} - g_{.j})^2 / (T-1)(J-1)$$

and the standard estimators for the other variance components are

$$s_\alpha^2 = \Sigma_t (g_{t.} - g_{..})^2 / (T-1) - s_u^2 / J$$

and

$$s_\beta^2 = \Sigma_j (g_{.j} - g_{..})^2 / (J-1) - s_u^2 / T.$$

The data used in this paper describe annual output growth at the sectoral level in Finland over the period 1961 - 1987. The Central Statistical Office provided the tables on the volume of value added classified by kind of economic activity in basic prices for the period

1960-75 in 1975 prices and for the period 1975-85 in 1985 prices. The data for the years 1986-87 were taken from the published National Accounts as of the early autumn 1988. The 31 industry categories used in the analysis roughly correspond to the two-digit level SIC classification. For a list of sectors, see Section 5. The growth rates used in the analyses were calculated by multiplying the logarithmic year differences by 100.

Table 1 reports some basic statistics on pooled data.

TABLE 1. BASIC STATISTICS. OUTPUT GROWTH IN FINLAND, 31 BRANCHES, ANNUAL DATA OVER THE PERIOD 1961 - 87.

NUMBER OF OBSERVATIONS	837
MEAN	4.34
VARIANCE	38.73
MINIMUM	-34.45
MAXIMUM	27.51
SKEWNESS	-0.59
KURTOSIS	4.34

One approach to predicting output growth for the representative sector or for the whole economy is to take the sample average 4.34 as the forecast. If model (1) can be applied and α_t is unknown, this is about the best forecast available for any year. The forecast would be very inaccurate, however. Even if we pretend to know for sure that the value of g is 4.34 per cent, the standard error of the forecast for the representative sector is 6.22 per centage points. An interval forecast failing in no more than 5 per cent out of all cases requires an interval as large as from $-7.9 = 4.3 - 1.96*6.22$ to $16.5 = 4.3 + 1.96*6.22$ per cent. This can be contrasted with the 95 per cent confidence interval for aggregate growth. This is much shorter, ranging from 2.1 to 6.5 per cent.

These computations are meant to be illustrative only. The measures of skewness and kurtosis in Table 1 indicate that the normality assumption

is very likely to be inaccurate, as both statistics differ significantly from the zero value implied by the normal distribution.²

Figure 1 displays the fixed effects estimates of the aggregate effect. These closely parallel the growth fluctuations of gross domestic product. This is what one would expect, given that growth rates do not differ systematically between large and small sectors. It should be noted that the fit does not depend on the strength of the economy-wide effect. The movements in the aggregate can be attributed equally well to a common aggregate effect or to the random sampling error in aggregating independent sectoral growth rates. Even if there were no aggregate effects at all (i.e. $\sigma_{\alpha}^2 = 0$), the estimates would mimic GDP growth almost as accurately as in the case where GDP growth is completely determined by the aggregate effect.

Figure 1.

GROWTH OF GROSS DOMESTIC PRODUCT AND AGGREGATE EFFECTS

GDP GROWTH, %

AGGREGATE EFFECTS ON OUTPUT GROWTH, %

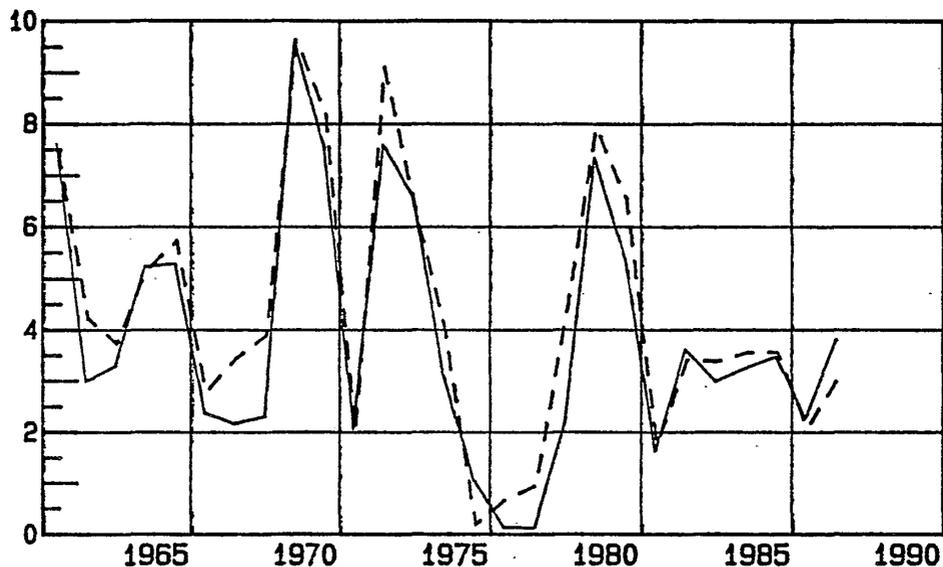


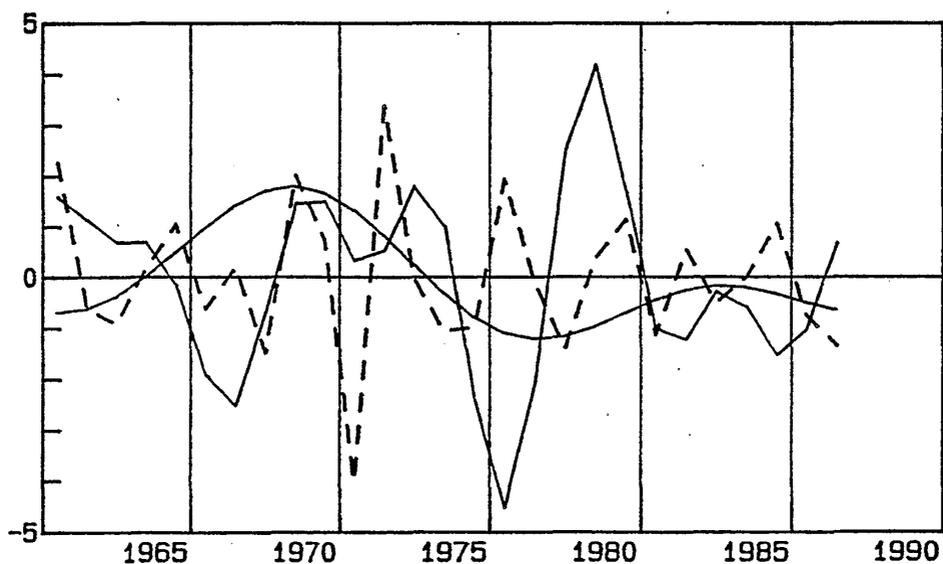
Figure 2.

COMPONENTS OF AGGREGATE EFFECTS, %

AGGREGATE TREND CHANGES

BUSINESS CYCLE

SHORT-RUN FLUCTUATIONS



A reasonable starting point for the analysis is to ask whether the observed differences in sectoral trends can be explained on the basis of the summation of random growth rates. Adopting the standard analysis of variance for testing the existence of individual effects, Table 2 presents the required data. The F-test statistics, $117.5/30.3 = 3.88$ is highly significant given the degrees of freedom 30, 780 and we conclude that variations in the average growth between sectors do not arise from a random sampling error only.

Focusing on that part of the variation which is left in the data after the removal of sectoral trends, the sum of "years" and "error" variances in Table 2 gives an estimate for the total (non-zero frequency) power of output growth in the representative sector.

TABLE 2. ANALYSIS OF VARIANCE OF OUTPUT GROWTH: FINLAND, 31 BRANCHES, ANNUAL DATA OVER THE PERIOD 1961 - 87.

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	s ²
SECTOR TRENDS	3524.6	30	117.5	3.2
YEARS	5216.9	26	200.6	5.5
ERROR	23639.4	780	30.3	30.3
TOTAL	32380.9	836	38.7	

Disaggregated real business cycle models explain aggregate business as arising from the combined effect of independent sectoral disturbances. In terms of the variance component model, the model can be interpreted to imply that $\sigma_{\alpha}^2 = 0$. Long and Plosser (1983) and Black (1983, 1987) have provided formal analyses of sectoral noise as the ultimate source of aggregate business cycles and also the one-sector models by Kydland and Prescott (1981), Hansen (1985) and Prescott (1986) can be interpreted in the same spirit. A more literal interpretation of the one-sector model is to take economy-wide productivity fluctuations as the source of the aggregate α -shocks. If only aggregated data are used, the two versions of the real business cycle theory are observationally equivalent.

The hypothesis $\sigma_{\alpha}^2 = 0$ can be tested easily using the data in Table 2. The value of the F-test statistics, $200.6/30.3 = 6.62$ is highly significant given the degrees of freedom 26 and 780. We conclude that models which explain the origin of all aggregate fluctuations as summation of independent sectoral disturbances do not provide a satisfactory account of business cycles, at least in Finland over the sample period.

Table 2 also includes the estimates for the variances σ_{α}^2 , σ_{β}^2 and σ_u^2 of the unobservables. They indicate that time-invariant sectoral forces explain less than 10 per cent and sector-invariant time effects less than 15 per cent of total variation in output growth in the sample. More than 75 per cent of total variation is 'explained' by idiosyncratic sector-specific factors. Alternatively, we can consider fluctuations around mean growth rates. In the representative sector, aggregate causes taken together explain about 18 per cent of the variations in the sector's output growth rate.

Within the prediction paradigm the main implication of this variance decomposition can be stated as follows. Suppose that g is known. In the absence of any information about the aggregate economic situation, g is a reasonable forecast for the growth of output in the representative sector. The 95 per cent confidence limits for the forecast are ± 11.7 per cent. If the forecaster also knows all the details of the aggregate economy and is able predict α_t without error, the forecast becomes $g + \alpha_t$. As a result, the 95 per cent confidence limits for the forecast shrink to ± 10.8 per cent. This is an important improvement in the accuracy of the forecast, but not overwhelmingly important. Most of the variation in sectoral growth rates is left unexplained by fluctuations in aggregate demand and other economy-wide phenomena.

On the other hand, g is also a reasonable forecast for the aggregate growth rate, if the forecaster does know g but not the values of either the α_t or the $u_{j,t}$'s. The approximate 95 per cent confidence limits are in this case ± 5.0 %. A complete knowledge of sectoral disturbances reduces σ_u^2 to zero. This reduces the 95 per cent confidence interval to ± 4.4 per cent. Again, this is an important but not overwhelmingly important improvement in the accuracy of the forecast. Most of the

variations in aggregate growth are left unexplained by independent sectoral disturbances.

In his analysis, Stockman considered growth of output in manufacturing industries at sectoral level in seven European countries, including small economies like Belgium, the Netherlands and Switzerland, which to some extent are comparable to Finland. The level of aggregation was about the same as in this paper, but the number of sectors was smaller because of the exclusion of non-manufacturing industries. The international dimension in the data allowed him to identify and present estimates of pure (national) aggregate effects relatively to industrial output in the United States, instead of the more heavily error-ridden estimates like those presented above in Figure 1. According to his results, (orthogonal) aggregate effects 'explain' about 12 per cent of the total variation in output growth in the manufacturing industries. The corresponding share in the present analysis is $5216.9/32380.9 = 16$ per cent. Stockman also notes that the estimated 'pure' aggregate effect and the index of total industrial production have a fairly high degree of correlation in all seven countries considered. On the other hand his data clearly reveal the international dimension in the sector-specific shocks completely overlooked in this paper. Although sector-specific disturbances are not important at the national level it is not inconceivable that they are a major source of fluctuations in the international economy.

4. TEMPORARY AND PERMANENT FLUCTUATIONS

To analyze the power of disturbances separately at short-run and long-run frequencies, we examined the data by grouping it by frequency into three subsamples. The number of groups and the limits conform in a rough way to the conventions of practical forecasting; otherwise, they are rather arbitrary. The low frequency range, trend changes, consisted of frequencies smaller than 1/10 years. Frequencies of at least 1/10 years but smaller than 1/4 years constituted the middle-frequency range, business cycles, and frequencies 1/4 years and less the range of short-term fluctuations. More precisely, we had data for 27 years, and thus the fundamental frequency, measured in radians, is 1/27 years. The finite Fourier transform of the original sectoral output growth series includes the zero frequency and the integer multiples of the fundamental frequency, i.e. 1/27, 2/27, ... and 13/27 together with their negative counterparts. The trend changes range included 4 frequencies $\pm 1/27$ and $\pm 2/27$, the business cycle range 8 frequencies $\pm 3/27$... $\pm 6/27$ and the short-run fluctuations range the remaining 14 frequencies $\pm 7/27$... $\pm 13/27$.

Each sectoral output growth series $g_{j,t} - g_j$ was transformed to the frequency domain and filtered there into three components, after which these were transformed back to the time domain. This procedure decomposed the original output growth variable into three components, which add up to the original variable. For each component, we conducted the same variance component analysis as above.

Figure 2 shows the fixed effects estimates of the aggregate effect for each frequency band. From the figure, it can be seen that the aggregate trend growth rate has tended to decrease during the investigation period, but not steadily and the degree of the deceleration is not clear on the basis of the figure. The business cycle component reached its trough and peak values in the latter half of the 70's, the peak apparently as a recovery from the previous recession. Short-term fluctuations were also strong during the 70's.

Exceptionally large fluctuations in GDP have occurred when all the components have happened to have extreme values in the same direction at the same time. The boom in 1969 - 70 was a product of a contemporaneous upswing in all of the three cyclical components. On the other hand, the exceptional stability during the 80's can be explained in part by offsetting cross-movements in the components, failing only in 1986 when the business cycle component and the inventory cycle component happened to be weak at the same time.

The amount of information in the transformed series is the same as in the original series, and there is little hope that the number of observations can be triplicated by simple filtering procedures. The main advantage of the frequency band filtering is a clear counting of the degrees of freedom of the filtered series. Each frequency has one degree of freedom per series. The 26 original degrees of freedom available in each series after the computation of the mean are divided between the three components in such a way that the band of trend changes receives 4 observations, business cycles 8 observations and short run fluctuations 14 observations.

The analysis of variance can be applied separately to each component in the same way as before, the only difference being in the degrees of freedom. The results from this analysis are presented in Table 3. For each frequency band, the first column gives the sum of squares 'explained' by aggregate and sectoral effects, respectively. The second column gives the degrees of freedom values. For the aggregate, these are obtained directly from the number of frequencies; for the sectoral residual, these are obtained by first multiplying the number of frequencies by the number of sectors and then deducting the degrees of freedom lost in computing the estimate of the aggregate effect. Finally, the power estimates s^2 are calculated in the usual way.

TABLE 3. ANALYSIS OF VARIANCE BY FREQUENCY BAND: OUTPUT GROWTH IN FINLAND, 31 SECTORS, ANNUAL DATA OVER THE PERIOD 1961 - 87.

A. TREND CHANGES

SOURCE:	SUM OF SQUARES	DF	MEAN SQUARE	POWER
AGGREGATE	713.4	4	178.4	4.6
SECTOR	4352.4	120	36.3	36.3
TREND CHANGES TOTAL	8590.4	124	40.8	40.8

B. BUSINESS CYCLES

SOURCE:	SUM OF SQUARES	DF	MEAN SQUARE	POWER
AGGREGATE	2722.1	8	340.3	9.8
SECTOR	8822.2	240	36.8	36.8
CYCLES TOTAL	11566.3	248	46.6	46.6

C. SHORT-RUN FLUCTUATIONS

SOURCE:	SUM OF SQUARES	DF	MEAN SQUARE	POWER
AGGREGATE	1759.4	14	125.7	3.3
SECTOR	10464.8	420	24.9	24.9
FLUCTUATIONS TOTAL	12224.2	434	28.2	28.2

D. ALL NON-ZERO FREQUENCIES

SOURCE:	SUM OF SQUARES	DF	MEAN SQUARE	POWER
AGGREGATE	5216.9	26	200.6	5.5
SECTOR	23639.4	780	30.3	30.3
NON-ZERO TOTAL	28856.3	806	35.8	35.8

The aggregate effect is highly significant in all bands, including the band of short-run fluctuations where its power is at its weakest, both absolutely and in relation to the power of the idiosyncratic disturbance. The aggregate effect is strong at business cycle frequencies, where it accounts for more than one quarter of the total variation within the band. Thus the evidence strongly reveals both the importance of aggregate shocks as the source of business cycles and, among different aggregate disturbance sources, the importance of those sources which emit shocks at business cycle frequencies.

The power of the idiosyncratic error component is quite evenly distributed over the low and middle frequency ranges, suggesting a rather random time-series behavior over the longer run. The power is clearly below its average value in the high frequency range.

The variance estimates are independent and we can employ the F-test to test the significance of their differences. The white noise assumption of no differences is adopted as the zero hypothesis. We compare the variance of business cycle fluctuations with the variance of both short-run fluctuations and trend changes and reject the zero hypothesis if the ratio of variances exceeds the 2.5 per cent significance limit. Given the degrees of freedom 240 and 420, the test statistic $36.8/24.9 = 1.47$ is significant. The probability that the maximum value exceeds the critical value is $1 - .975^2 = .05$, and thus the true significance level is 5 per cent. We conclude that sectoral effects are not completely random.

The simple random walk model for aggregate output has proved to be difficult to refute empirically using aggregate time series evidence. Yet the estimates in Table 3 seem to run counter to the assumptions of the model. At the business cycle frequencies, the aggregate effect is almost three times as powerful than at the short-run frequencies and more than twice as powerful as at long-run frequencies. Are these differences significant? The same procedure as above can be used to test the randomness of the aggregate growth effect. Because variance estimates are purged from the contribution of sectoral noise, this test is more efficient than tests which are based on aggregate time series evidence only, as far as the behavior of the 'pure' aggregate effect is concerned.

The differences in aggregate power between frequency bands are significant at the 10 per cent but not at the 5 per cent level, the variance ratio $9.8/3.3=2.97$ with the degrees of freedom 8 and 14 being the more significant of the two test statistics. Thus strictly speaking we have no hard evidence against the random walk hypothesis, in spite of the uneven distribution of power between frequencies.

If the random walk hypothesis is accepted for the aggregate effect, the three components shown in Figure 2 are statistical artifacts sampled from random numbers, without any economic content beyond the random walk assumption. On the other hand, the evidence in favor of the random walk hypothesis is not strong either. Given the limited number of the degrees of freedom available for testing purposes, this inconclusive state of affairs is more or less what is to be expected in the aggregate analysis. It not inconceivable that the observed business cycles have been random fluctuations in output growth. If the random walk specification is abandoned, however, the alternative model has to be quite complicated in order to be able to generate the concentration of power at business cycle frequencies. The evolution of the aggregate output is not easily described by a low order linear differential or difference equation. Instead, in order to be able to explain how the cycle has arisen, one has either to adopt a complicated dynamic model or to make recourse to the 'ad hoc' or fixed effects approach.

Although the degrees of freedom indicated in Table 3 are correct for testing the significance of aggregate effects, i.e. the hypothesis that

$$\sigma_{\alpha, v}^2 = 0 \text{ for all } v \text{ within the band,}$$

as well as the hypothesis that the sectoral error components have equal power, the variance estimates for the aggregate effect include the estimate of the error variance as a nuisance parameter. The test is 'asymptotic' in the sense that it implicitly presupposes that within the bands there is no sampling error associated with the estimate of σ_u^2/J .

5. REFINEMENTS AND QUALIFICATIONS

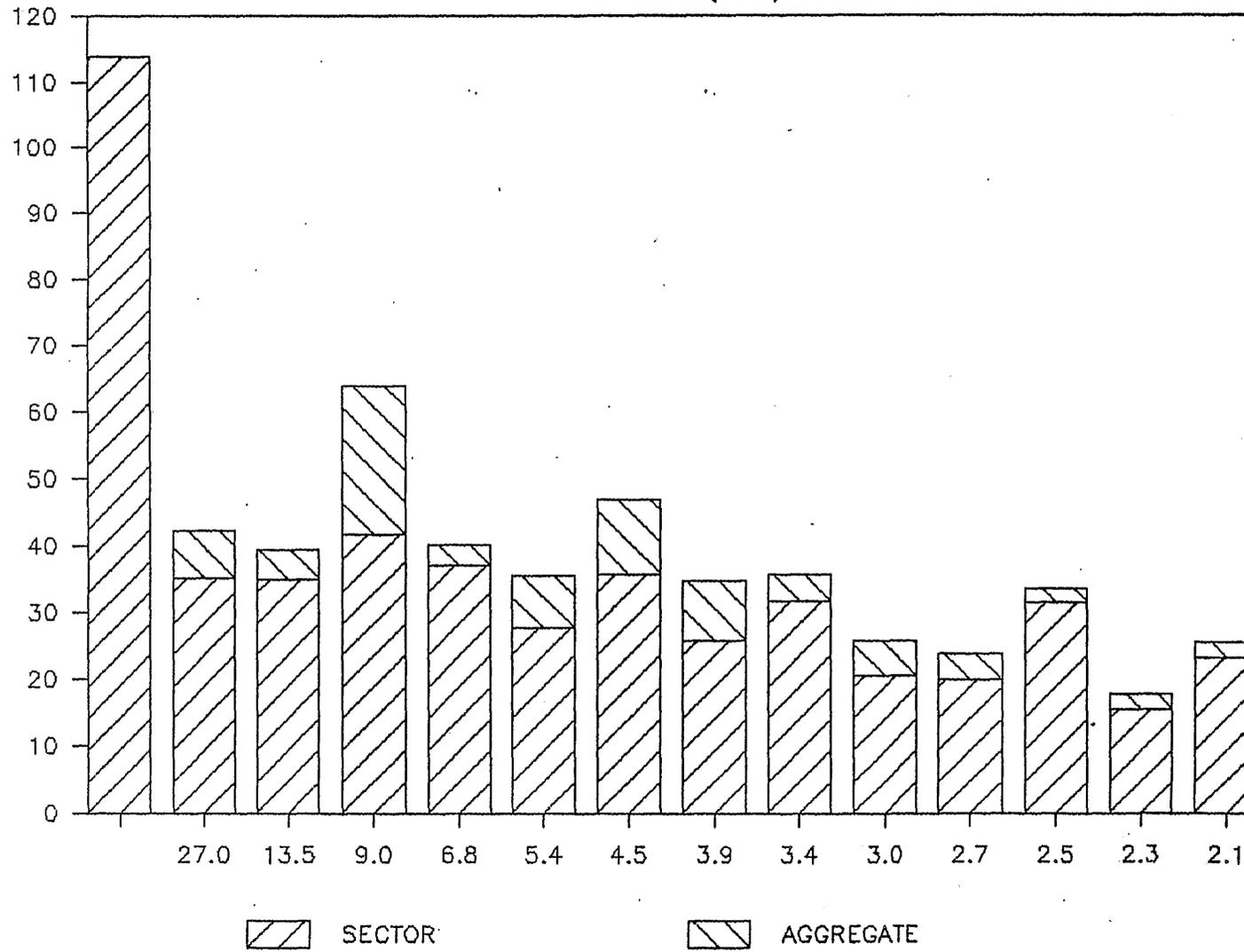
To examine whether the results are sensitive to the particular choice of band limits, average sample power and its two components were calculated frequency by frequency. Figure 3 depicts the graph of the average sample power as a function of cycle length (the inverse of frequency) in years, including the cycle length of infinity which corresponds to the zero frequency omitted from the analysis in the previous section. The height of the whole bar gives the value of the average sample power of output growth. The two components are stacked so that the upper and lower part indicate the estimated power of aggregate and idiosyncratic effects, respectively. The graph differs from normal spectrum estimates in that the periodogram values are averaged over different sectors, not over near-by frequencies. Moreover, it is scaled so that the average and not the sum of power at different frequencies is equal to the total power of the series.³

The aggregate effect has three evident power peaks. Two of these are at the limits of the business cycle frequencies and thus almost any other selection of band limits than the one adopted above would have yielded a lower estimate for the power of the business cycle frequency band. The adopted choice can be defended, however, on the basis of the aliasing problem. It is difficult to distinguish empirically the power of the underlying process at the frequencies $3/27$ and $6/27$ years.

The removal of aggregate disturbances from the series greatly flattens the peaks of the representative periodogram but does not eliminate them. The idiosyncratic disturbance component has power peaks at the same frequencies as the aggregate disturbance component. In addition, there is an extra peak at the frequency $1/2.5$ years.

Figure 3.

POWER OF DISTURBANCES BY CYCLE LENGTH (YRS.)



Because of the strong cycles in the aggregate effect, phase differences between the sectors provide one explanation for power peaks in the residual periodogram. The models considered above assume that there are no time differences in the response to aggregate disturbances. Phase differences cause the power of the aggregate effect to leak at frequencies where the aggregate effect is powerful, with the consequence that sectoral power tends to concentrate at the same frequencies where the aggregate effect is most powerful.

In the presence of phase differences, the fixed effects estimates underestimate the power of the aggregate effect. A very rough estimate of the order of the bias, based on inspection of Figure 2, may be that some 5-10 per cent of the variations attributed to sectoral disturbance sources may actually be caused by aggregate disturbances. The correction reinforces the estimated power of frequencies which are near integer multiples of $1/10$, and thus, we may interpret the evidence in such a way that the more refined frequency decomposition strengthens rather than weakens the conclusion that aggregate business cycle fluctuations have been important in the Finnish economy.⁴

Table 4 presents the sectors considered in the analysis together with the averages and variances of the output growth rates.

TABLE 3. AVERAGE GROWTH RATES AND GROWTH VARIANCES BY SECTOR: FINLAND, ANNUAL DATA OVER THE PERIOD 1961 - 87.

SECTOR:	AVERAGE	VARIANCE
1. AGRICULTURE	-0.6	53
2. FORESTRY AND LOGGING	0.0	66
3. FISHING AND HUNTING	3.9	87
4. MINING AND QUARRYING	3.7	47
5. FOOD, BEVERAGES AND TOBACCO	3.6	9
6. TEXTILES AND CLOTHING	2.1	27
7. WOOD PRODUCTS, EXCL. FURNITURE	2.0	101
8. FURNITURE AND FIXTURES	4.8	45
9. PAPER AND PULP	4.4	65
10. PRINTING AND PUBLISHING	4.3	8
11. CHEMICALS AND CHEMICAL PRODUCTS	7.5	49
12. NON-METALLIC MINERAL PRODUCTS	6.1	44
13. PRIMARY METALS	7.5	84
14. METAL PRODUCTS	6.1	28
15. ELECTRICAL MACHINERY ETC	7.2	59
16. TRANSPORT EQUIPMENT	3.4	82
17. OTHER MANUFACTURING	4.8	44
18. UTILITIES	6.0	14
19. BUILDING	2.8	34
20. OTHER CONSTRUCTION	0.5	14
21. WHOLESALE TRADE	4.8	23
22. RETAIL TRADE	3.4	14
23. RESTAURANTS AND HOTELS	4.5	20
24. TRANSPORT AND STORAGE	3.3	14
25. COMMUNICATION	6.7	7
26. FINANCIAL INSTITUTIONS	6.7	11
27. INSURANCE	4.9	51
28. LETTING AND OPERATING OF DWELLINGS	4.4	1
29. OTHER REAL ESTATE SERVICES	6.0	1
30. BUSINESS SERVICES	7.0	16
31. COMMUNITY, SOCIAL AND PERS. SERVICES	4.2	1

The variance column casts doubt on another basic assumption underlying the various versions of the variance-component models, namely that all branches respond to aggregate disturbances with the same sensitivity. Differences in the variances of size recorded in Table 3 are not likely to arise from sampling error only, and given the power of the aggregate effect, the pervasiveness assumption implicit in models (1) - (3) can

be suspected. It is quite likely that the impact of the aggregate effect is not the same in all sectors.

In order to see whether the results are sensitive to differences in sectoral response behavior, (2) can be generalized in order to allow for different responses to aggregate shocks in different sectors:

$$g_{j,t} = g + \beta_j + a_j \alpha_t + u_{j,t}.$$

In this model, the impact of the aggregate effect varies systematically between sectors, as indicated by the sector's response coefficient a_j .

Treating the a_j 's as random variables having an independent normal distribution with mean 1 and variance σ_a^2 , the model can be rewritten as

$$g_{j,t} = g + \beta_j + \alpha_t + v_{j,t}$$

where the error term is now

$$v_{j,t} = (a_j - 1) \alpha_t + u_{j,t}$$

with variance

$$(4) \quad \sigma_v^2 = \sigma_a^2 \sigma_\alpha^2 + \sigma_u^2$$

If $\sigma_a^2 > 0$, part of the variance attributed to idiosyncratic forces in models (1)-(3) may in fact be due to the aggregate effect. To evaluate the order of this bias, we estimated the a_j 's sector by sector from the regressions

$$g_{j,t} - g_j = a_j g_t + u_{j,t}.$$

The ordinary least squares estimates have the useful property that their mean is automatically equal to one. We then computed

$$\sigma_a^2 = \Sigma (a_j - 1)^2 / J$$

using estimated values for the a_j 's. The estimate was .51. Together with the estimate 5.5 for the σ_α^2 , we obtain the estimate 2.8 for the bias term on the right-hand side of (4). This is almost one tenth of

the estimated variance of the idiosyncratic variance component and about half of the aggregate variance component in Table 2.

If we take into account differences in both the timing and the strength of responses, the importance of aggregate effects in explaining output growth is enhanced. Taken together, the effect may be as large as to double the power of the aggregate effect. In this case, about one quarter of the variance in output growth in the representative sector may be due to aggregate causes.

On the other hand, the least squares estimates are sensitive to extreme observations. As there are large differences in the growth variances between the sectors, it may be that the estimates of the aggregate effect depend heavily on outlying observations. In the extreme case the outliers come from a single sector - or a group of sectors - and the estimates of the aggregate effect reflect fluctuations in that sector. However, approaches like the one adopted in this paper which are heavily based on the existence of a representative sector are not likely to be useful in this case.

5. CONCLUSION

This paper has adopted the variance-components framework to consider the sources of variations in economic growth trends and in business cycle fluctuations. Like other types of growth accounting, variance-component models do not explain the elements of policy or circumstance that underlie interesting phenomena. Rather, they attempt to identify which facts are important and need explanation. The approach offers its own particular point of view; the 'proximate' causes considered are not the same as in other types of growth accounting. The focus is on the role of aggregate and sector-specific disturbances to output growth.

Industry-specific disturbances dominate output growth at the industry level. Sectors deviate from the aggregate growth rate quite randomly, although there is some evidence of return-to-normality phenomena. A substantial fraction of changes in aggregate output can also be attributed to sector-specific disturbances. However, the largest part of variation in aggregate output growth stems from sources common to all sectors. Aggregate disturbances to output are most powerful at business cycle frequencies, corresponding to a cycle length of 5 or 10 years. It is conceivable that the rather regular aggregate cycles observed in the Finnish economy are due to a random walk output growth process. However, the random walk hypothesis is not very convincing. According to our interpretation of the evidence, it is quite likely that there have been non-random cycles in aggregate output growth. This paper does not investigate the causes of these cycles. Macroeconomic models are required to distinguish the roles of different aggregate disturbance sources or the peculiarities of the propagation mechanism.

FOOTNOTES

1. The analysis in the frequency domain focuses on the contribution of various periodic components to the total variation of a given time series. Any stationary time-series can be thought of as a sum of an infinite number of uncorrelated periodic sinusoidal components, each associated with different frequencies or periodicities. Low-frequency components are associated with long-run time intervals, and high frequency components with short-run fluctuations. In a completely random time series all periodicities contribute to the total power with the same force and thus the power is distributed uniformly between all frequencies. Another example is provided by a deterministic trend. It is monotonic and non-repeating, characterized by a near-infinite period and thus the mass of the power is concentrated near the origin.

2. The distribution of growth rates is skew to the left. In Table 1, this is highlighted by the negativeness of the skewness measure and by the difference between the largest decrease and the largest increase. In the sample, contractions in the sectoral output growth have on average been shorter and steeper than expansions. The view that such an asymmetry exists is not new. Keynes, for example, wrote that "the phenomenon of the crisis - the fact that the substitution of a downward for an upward tendency often takes place suddenly and violently, whereas there is, as a rule, no such sharp turning-point when an upward is substituted for a downward tendency" (1936, p.314). The view has also found support in time series evidence at the aggregate level, although opinions are not completely unanimous (see Zarnowitz, 1988 for a summary of the evidence and implications). It is interesting to note that data at a more disaggregated level gives some support to the existence of asymmetries.

3. If the model (1) is correct and the number of both the sectors and the periods is large, the law of large number implies that the average periodogram approaches its expected constant value. In the present case, there are only 31 observations per frequency and furthermore, the time span is only 27 years. Due to sampling error, the empirical power distribution may not be uniform even if (1) is correct.

4. There has been much discussion in Finland on the existence of strong cyclical fluctuations, peculiar to our economy, with a rather regular cycle length of about 10 years. If the evolution of output growth has been significantly influenced by these 'devaluation cycles, we would expect empirical periodograms for the output growth to have peaks at near the frequencies $1/10$, $2/10$, $3/10$, $4/10$, etc, the distribution of the power between the aggregate and idiosyncratic components depending on whether the sectors are in phase or not. This is more or less what we observe in Figure 3. For some examples of the literature, see, for example, Korkman (1978) and Kostianen and Taimio (1988).

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