A MEASURE OF STRUCTURAL CHANGE IN OUTPUT

BY JOHN H. MOORE*

Law and Economics Center, University of Miami

This article proposes a method of characterizing the growth process using two parameters, a production index measuring growth, and a structural change index measuring the changes in the composition of output. It discusses the properties of the structural change index that is developed, including its relation to the bias in growth rates measured by conventional index numbers. It then applies the measure to an examination of Yugoslav industry for the period 1952–71.

The index number problem in measuring output arises because the outputs of all commodities do not grow at equal rates; growth in output does not generally take place along a single ray defined by the base period output vector. Laspeyres and Paasche output index numbers estimate growth in productive capacity by effectively treating the commodity bundles of the base and given years as if the compositions were the same, a procedure which gives rise to well-known biases in those index numbers.[1] These biases depend, among other things, on the extent of structural change in output which takes place over the period in question; consequently, measuring structural change is an important part of assessing economic growth. For this purpose, it is desirable to have a measure which is based on the same theoretical foundations as the index numbers commonly used to measure the rate of growth of output and which abstracts from the overall growth rate measured by those index numbers. Such a measure is suggested in this paper. As will be seen later, some other measures of structural change do not satisfy these criteria.

MEASUREMENT OF STRUCTURAL CHANGE

Several approaches to the measurement of structural change have been suggested by others. One general approach is based on the observation that structural change can occur only if there are differences in growth rates among the various elements of the output bundle. In 1969, Roman proposed the use of the (weighted) average of the ratios of individual branch growth rates to the average growth rate for the economy as a whole.[2] Similarly, several Yugoslav

*This research was supported by the National Fellows Program of the Hoover Institution, Stanford University, and the Thomas Jefferson Center Foundation. Computer time was provided by the Computer Science Center of the University of Virginia. Helpful comments on an earlier draft were provided by Professor G. Warren Nutter.

[1] See Nutter (1966).

[2] Roman (1969). Algebraically, his measure is $V=(1/n)\sum|s_i|$, where $s_i=[(1+(r_i/100))/(1+(\bar{r}/100))]\,100-100$. $\bar{r}$ is the average of the percentage growth rates of the elements of the output bundle, r_i the percentage growth rate for element i, and n the number of elements. As written, V is an unweighted average, but Roman specified that this version of the formula was for "... similarly important structural elements," clearly indicating that he meant a weighted average in the general case. Roman (1969), p. 266.

economists have measured structural change by the standard deviation of the (unweighted) growth rates of the individual components of the output vector.[3] Although there might be a case for measuring structural change in terms of divergence in growth rates, there is no analytic relation between such a measure and a production index or the process of growth itself. Furthermore, as is readily seen by appropriate substitution in the formulas, neither of the measures mentioned here is invariant to homogenous growth in the output bundle, and hence neither is independent of changes in the overall growth rate unaccompanied by structural change. Consequently, both are analytically weak.

A second approach enlists information theory concepts. Here the idea is that changes in the coordinates of an output vector may be taken to indicate "surprise" in the information theory concept of the term. As this approach has been used in practice, the basic data have been shares of aggregated values of output (industry branches and sectors of the economy) rather than physical outputs, so the elements necessarily have been expressed in value terms. These shares have then been used in the calculation of entropy in a way similar[4] to that in which the information content of bits of information enters the entropy measure familiar in information theory. Its novelty notwithstanding, this approach seems weak. Not only is there little link to the theory of growth or the index numbers measuring it, but there is something paradoxical about the measure: it is the absence of structural change that would be surprising, not its presence.

Finally, brief mention may be made of another measure based on shares of value of output. This is the simplest of all approaches: for each of the two vectors, rank the elements by their shares; correlate the ranks; and measure the degree of structural change by the inverse of the rank correlation coefficient.[5] Although this measure is distantly related to the new measure proposed below, there is little theoretical justification for it and it is subject to the weaknesses of rank correlation methods.

THE PROPOSED MEASURE

The measure proposed here is based on the fact that the structure of output in any period can be described by a vector whose coordinates are the quantities of outputs which form the basis for calculating the index numbers. In measuring economic growth with Laspeyres or Paasche index numbers, the commodity bundles described by these vectors are assumed to lie on the production possi-

[3]Kovać and Madžar (1970) and Korosić (1970). Algebraically, these measures can be represented by $s = [1/(n-1)\sum(r_i - \bar{r})^2]^{1/2}$, where the notation is the same as in the previous footnote.

[4]But not in exactly the same way. The formula actually used by Kovać and Madžar for this purpose was

$$S_r = \sum_i W_{ri} \ln\left[\max\left(\frac{W_r^{+1,i}}{W_{ri}}, \frac{W_{ri}}{W_r^{+1,i}}\right)\right]$$

where W_{ri} denotes the share of the ith sector in the rth year. In contrast with the basic definition of entropy ($H = -\sum x_i \ln x_i$), the shares here enter nonsymmetrically. See Kovać and Madžar (1970) and Theil (1967), pp. 25–29.

[5]This method was used by Kovać and Madžar (1970).

bility surfaces; economic growth corresponds to an outward shift of those surfaces, and the extent of that growth is estimated by index numbers calculated by weighting the elements of the output vectors. If growth in output is measured in this way, it is natural and straightforward to measure structural change by the angle between the two vectors, a calculation which can be done very simply by the formula from linear algebra for the cosine of the angle between vectors.

This simple measurement may be illustrated by the two-commodity case; the extension to n-space is direct. In Figure 1, the original or base-period output bundle is represented by vector OP (which corresponds to point P on the production possibilities surface q_0) and the second or given-period vector OQ (corresponding to point Q on the production possibilities surface q_1). The growth ratio in terms of index numbers would be calculated by computing the expansion of output as if there had been no change in its composition; in the case of a Laspeyres index, the measurement is the ratio $OQ'/OP = OQ/OP'$. The angle between the two vectors, θ, measures the extent of structural change.[6] Clearly,

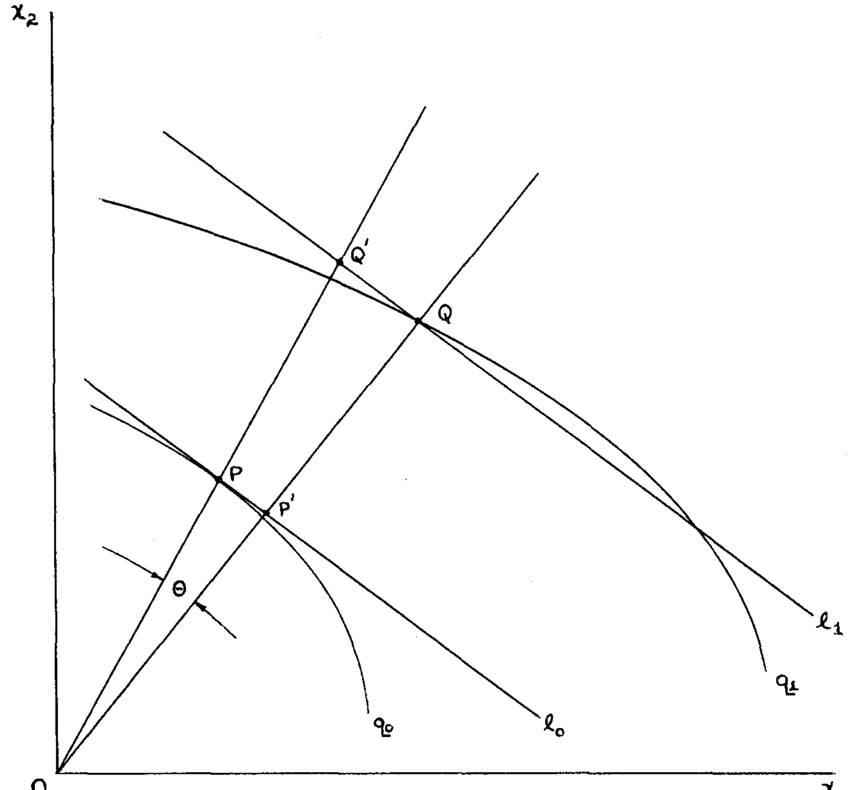

Figure 1

[6] The use of the cosine of the angle between commodity vectors was suggested by Linnemann in 1966, but in the analysis of the commodity composition of foreign trade, where its theoretical basis is weak. Linnemann himself did not use the measure in his empirical work. See Linnemann (1966), pp. 141 ff. Two Yugoslav economists took the idea from Linnemann and used it as one of several measures in a study of the change in output composition in Yugoslavia. They did not, however, note the connection with the usual index numbers nor the theoretical tie with the theory of economic growth. See Kovać and Madžar (1970).

output bundles lying on the same ray from the origin have the same relative compositions. Thus, for given output bundle compositions, the angle between the vectors is constant; this means that it is invariant with equi-proportional changes in the growth rates of the individual commodities, and hence with the overall growth rate if the commodity composition of output remains the same.[7] On the other hand, it is clear that the same measured growth rate could, depending on the actual movement of the production possibilities surface, correspond to different degrees of measured structural change, since any given-period output along the "index frontier" l_1 (which would result from different movements of the production possibilities surface) would give the same measured growth rate but different measured structural change.

The growth process can therefore be characterized by two parameters computed from the same physical output data: a production index measuring growth, and a structural change index, the angle between successive output vectors. These parameters yield derivative measures. For example, the structural component of total change in output can be calculated by the ratio of the vector distance PQ (readily computed by use of the law of cosines) and the vector distance PQ'. This measure is later reported as ρ. If there is no structural change (so that expansion takes place along the ray OP), the value of this measure is unity. Otherwise, it would be greater than one, and the larger its magnitude, the greater would be structural change relative to the change in measured output alone. In addition, an index of total change in output, denoted here by γ, can be calculated as the sum of the vector lengths OP and PQ divided by the base year vector length OP. For any given growth ratio measured between two years, the measure γ will be larger than that ratio if there is structural change, and the greater the structural change, the greater will be the difference between γ and the growth ratio. If there were no structural change between two years, the ordinary growth ratio and γ would be equal.

The proposed index of structural change is intended to be used with the conventional Paasche and Laspeyres indexes of output. Thus, the structural change index, like those output indexes, has a fixed sample; once the sample is chosen for the base period, the same sample must be used for the given period. Therefore, in order to make the interpretations suggested in this paper, the same level of detail, to the extent that the usual measurement problems allow, must be used in both base and given period samples. However, the properties of the index and its relationship to Laspeyres and Paasche indexes defined for the same sample remain the same regardless of the level of detail used. Changes in level of detail between base and given periods or differences in level of detail between the structural change index and the corresponding Laspeyres or Paasche index cause unpredictable changes in those relationships. The interpretation of the

[7]By definition,

$$\cos\theta = \frac{a'b}{|a|\,|b|} = \frac{\sum a_i b_i}{[\sum a_i^2]^{1/2}\,[\sum b_i^2]^{1/2}} = \frac{\sum r_i a_i^2}{[\sum a_i^2]^{1/2}\,[\sum r_i^2 a_i^2]^{1/2}}$$

where a, b are the base- and given-period output vectors, respectively, and r_i designates the growth ratio for the ith commodity (*i.e.*, $r_i = b_i/a_i$). It is evident that an equi-proportional change in all growth rates, represented by multiplying each r_i by a constant K, leaves $\cos\theta$ unchanged.

structural change index in such cases becomes obscure. Ordinarily, a sample will have been chosen for use in calculating the output index in base and given periods; one of the desirable properties of the suggested structural change index—and a requirement in its use—is that the same sample be used in its calculation.

Several additional properties of the vector angle index of structural change should be noted. First, for many purposes it is convenient and useful to express outputs not in physical but in value terms. The vector angle can still be used as an index of structural change if this is done, but its relation to the production indexes becomes indirect. Second, the calculated vector angle is the same whether physical quantities or output values, on the one hand, or their respective shares, on the other, are used in the computation.[8] Third, it can readily be shown that the angle between two output vectors is inversely related to the covariance of the elements of the two vectors—a relationship that is clearly desirable—and directly related to the variance of the elements of the base-period vector.[9] The second property is desirable for measuring structural change in one country,

[8]This is easily shown. Let q_t denote the vector of quantities or values in period t, so that

$$\cos\theta = \frac{\sum q_i^0 q_i^1}{[\sum (q_i^0)^2]^{1/2}\,[\sum (q_i^1)^2]^{1/2}}.$$

Then let x_t denote the corresponding vector of output shares in period t, so that $x_t = q_i^t/\sum q_i^t$. (If physical quantities are used here, "share of output" loses its common sense meaning, but the principle remains the same.)

Then the vector angle in terms of output shares is defined by

$$\cos\theta = \frac{\sum x_i^0 x_i^1}{[\sum (x_i^0)^2]^{1/2}\,[\sum (x_i^1)^2]^{1/2}}.$$

Substituting:

$$\cos\theta = \frac{\sum (q_i^0/\sum q_i^0)(q_i^1/\sum q_i^0)}{[\sum (q_i^0/\sum q_i^0)^2]^{1/2}\,[\sum (q_i^1/\sum (q_i^1)^2]^{1/2}} = \cos\theta.$$

[9]Let q_i^t denote the representative element in the output vector for the period t. Then the base year variance is given by

$$\sigma_0^2 = \frac{1}{n}\sum (q_i^0)^2 - (\bar{q}_0)^2$$

and the given year variance by

$$\sigma_1^2 = \frac{1}{n}\sum (q_i^1)^2 - (\bar{q}_1)^2.$$

The covariance is given by

$$\sigma_{01} = \frac{1}{n}\sum q_i^0 q_i^1 - \bar{q}_0\bar{q}_1.$$

Substituting in the formula for the cosine of the angle between the two vectors:

$$\cos\theta = \frac{\sigma_{01} + \bar{q}_0\bar{q}_1}{(\sigma_0^2 + \bar{q}_0^2)^{1/2}\,(\sigma_1^2 + \bar{q}_1^2)^{1/2}}$$

As the sizes of the cosine of the angle and the angle itself are inversely related, the relationships in the text are obvious. It is this relation between θ and the covariance which provides the link to the rank correlation measure of structural change but the link obviously is very weak.

because it implies that measured change for different starting output bundle compositions will be different even with the same set of individual growth rates (a property not shared by the standard deviation measure).

It should also be noted that vector angles measuring structural change over a series of years or subperiods are not additive in the sense that the sum of angles for a sequence of years or sub-periods generally equals the angle measured between the vectors defining the first and last years of the period. Structural changes in intermediate years define vectors whose movements in the n-dimensional output space are sure to be complex, since the directions of change, in the sense of the relative growth rates of different components of the output vector, are not likely to be the same in each subperiod. The output vector conceivably could return to its original composition at the end of a series of structural changes; if so, the vector angle between base and final year outputs would be zero. Since the values of the angles for intermediate years cannot, by the definition of their measurement, be negative, their sum could not be zero unless each was identically zero.

The relation of the measure of structural change to the bias in growth rates measured by conventional index numbers can be described only qualitatively. It is not true that there is a uniform positive relationship between the index of structural change and the degree to which a Laspeyres index overstates growth in capacity to produce the base year output mix. A uniform relationship would hold only over a range of the value of the structural change index, and that range cannot be specified on *a priori* grounds because the degree of overstatement of the Laspeyres eventually declines as the mix changes.[10] However, it is possible to delineate the range over which there is a positive relationship: as long as the value of the Laspeyres index exceeds that of the Paasche for the same period, there is a positive relation between the value of the index of structural change and the bias in the Laspeyres index.[11] *Mutatis mutandis*, the same statements hold for the bias in the Paasche index.

Finally, international comparisons of structural change based on vector angles observed in different countries are feasible but must be treated with caution. It is highly unlikely that the structure of output will be the same, even in value terms or shares of output, in two countries at a particular time or at two different times chosen as base periods for the two countries, and simple comparison of the vector angles for the two is likely to be misleading for this reason. Provided that the number of elements in the output vector for the base year is the same in the two countries, the extent of incomparability between structural change as measured by the vector angles for two countries may be determined by comparing the coefficients of variation in the base year output vectors used in the computation. The smaller the difference in coefficients of

[10]In Nutter's terminology, this point is the boundary of the "normal" region of growth. If the output mix shifts "beyond" that defined by this limit, the value of the Laspeyres recedes toward that corresponding to measurement along the original output ray, and if the mix changes radically enough, the bias may be eliminated altogether.

[11]The normal relationship between Laspeyres and Paasche indexes holds over the normal region of production, as Nutter (1966) has shown.

variation, the smaller the degree of incomparability.[12] Given the vector angle for one country, and assuming that the number of elements is the same, the vector angle for the second country will be over- or understated as its coefficient of variation is greater or smaller than that for the first country.[13]

An Application: Yugoslav Industry

During the first twenty years of workers' self-management in Yugoslavia (1952–71), output of industrial products expanded rapidly but at a decelerating rate. At the same time, there was substantial change in the structure of output. The older, traditional branches of industry tended to become relatively smaller, while newer, more "modern" branches expanded.[14] The combination of rapid expansion in output with extensive structural change, typical of industrializing economies, provides a good opportunity to test the proposed measure of structural change.

For this purpose, industrial growth was measured by an arithmetically weighted output index using 1961 value-added weights.[15] The physical output quantities included in the output index were used to calculate the angle between the relevant output vectors so the samples in the output and structural change indexes are identical. Indexes were calculated for subperiods and for year-to-year changes within the entire twenty years.

The results for the period as a whole and for certain subperiods are presented in Table 1. The subperiod with the most extensive structural change was the first, from 1952 to 1957. This was a period during which there was no five year plan in Yugoslavia; instead, there were a series of annual plans which dictated very high rates of investment and mobilization of other resources for industrial growth. As the data in Table 2 show, the first year in this subperiod, 1952–53, had the most rapid structural change of any year in the entire period. (If the structural change index is recalculated for 1953–57, its value falls to 22.6.) The next period

[12]Manipulation of the formula for the vector angle in terms of the variance and covariance gives:

$$\cos\theta = \frac{(\sigma_{01}/\bar{q}_0\bar{q}_1)+1}{(V_0^2+1)^{1/2}(V_1^2+1)^{1/2}}$$

where V_t denotes the coefficient of variation in the output vector for year t. The base year affects $\cos\theta$ through V_0 and $\bar{q}_0$.

If the computation is carried out in terms of shares of several output branches, $\bar{q}_0 = 1/n$, where n is the number of branches. It will be recalled that $\cos\theta$ is the same whether shares or actual values are used in a computation in value terms, so equality in the number of elements is sufficient to eliminate the influence of q_0 in the numerator. As can be seen, if the number of elements is the same and V_0 is the same for the two countries in some base period, differences in θ accurately reflect differences in structural change. If the number of elements is the same but V_0 is not, this is not the case; the extent of the error in θ is obviously a nonlinear function of the difference in the values of V_0 and θ but can be computed readily.

[13]As can be seen from the formula in the previous footnote, the relation is not linear in V.

[14]For example, among the industrial branches, the share of coal and coal products in national income originating in industry fell from 8.9 percent in 1952 to 2.8 percent in 1971, and that of tobacco and tobacco products from 4.6 to 1.5 percent in the same period. On the other hand, the share of chemical products rose from 2.5 to 9.9 percent and that of electrical products from 1.9 to 6.3 percent. See Savezni zavod za statistiku, *Statistički godišnjak SFRJ* 1971, p. 98, and *Statistički godišnjak SFRJ* 1972, p. 103.

[15]See Annex for further information about the data sources and the calculations.

TABLE 1

GROWTH RATES AND STRUCTURAL CHANGE: YUGOSLAV INDUSTRIAL SECTOR, SELECTED PERIODS

Period	Average Annual Growth Rate, Percent[a]	Index of Structural Change[b]
1952–71	9.6	46.6
1952–57	12.6	32.2
1957–60	13.8	11.9
1961-66	10.2	16.8
1966–71	4.7	18.8

Source: Calculated from output and value-added data derived from official Yugoslav sources. See Annex for details.

[a]Calculated between terminal years by the compound interest formula from index numbers for industrial production using 1961 value-added weights.

[b]The angle whose cosine is calculated by the formula discussed in the text.

TABLE 2

ANNUAL GROWTH RATES AND OUTPUT STRUCTURE CHANGE: YUGOSLAV INDUSTRIAL SECTOR

Years	Percent Increase in Industrial Output[a]	Index of Structural Change[b]
1952–53	7.8	24.0
1953–54	12.7	13.0
1954–55	14.9	14.3
1955–56	8.2	12.3
1956–57	19.7	10.2
1957–58	12.7	8.9
1958–59	13.2	7.5
1959–60	15.6	6.6
1960–61	5.0	6.4
1961–62	11.1	8.3
1962–63	15.1	7.7
1963–64	17.6	7.0
1964–65	6.3	5.3
1965–66	1.8	11.5
1966–67	−2.8	12.3
1967–68	3.6	8.8
1968–69	10.2	9.0
1969–70	5.3	10.6
1970–71	7.8	6.6

Source: Calculated from output and value-added data derived from official Yugoslav sources. See Annex for details.

[a]Based on an index of industrial production with 1961 value-added weights.

[b]The angle whose cosine is calculated by the formula discussed in the text.

corresponds to that covered by the First Five Year Plan. Originally intended to extend through 1961, this Plan was deemed to have been fulfilled in four years instead of five because of the rapid industrial growth which occurred in that time. The structural change index reveals that this rapid growth was accompanied by the slowest pace of structural change of the entire period.

The next two subperiods correspond to the Five Year Plans of the reform period. In both of these Plans, and especially in the second one, the role of the central government was supposed to be weakened relative to that of the local executors of the Plan, especially the enterprises. The reforms included a shift of responsibility for investment credit allocation to the banking system in 1963–66, foreign trade reforms in 1961 and 1965, a price reform in 1965, and a reduction in taxes on enterprises (which led to their having a greater share of their net income to disburse as wages or retain for investment) in 1964–65.[16] The immediate impact of the reforms, at least during the first year or so of each of the respective five year periods, was to strengthen market forces, previously held in check by a variety of regulatory constraints. In fact, the Second Five Year Plan was abrogated after its first year of operation and for the remainder of the period only annual plans were issued. Similarly, there were important reversals of the reforms of the Third Five Year Plan after its second year of operation; a general price freeze was imposed in 1967, and the share of income left at the disposal of enterprises retreated after reaching a peak in 1967.[17]

Structural change in both of these subperiods proceeded at higher rates than in the First Five Year Plan; furthermore, change in the early parts of both subperiods was generally greater than that later on, as the data in Table 2 indicate. While it is not linear, there seems to be an inverse relation between growth rates and structural change over these groupings of years, a relation explored further below. In the last subperiod, whose beginning was marked by a sudden and unprecedented relaxation of central control, very rapid structural change occurred, and structural change was rapid throughout the six years. Growth rates in this period were relatively low. In the 1961–66 period, structural change was less rapid, and growth rates higher.

As suggested earlier, the relative importance of structural change and growth in capacity to produce the base year bundle of commodities can be represented by the measure ρ. The larger is ρ, the more important is structural change relative to growth in the base year capacity. For Yugoslav industrial growth after 1952, this measure provides useful insights, as can be seen from Figure 2. The first year of the self-management period was, it is plain, a year of relatively important structural change, the result of the initiation of the new industrialization drive. Up to the beginning of the First Five Year Plan, structural change diminished in importance and, as can be seen, during that five year plan it was relatively small. With the beginning of the next FYP, there was a temporary upswing in the relative importance of structural change; at the same time, there was a corresponding temporary setback in growth rates. The reason for the more rapid structural change is not entirely clear, but it is possible that

[16]For additional details about these reforms, see Sekulić (1970), Jovanović, (1968), OECD (1964), and OECD (1970).

[17]See the data on enterprise income distribution in various issue of *Statistički godišnjak SFRJ.*

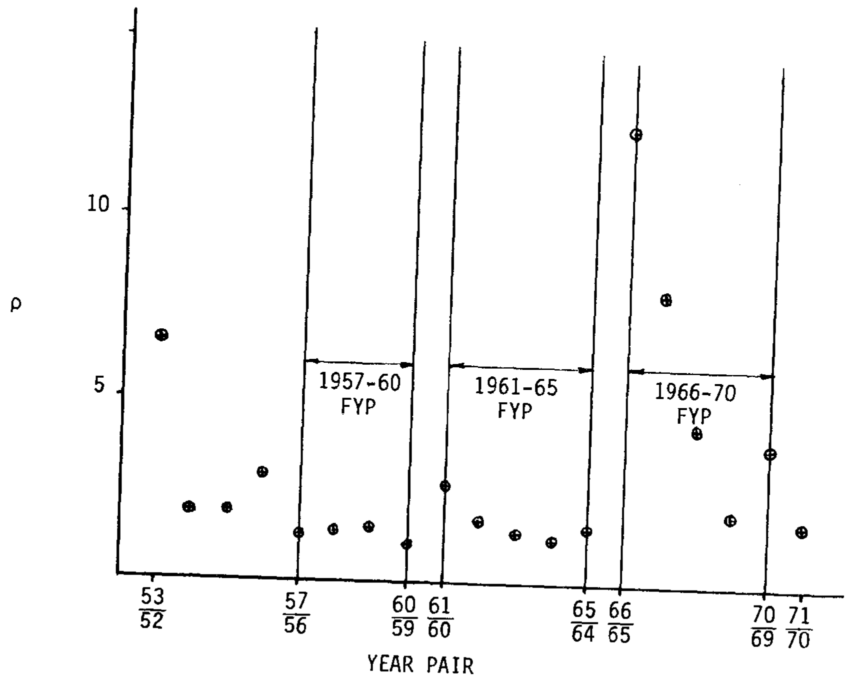

Figure 2

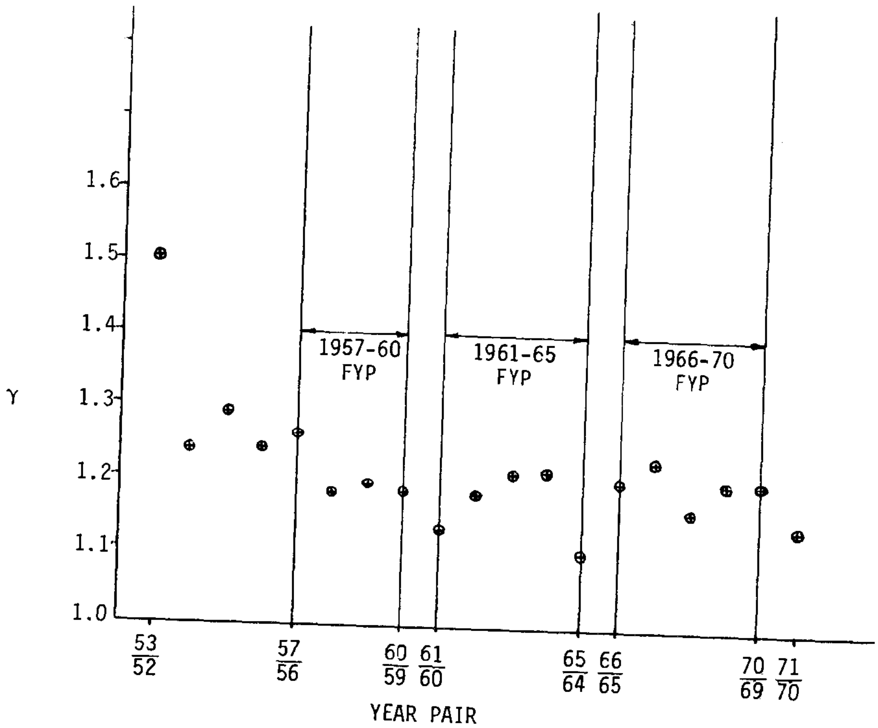

Figure 3

the reforms adopted at this time partially released previously restrained market forces, causing restructuring of the output mix. However, the reform in this direction was short-lived, and, as can be seen, so was the greater relative importance of structural change.

The more extensive reforms of the mid-sixties followed, reaching their peak intensity around the inauguration of the Third Five Year Plan. As noted, the reforms included in this Plan (and other legal changes) had the effect of increasing the importance of market forces relative to administrative restrictions in influencing resource allocation. The result was a very large increase in the rate of structural change and a corresponding or, at least, simultaneous decline in the rate of growth of output measured by a Laspeyres index. This suggests that prior to the reforms there existed substantial disequilibrium in the industrial sector, the result of years of price, foreign exchange, and output controls. It appears that this might have been the cause of the very sharp reductions in growth rates experienced at this time. That interpretation is superficially consistent with the commonly held view that the reforms caused the slowdown.

At another level of analysis, however, this view seems misguided. To see why, the third measure, γ, of the combined effects of output growth and structural change is useful. In the process of economic development, as opposed to sheer growth in output, change in the structure of output—which is not costless—may be considered as an alternate use of resources which otherwise could be used to increase proportionally the rates of production of the existing set of products. If so, this third measure can be taken as an indicator of the overall performance of the system in generating development. The values of γ, plotted in Figure 3, suggest that the performance of the sixties was viewed by the Yugoslavs with, perhaps, more alarm than was appropriate. It is true that there was a secular decline in γ over the entire period, but this is to be expected in any developing economy. On the other hand, except for 1964–65 (which was *not* singled out for attention as a particularly bad year), there seems to have been no precipitous fall in the index during the last decade. From this point of view, what was seen by Yugoslav economists and politicians as the disastrous results of the reform in the first two years of the Third Plan was only an adjustment of the structure of output which might well have been expected. Overall, performance was neither much better nor much worse than in the preceding two plan periods. The single-minded focus on measured rates of growth of output may have led to an incorrect interpretation of the situation and to possibly incorrect policy measures.

Much of what has been said above rests on the assumption that there is a trade-off between structural change and growth in capacity to produce the base year output bundle. The basis for this assumption is that it is more costly to produce the same measured growth in output if that growth is also accompanied by structural change than it would otherwise be. In turn, this rests on the presumption that it is costly to change the output mix.[18] Put this way, the

[18]If the process of growth is depicted by movements of production possibility frontiers over time, this amounts to saying that the envelope frontier open to a system at time t is furthest from the existing frontier along the ray corresponding to the existing output bundle. (See Nutter (1966) for the concept of the envelope frontier.) This is a very broad assertion about economic growth and its evaluation is beyond the scope of the present paper. The test carried out here should be regarded only as a single instance in which it apparently is not refuted.

relation is more a working hypothesis than an assumption, and it is useful to test it with the Yugoslav data.

However, a simple relation between a production index (λ) and the structural change index (θ) should not be expected. First, there was secular retardation in the growth rate during the period, shown by the combined measure, γ, of growth and change. Since the product $\lambda\theta$ is proportional to γ, the relation $\lambda\theta^{\beta_1} = e^{-(\beta_0+\beta_2 t)}$, or $\log \lambda = -\beta_0 - \beta_1 \log \theta - \beta_2 t$ may be specified as a means of taking secular change into account. However, in Yugoslavia the situation is more complex because of the apparent existence of business cycles. Yugoslav economists were among the first in the communist countries to recognize, date, and try to measure cycles in economic activity.[19] To account for cyclical swings, two dummy variables were included in the test equation, taking values of unity in those years in which, according to Horvat's dating,[20] cyclical extremes occurred.

The regression results were as follows. In this equation,

$$\log \lambda = 0.26 - 0.057 \log \theta - 0.0053t + 0.055P - 0.17T$$

$$(3.45)^* \quad (-2.01)^* \quad (-2.80)^* \quad (2.38)^* \; (-0.76)$$

λ, θ, and t are defined as indicated in the preceding paragraph, and P and T are dummy variables for peak and trough years. All variables have the expected signs, and all except the dummy variable for troughs are significantly different from zero at the 95 percent level. Approximately 63 percent of the variance in year-to-year changes in λ was explained by the equation.[21] Thus, when account is taken of secular changes in growth rates and cyclical movements in output, the expected relation between growth in output and structural change emerges clearly.

In fact, the results of this test, along with the observed behavior of the measure γ of the combined effects of growth and structural change in output, suggest that a reconsideration of the alleged business cycle in Yugoslavia might be in order. The measurement and dating of cycles in Yugoslavia generally has been carried out by observing movements in growth rates of output. This is the method used by Horvat and by Bajt in their work on the Yugoslav cycle. But in none of these works is structural change in output taken into account. Horvat argues at one point in his major work on cycles that there is an association between cyclical extremes and administrative changes.[22] Those changes have been importantly associated with economic reforms, which in turn have generally led to realignments of the structure of output. If it is true that structural changes represent a use of resources which is competitive with measured growth in output, the association Horvat notes and the results of the present research suggest that measuring cycles by changes in measured growth rates

[19]See Bajt (1971) for a summary of the work of economists in communist countries on business cycles.

[20]Horvat (1966), p. 45.

[21]The Durbin–Watson statistic was 1.33, lower than ideally desirable but nevertheless in the indeterminate range. The null hypothesis of zero serial correlation cannot be rejected on this basis.

[22]Horvat (1971), p. 172.

alone is incorrect. The fact that inventories rise during the downturn and fall in the upswing of Yugoslav cycles[23] seems consistent with this view, since an increase in the rate of structural change would be likely to be associated with inventory buildups, and vice versa. There may well be business cycles in Yugoslavia and other communist countries, but unless the only important measure of economic activity is the growth rate of output, the existing methods of dating and measuring those cycles seem to require modification.

ANNEX

Output data were obtained from the Yugoslav statistical bulletins *Industrija*. Weights were calculated from 1961 product unit values published in Yugoslavia (1972) by deducting turnover tax and adjusting the remaining sums by the ratio of value added to sale value in the sub-branch to which each product belonged. Data on turnover tax rates were obtained from the Yugoslav Official Gazette (*Službeni list*). Data for calculating the ratio of value added to sales value were taken from Yugoslavia (1963). Altogether 541 output series and 417 weights were obtained; the intersection of the weight and output sets for which data were available for all series in all years contained 322 series. Growth ratios were calculated between base and subsequent years by means of the usual formulas:

$$\lambda = (\sum_{i=1}^{n} w_i x_i^t)/(\sum_{i=1}^{n} w_i x_i^0),$$

where w_i denotes a weight derived as described above and x_i^t denotes the output of the corresponding product in year t. In the case of the present study, n equalled 322. The same products included in this sample were used to calculate, year by year and between years at greater separations, the indexes of structural change by means of the basic formula given in f.n.8. The reported values for ρ and γ were obtained from the basic data by applying simple trigonometric formulas. Full details on the calculations may be obtained from the author.

REFERENCES

[1] Bajt, Aleksander, "Investment Cycles in European Socialist Economies: A Review Article," *Journal of Economic Literature* 9:1 (March, 1971), pp. 53–63.

[2] Horvat, Branko, "Business Cycles in Yugoslavia," *Eastern European Economics* 9:3–4 (Spring-Summer, 1971), pp. 1–259.

[3] Jovanović, Božidan, "Taxation of Workers' Personal Incomes," *Yugoslav Survey* 9:3 (August, 1968), pp. 103–8.

[4] Korosić, Marijan, "Strukturne promjene i stope rasta industrije," *Ekonomist* 23:4 (1970), pp. 645–62.

[5] Kovać, Oskar and Ljubomir Madžar, "Stopa rasta i promene u privrednoj strukturi," *Ekonomist* 23:1 (1970), pp. 5–31.

[6] Linnemann, Hans, *An Econometric Study of International Trade Flows*. Amsterdam, 1966.

[7] Nutter, G. Warren, "On Economic Size and Growth," *Journal of Law and Economics* 9 (1966), pp. 163–88.

[8] O.E.C.D., *Socialist Federal Republic of Yugoslavia*. Paris, 1966.

[23] Horvat (1971), pp. 93–4.

[9] ———, *Socialist Federal Republic of Yugoslavia*. Paris, 1970.
[10] Roman, Zoltan, "A Note on Measuring Structural Changes," *Review of Income and Wealth* 15:3 (1969), pp. 265–8.
[11] Sekulić, Slobodan, "Investment Capital of Socio-Political Communities," *Yugoslav Survey* 11:4 (November, 1970), pp. 1–12.
[12] Theil, Henri, *Economics and Information Theory*. Amsterdam, 1967.
[13] Yugoslavia, Savezni zavod za statistiku, *Industrija*, various issues.
[14] ———, *Industrijski preduzeća 1962* (Statistički bilten broj 283), Beograd, 1963.
[15] ———, *Industrijski proizvodi 1970* (Statistički bilten broj 717), Beograd, 1972.
[16] ———, *Službeni list*, various issues.