FINAL REPORT TO
NATIONAL COUNCIL FOR SOVIET AND EAST EUROPEAN RESEARCH

TITLE: CHANGES IN TECHNICAL EFFICIENCY
AND THE ECONOMIC SLOWDOWN IN
EASTERN EUROPE AND
THE SOVIET UNION

AUTHORS: David M. Kemme
Wichita State University

Robert S. Whitesell
Williams College

CONTRACTOR: Wichita State University

PRINCIPAL INVESTIGATORS: David M. Kemme
Robert S. Whitesell

COUNCIL CONTRACT NUMBER: 802-04

DATE: June 1989

The work leading to this report was supported by funds provided by
the National Council for Soviet and East European Research. The
analysis and interpretations contained in the report are those of
the authors.
Contents*

Executive Summary v

1. Introduction 1

2. Review of the Literature 6

3. Model Specification 19

4. Empirical Results 23

5. Conclusions 46

6. References 54

7. Notes 64

8. Appendix A: The Frontier Production Function: Theoretical Considerations

9. Appendix B: The Data Base

10. Appendix C: Estimation Results

11. Appendix D: Rates of Change of Inefficiency

*The Appendices to this report, which total approximately 170 pages, are available from the National Council on request.
Section 0: Executive Summary

Solow (1957) first drew a distinction between output growth attributable to input growth and output growth attributable to technological change. The debate on the causes of the economic slowdown in the Soviet Union and Eastern Europe has been placed in this context and both the role of technological change and the role of input growth have been explored. In this framework the concept of total factor productivity growth is synonymous with technological change. But, this is true only because it is implicitly assumed that production is continuously efficient. Simply said, production is efficient if inputs are transformed into output with no wasted inputs, holding technology constant. If the full efficiency assumption is relaxed the rate of growth of total factor productivity may be decomposed into the rate of technological change and the rate of change of efficiency. Thus, Solow's original dichotomy may be extended. Output growth may be caused by input growth, technological change or change in efficiency. Fundamentally different policies are required to address difficulties in promoting technological change as opposed to addressing problems of falling efficiency; yet the debate on the economic slowdown in the Soviet Union and Eastern Europe has not fully considered the distinction between the two.

One method to measure both technological change and efficiency is to estimate frontier production functions rather than standard, average production functions. This technique
allows us to measure efficiency of production, but in a limited sense. For each industrial sector in each country the efficiency of each observed level of output is measured relative to the best practice, i.e. the most efficient production for that industry and country. The measure of efficiency employed addresses the issue of whether production, at a particular time, is efficient relative to the most efficient observed production - given the actual technology available. This should not be confused with whether or not the industry has the most technologically advanced production process. Our efficiency measures show changes in efficiency relative to best practice observed and is not an "absolute measure" in the sense of making world wide technological comparisons.

In this study frontier production functions have been estimated for industrial sectors in five East European countries and the Soviet Union, for the period from 1960 to the mid-1980s. The major purpose has been to more fully identify the factors leading to the slowdown in industrial growth. Generally, our results support the hypothesis that there has been a decrease in the efficiency with which inputs are used throughout Eastern Europe and the Soviet Union in the late 1970s and 1980s. The results also indicate that technological change has been somewhat higher than reported in studies using standard estimation techniques. These two results imply that the decline in industrial growth has been more affected by decreases in
efficiency and less affected by decreases in the rate of technological change than can be inferred from previous studies.

However, with the possible exception of Poland, the decrease in efficiency appears to be rather small. The results indicate that production is only about 3 or 4 percent less than best practice, even in the early 1980s which was the least efficient period. Changes in efficiency seem to be small relative to our prior expectations - based on anecdotal evidence of rampant inefficiency in the Soviet and East European economies. The anecdotal evidence suggests substantial overuse of labor, large amounts of idle labor and capital, difficulties in procuring necessary inputs, etc.; all of which should result in low levels of efficiency. Furthermore, discussions of the "era of stagnation" in the Soviet Union and similar phenomena in Eastern Europe imply that efficiency was falling in the 1970s and 1980s. Our results indicate that changes in efficiency over time are small, regardless of the overall level of efficiency. This implies that decreases in efficiency, relative to the most efficient points observed, have had only a minor influence in reducing industrial growth. Thus, the results of this study are consistent with earlier studies which have emphasized low and declining rates of technological change, and declining input growth -- especially labor -- as the principal causes of the growth slowdown, but suggest efficiency changes are another significant contributing factor.

Another finding is that there is substantial cross-sectoral
variation in both rates of technological change and rates of efficiency within all the countries studied. Generally, the variation in technological change tends to conform with prior expectations. High priority sectors, such as machine building and chemicals, tend to have high rates of technological change. Low priority sectors, such as the light industrial sectors and food processing, tend to have low rates of technological change. Also, sectors with particularly difficult technical problems, such as fuels, tend to have very low (often negative) rates of growth of technological change. Technological change for total industry appears to be an average of these strong and weak performing industrial sectors.

Cross-sectoral variations in rates of change in efficiency seem to have no identifiable pattern. High priority sectors with high rates of technological change sometimes have relatively large changes in efficiency and sometimes have relatively small changes in efficiency compared to low priority sectors. This varies from country to country.

A final important result is that estimates of changes in efficiency for the Soviet Union appear to be somewhat lower, have less cross-sectoral variation, and fluctuate less over time than in the East European countries. This implies that efficiency changes are less problematic for the Soviet Union than Eastern Europe.
Section 1: Introduction

The dilemma of transforming an economy from an extensive to an intensive method of growth has faced the economies of Eastern Europe and the Soviet Union for nearly three decades. The crux of the problem is to increase factor productivity, thus increasing the rate of growth of output without increasing the rate of growth of inputs. In general, there are two methods of intensifying production. The first is technological change, which may be thought of as an upward/outward movement in the production frontier. This movement may be brought about by the introduction of more technologically advanced production methods, either imported or indigenously developed. These can be in the form of better machinery, equipment, production processes, reorganization of labor and/or management, etc. The shift in the frontier represents the implementation of new technology by a firm, enterprise or industrial branch which, by its possession of the most productive methods of production, defines the frontier. Other firms, enterprises or industrial branches which are not producing on this new frontier strive to reach it.

This method of intensifying production, defined here as technological change, is measured typically by the rate of growth of joint factor productivity (the Solow residual) in an "average" production function. Technological change and factor productivity growth are used synonymously in this context.
Although this approach is sometimes criticized on the basis of aggregation biases and omitted variables, the resulting estimates of factor productivity growth have proven useful for policy purposes. However, a second weakness is that this methodology does not permit the distinction between technological change and changes in the efficiency with which known technology is utilized in the existing production process. Quite different policy prescriptions may be necessary to address problems in these two distinct sources of growth and therefore it is of interest to disentangle the two if possible. This leads us to a more careful consideration of the second method of intensifying production.

Changes in technical efficiency represent a second source of growth potential. These represent productivity changes caused by the diffusion of technology from the pioneering, frontier-defining firms, enterprises or branches to other potential users, as well as improved management techniques, adjustment to supply bottlenecks, and/or systemic reforms which increase the productivity of non-frontier production units relative to those units which define the frontier. Such changes in technical inefficiency, which are changes in the distance from the frontier (which may itself be moving) at a point in time, are measured typically in one of two ways. The first is to measure changes in the (one-sided) residual in a parametric frontier production function. Technical inefficiency is defined as the amount by which measured total factor productivity is less than the potential or frontier level. The residual, i.e., the distance
between a particular observation and the frontier itself, is the measure of this difference. The frontier is specified generally as a parametric function of inputs (Cobb-Douglas, for example) and may be stochastic or non-stochastic.

The second method of measuring technical efficiency involves estimating a non-parametric non-stochastic specification of the production technology - the programming approach. The level of efficiency is estimated by the ratio of potential to actual output where the potential output is the maximand of a linear or quadratic program. For example, the objective function to be maximized may be a linear combination of observed outputs and the constraints are that no more than the observed level of inputs may be used.

The frontier production function framework allows us to address the question of intensifying production in a very illuminating way, distinguishing between technological progress and changes in technical efficiency. Given a certain technological base, a specific pattern of diffusion within and among industrial branches may be necessary to reach the frontier level of technical efficiency. According to Nishimizu and Page (1982), there is growing evidence that productivity gains due to later "technological mastery" or diffusion of known technology are significant for developing countries and may outweigh the gains from technological change alone. There are two important reasons why we should explore how far a particular enterprise or branch is from the frontier, and how quickly production processes
are moving towards the frontier. The first is that the shifting of the frontier and the movement of enterprises toward the frontier are two distinct sources of intensive growth and require two distinct sets of policies, or reform programs, to achieve.\(^7\)

The second is that current explanations of the slowdown in growth for the U.S.S.R. and Eastern Europe revolve heavily on different interpretations of the Cobb-Douglas and CES production function parameter estimates for average production functions. We argue below, in the literature review section, that the empirical evidence for the two different explanations based on the average production function estimates is weak and the implications of the different explanations are not very different, in any event. However, if there is significant technical inefficiency and overall joint factor productivity growth estimates are different from those estimated via average production functions then an alternative explanation for the slowdown in economic growth may be offered.

In fact, in many cases we do find significant differences and those differences are more pronounced for the East European economies than for the Soviet Union. Our results suggest that the traditional explanations are still valid, but that decreases in the level of efficiency during the late 1970s and early 1980s also contribute to the overall growth slowdown in Eastern Europe and the Soviet Union.

The next section provides a review of empirical studies focusing on the Soviet Union and Eastern Europe. The sections
following provide the results of the estimation for the countries under consideration. Section 3, describes the specification and parameterization of the models. Section 4, discusses the empirical results, and section 5 the conclusions. Appendix A provides a brief theoretical discussion of technical efficiency and the frontier production function approach. Appendix B provides a discussion of the data and details with respect to sources and variable names, etc. Appendices C and D contain tables of results referred to in the text below.
Section 2: Review of Empirical Literature

There is an extensive literature using aggregate production functions to analyze economic growth and efficiency in the Soviet and East European economies. To a large extent this literature seeks to analyze the structure and character of growth in these economies, and more specifically, to explain the slowdown in their growth rates. This growth slowdown began in the Soviet Union in the early 1960s and in Eastern Europe in the 1970s. We can distinguish four different research methodologies in this literature: (1) characterization of the growth process through time-series estimates of various forms of the production function; (2) estimates of frontier production functions which distinguish technical efficiency from other sources of productivity; (3) estimates of the output loss caused by resource misallocation across sectors of the economy; and (4) estimates of the productivity differential between imported and domestically produced capital. Only the first two are directly relevant to our purposes, so this review will concentrate on them. The following is a discussion of these two methodologies, in each case stressing the relationship of the investigations to the question of analyzing the structure of economic growth and explaining the growth slowdown.

Initial production function estimates sought to explain the pattern of growth in the Soviet Union and Eastern Europe for the post-WWII period. Much of the discussion has centered on whether
the Cobb-Douglas (C-D) or the constant elasticity of substitution (CES) production function is a better description of the growth process. Generally, research has found that both the C-D production function, and the CES production function fit the data rather well. Research using the C-D production function has found that the rate of growth of factor productivity has been decreasing over time. This implies that the growth slowdown is caused by decreasing factor productivity growth. Research using the CES function has found that the rate of growth of factor productivity is constant over time, but that the elasticity of substitution is significantly less than one. Since growth rates of capital have been much higher than growth rates of labor in all of these countries the capital-labor ratio has been increasing rather rapidly. This, combined with a low elasticity of substitution, implies that the output elasticity with respect to capital is decreasing and the output elasticity with respect to labor is increasing over time. This leads to the conclusion that the slowdown in growth is attributable to diminishing returns to capital accumulation, since capital accumulation is yielding smaller output increases over time. Given constant factor productivity growth, this places an increasing burden on growth rates of labor in order to maintain or increase output growth rates. But, with growth rates of the labor force low and/or decreasing in most of the East European countries, labor shortage is becoming a major constraint on growth.

Weitzman (1970) was the first to point out that diminishing
returns to capital might be a significant explanation of the
growth slowdown in the Soviet Union.\textsuperscript{10} He found that the CES
function fit the data for Soviet industry better than the C-D
function, and concluded that diminishing returns to capital was a
more important explanation of growth retardation than decreases
in technological innovation. He stressed the significance of
labor shortage as an impediment to growth. Other studies came to
similar conclusions (eg., Desai (1976) and Rosefielde and Lovell
(1977)). In fact, Rosefielde and Lovell found that strong
diminishing returns to capital were retarding the industrial
growth rate in spite of an increasing rate of factor productivity
growth over time.

Thornton (1970) and Gomulka (1976 and 1977) came to very
different conclusions. Thornton noted that if factors of
production are paid the value of their marginal products then the
elasticities of output with respect to inputs should be equal to
the actual income shares of those factors. Using data on actual
income shares of labor and capital in the Soviet economy she
showed that the elasticity of substitution might be greater than
one.\textsuperscript{11} She concluded that the elasticity of substitution could
not be estimated accurately so it was preferable to use the C-D
production function.\textsuperscript{12} Her C-D results implied a decreasing rate
of factor productivity growth over time.\textsuperscript{13}

Gomulka (1976 and 1977) differs from other studies in
several important ways. He argues that Soviet growth has several
important characteristics which have been overlooked by other
research: the postwar recovery, the reduction of weekly hours worked beginning in 1956 accompanied by a campaign to increase worker productivity and the relaxation of this campaign after 1961. He estimates a CES production function with Harrod-neutral rather than Hicks-neutral technological change, and uses dummy variables to control for the effects of the peculiarities of Soviet growth. He finds that the estimates are insensitive to the value of the elasticity of substitution and that the rate of growth of factor productivity is constant. Gomulka rejects both the diminishing returns and the decreasing rate of factor productivity growth explanations of the Soviet growth retardation. He argues that the slowdown in the growth of inputs is the major explanation for slower growth.

So the question of which functional form fits Soviet industrial data best appears to be problematic. Several more recent studies have focused on this question directly. Weitzman (1983) concedes that both functional forms fit the data rather well, but thinks the CES explanation is better on theoretical grounds. Whitesell (1983 and 1985) argues that for Soviet industry there is no statistical evidence to prefer one over the other. Desai (1985 and 1987) argues that for the period up to 1975 the CES function fits the data best, but that the C-D function is preferable when the data are extended to 1980. Similarly, Cameron (1981) argues that there is a break in the Soviet data sometime in the mid-1960s and that, if the data are divided into two periods, the elasticity of substitution is
significantly higher in the latter than in the former period. Weitzman (1983) tests this hypothesis and finds no support for it.

Aggregate production functions have also been used to analyze growth in Eastern Europe. Brown, Licari and Neuberger (1973) found that a CES production function fit Hungarian data better than a C-D production function, but that the elasticity of substitution was not significantly different from one. Brown, Licari and Neuberger (1976) hypothesized that the production process was characterized by a zero elasticity of substitution, but that the parameter values were changing over time because of Hungarian investment cycles. While this is an interesting hypothesis they do not offer a model of how the parameter values change over time. Cameron (1981) was unable to estimate any reasonable CES parameter values for Hungary or the GDR. He argues that the pattern of growth in these countries is not similar to the Soviet Union, but his results appear to be too weak to make any significant conclusions.

Sapir (1980) finds that a C-D production function with constant factor productivity growth best explains growth in Yugoslavia. Thus, the slowdown in the growth of labor appears to be the major cause of growth retardation in Yugoslavia. Kemme (1984) estimates CES, C-D and variable elasticity of substitution production functions for Poland and also finds that a C-D production function with a constant rate of factor productivity growth fits best. Similarly, Whitesell (1985) finds that the C-D
production function with constant factor productivity growth fits the data best for five East European countries: the GDR, Poland, Czechoslovakia, Hungary, and Yugoslavia. This leads to the same conclusion that changes in growth rates of industrial output are caused primarily by changes in input growth rates.\textsuperscript{15}

The methodology of aggregate production function analysis has been criticized on several bases. First, the very existence of the aggregate production function is often questioned. It is argued that the theoretical restrictions on production processes which are necessary to ensure the existence of an aggregate production function are so severe that they cannot be expected to exist in any real world economy.\textsuperscript{16} Therefore, some would argue, the aggregate production function concept is meaningless, and estimation results have no meaningful interpretation. However, as Weitzman (1972) argues, this qualification holds for the use of any aggregate statistics, and if one wants an analysis of aggregate performance there appears to be no choice but to rely on aggregate statistics.

Another criticism of the approach is that often implausible parameter estimates are obtained. For example, Brubaker (1972) and Bergson (1979) argue that Weitzman's (1970) CES results imply rates of return on capital that are implausibly high in the 1950s. Results of other work using the CES production function imply similarly high rates of return for that period. The literature to date appears to offer no reasonable explanation.\textsuperscript{17}

Another problem is the quality of the data. The measure of
output is especially troublesome because of the gross value of output definition and because of problems with price weights. These difficulties are discussed extensively by Bergson (1979).

Problems also exist for data on inputs. The measure of hours worked is actually a measure of hours paid. Hewett (1988) argues that there has been substantial downtime in production due to broken machinery, inadequate labor availability, unavailable inputs, etc., and that these problems have probably increased over time. These problems imply that measures of labor input do not adequately reflect labor services, because workers may be on the job but not working. Furthermore, these problems will result in low utilization rates of capital as well. If these difficulties are increasing over time, then estimated rates of factor productivity growth will be biased downward. This is precisely the advantage of the frontier production function approach utilized in this study. The frontier approach enables such changes in the efficiency with which inputs are used to be separated from other influences on factor productivity growth, such as technological innovation.

Another problem is the use of gross capital rather than net capital. This is a difficult problem and researchers are not agreed as to which measure is preferable. Hewett (1988, 77) argues that "the particular difficulty with Soviet data is that...Soviet enterprises keep old equipment on the books far beyond the end of its useful life." This implies that gross capital is an overestimate of actually available capital. On the
other hand, depreciation rates are notoriously arbitrary. This is likely to be especially problematic in the Soviet case because old outdated equipment is often used simultaneously with newer equipment. Depreciating such equipment would result in an underestimate of available capital and thus bias upward the estimated productivity of newer capital. Which of these two opposing forces is more important is an empirical question for which the necessary data are unavailable.

Researchers need to make data adjustments whenever possible, need to be aware of the potential biases the data create and must attempt to analyze the possible directions of these biases; but this is another case in which the available, though imperfect, data must be used if we are going to attempt any assessment of performance.

Some authors have noted that the estimated value of the elasticity of substitution is not sensitive to the values of other estimated parameters. Gomulka (1977) and Bergson (1979) stress this point. Cameron (1981) and Desai (1987) have indicated that the value of the elasticity of substitution may be increasing over time. Brown, Licari and Neuberger (1973), Cameron (1981), Whitesell (1983) and Brada (1985) have noted that estimating any reasonable parameter values for the production function appears to be problematic.

How can we choose between the C-D and CES interpretations? One argument is that they are merely two ways of representing the same statistical trend. If one looks at the results carefully
the two explanations do not appear to be very different. The CES function tends to result in a higher growth of combined factor input growth in the early period and a lower combined factor input growth in the later period relative to the rates of combined factor input growth estimated by the C-D function. The C-D function tends to show higher rates of factor productivity growth in the early period and lower productivity growth in the later period relative to that produced by the CES function. This trade-off seems to indicate that both types of production function are presenting much the same story, that some kind of productivity is decreasing over time. In the CES case reductions in the productivity of capital are stressed, and in the C-D case reductions in the productivity of combined factor inputs is stressed. Since changes in the productivity of capital are more constrained by the assumption of the unitary elasticity of substitution in the C-D case one would expect that some of the effect of decreases in the productivity of capital would be captured in the factor productivity residual. On the other hand, some of the diminishing returns to capital in the CES case might be caused by decreases in the rate of growth of new technology embodied in new capital. If this analysis is true, the implications of the two functional forms may not be very different. Weitzman (1983) supports the argument of the similarity of the two functional forms when he states that

Both regressions yield about the same error sum of squared residuals. The real world might even be some mixture of the two scenarios. Fortunately the choice may not make that much difference for short-term forecasting at the current
Brada (1985) implies a similar interpretation when he notes that

In the case of Cobb-Douglas studies the deterioration is caused by a slowdown in technological progress. In the CES case it stems from a very low elasticity of substitution coupled with disparate rates of growth of capital and labor inputs. In either case no prospect is held out for a change in performance... If one accepts the Cobb-Douglas or CES view, then economic reform, campaigns for greater discipline and efficiency and the importation of foreign technology may be viewed as possible means of either increasing the rate of disembodied technological progress or raising the elasticity of substitution between capital and labor.19

Those who stress the insensitivity of the elasticity of substitution to the values of other parameters also seem to accept a similar point of view.

The implication of this argument is that research on the production function interpretation of economic growth in the Soviet Union and Eastern Europe, regardless of whether the C-D or CES functions are used, implies that decreases in factor productivity of some unspecified origin are the cause of the retardation in economic growth. Thus, the choice between the CES and C-D views of Soviet and East European growth must be made either on theoretical grounds or on the basis of further research attempting to isolate the sources of the slowdown in the growth of factor productivity.

Weitzman seems to be the only researcher who has approached this issue on a theoretical basis. He argues that the dramatic decline in the growth rate of factor productivity implied by the C-D interpretation is difficult to believe since, "judging by the literature, far greater attention is paid to questions of
economic efficiency in more recent years than in the past."²⁰ Weitzman argues that the CES interpretation provides a more plausible story about the Soviet economy. In this story the Soviet economy has been transformed from an economy in which capital was the major constraint in the early 1950s into one in which labor was the major constraint by the mid-1970s. This occurred because of the rapid rates of capital accumulation that occurred during this period.

This certainly is a plausible story about Soviet economic growth, also applicable to Eastern Europe. However, the C-D interpretation is not so unreasonable either. An alternative explanation consistent with the C-D estimates is possible. In the post-Stalin period there has been a gradual but persistent decrease in the pressure exerted by the central authorities on individual firm behavior. Since most major technological change in these economies comes about because of pressure from above, this scenario would imply that the introduction and diffusion of new technology is decreasing through time. In addition, plans have become less taut and firms have been able more often to secure excessive inputs. This implies that inefficiency may have been increasing through time. This explanation of Soviet growth seems as plausible as Weitzman's.

It appears that the choice between the C-D and CES interpretations cannot be made on either statistical or theoretical grounds. So it is necessary to isolate more specifically the possible sources of decreasing growth. The
interpretation above indicates that one source of changes in factor productivity may be changes in technical efficiency. Frontier production functions allow one to separate changes in technical efficiency from other sources of factor productivity growth.

There are relatively few applications of the frontier production function approach dealing with the Soviet Union and Eastern Europe. Nishimizu and Page (1982) first applied this methodology to Yugoslavia. They estimated a translog production function specification for Yugoslav industrial data disaggregated by industrial branch and by republic, and used the non-stochastic programming technique. Their conclusion was that both decreasing factor productivity growth and increasing technical inefficiency contributed to the slowdown in growth in the 1970s, but that increases in technical inefficiency were more significant.

Danilin, et al. (1985) applied the stochastic frontier production function methodology to the cotton refining industry in the Soviet Union. They estimated a variant of the CES production function with vintage capital in a cross-section estimation using data for 151 cotton refining enterprises in 1974, and found that this industry was on average about 92 percent efficient. They concluded that such a surprisingly high level of efficiency implies that inter-enterprise variations are not a major source of inefficiency in the Soviet economy. Of course, as they point out, this result does not imply that Soviet
industry is not inefficient relative to true engineering potential or by international standards. But they do stress the implication that Soviet methods may be more effective in controlling efficiency than is usually argued.

Finally, a recent study by Brada (1988) is most comparable to the present study. He calculates frontier production functions, using a linear programming technique, for total industry in Hungary, Poland, Czechoslovakia, and the GDR for the period 1960-85. He finds that rates of factor productivity growth are higher than previous estimates using standard OLS techniques, and that decreases in efficiency in the late 1970s and 1980s are a significant cause of declining industrial growth rates.

Having reviewed the extensive literature on empirical estimation and explanation of the slowdown in economic growth let us now turn to the theory underlying the concept of the frontier production function and technical efficiency. Then we shall proceed with the estimation of frontier production functions for the Soviet Union and Eastern Europe in an attempt to further explain the origins of the economic slowdown. In the next sections we will discuss the frontier production function technique (Section 3), then the specification of the models for each country (section 4), and provide an explanation of the empirical results and the role of technical efficiency in the economic slowdown (section 5). Appendix A provides details of the data sets compiled for each country, and Appendix B contains
Section 3: Model Specification

In section 2 we discussed several of the issues relating to the estimation of production functions for the Soviet Union and Eastern Europe. In Appendix A, below, the basic theory underlying the frontier production function approach is detailed. There three different approaches to the estimation of production frontiers are discussed: the non-parametric programming approach, the parametric programming approach and the parametric statistical, or stochastic, approach. We have adopted the third technique because it is less sensitive to outliers and measurement error and provides statistical information for goodness of fit measures and hypothesis testing. As noted in the literature review the first two techniques have been applied on a very limited basis to the Soviet Union and Eastern Europe, but aggregate stochastic frontiers have not been estimated for any of the countries being considered.

We adopt the stochastic frontier as described in Appendix A. The general form of the frontier production function is:

\[ y = f(k,l)\exp(v - u). \]

Here \( y \) is a measure of output, \( k \) is a measure of capital and \( l \) is
a measure of labor. The variables utilized for output, capital stock and labor vary by country. The exact definition for each is given in Appendix B along with detailed source notes for the entire data set. The estimation results which we report in Appendix C and describe in the next section, specify $f(k,l)$ as one of several forms of the Cobb-Douglas production function with constant returns to scale. Several alternative specifications, including several forms of the CES production function and non-constant returns to scale Cobb-Douglas were also estimated, but are not reported below. Also for all specifications $v$ is a normally distributed error term, with each element independently and identically distributed as $N(0, \sigma^2_v)$, which makes the frontier stochastic and accommodates measurement error, etc., and $u$ is the one sided error term, in which the individual elements are the absolute value of variables independently and identically distributed as $N(0, \sigma^2_u)$, and represents the distance to the frontier, or inefficiency. This specification of the error term, $\Omega = v - u$, was selected because it has been widely utilized and the density function has been derived and the properties are well established in the literature.

Six models of the frontier were estimated and then the same six models were estimated with Ordinary Least Squares as "average production functions" for purposes of comparison. Three of the models are Cobb-Douglas, constant returns to scale, expressed in logarithmic terms and three are Cobb-Douglas, constant returns to
In all six specifications \( \Omega \) is the composite error term, \( \Omega = \nu - \mu \). In specifications four through six \( \gamma \) denotes the percentage change in the relevant variable. The six average production functions have the same specifications as above, but are estimated using OLS with \( \Omega \) replaced by \( \mu \). These are labelled specifications seven through twelve.

The first item of interest is whether or not frontiers can be fitted to the sectoral data for Soviet and East European industry. The literature on frontier estimation suggests that this is not always the case. Two problems may arise. First the frontier may be fitted from the wrong side. In terms of our isoquants there may be several observations defining the isoquant...
with the remainder lying below it rather than above it. The implied $\sigma_u$ is negative and this is sometimes referred to as a Type I failure and the probability of it happening is larger when $\sigma_u/\sigma_v$ is small.\textsuperscript{24} This may be detected by examining the estimate of the third moment of the density function of $\Omega$.\textsuperscript{25} If this is the case then it is usually assumed that the entire set of observations is defining the frontier. This means that the OLS estimates are interpreted as providing an accurate representation of the frontier and there is no inefficiency.

The second problem that may arise is that the estimated $\sigma_v$ may be negative. This certainly calls into question the validity of the error specification and is sometimes referred to as a type II failure.\textsuperscript{26} The probability of this occurring increases when $\sigma_u/\sigma_v$ is large. The parameter reported with the coefficient estimates in Appendix B called FLAMBDA is the estimated value of $\sigma_u/\sigma_v$ and provides some guidance in interpreting the frontier results.\textsuperscript{27} When FLAMBDA is small we have a high probability of Type I failure, i.e., OLS is essentially estimating the frontier, and when FLAMBDA is very large we have a high probability of a Type II failure and specification error. If this occurs we simply do not report the frontier estimates since they are not meaningful. In addition, only specifications which yield frontiers which have meaningful production function parameter estimates in terms of economic theory are reported.

Once reasonable frontier production function estimates have been obtained the average level of inefficiency may be estimated
as: 28

\[ \text{INEFF} = E(u) = (\sqrt{2/\pi}) \hat{\sigma}_u \]

This is also reported in the tables of results and discussed in the next section.

The second item of interest is how the parameter estimates of the frontier production function, \( \Gamma, \lambda, \mu \) and \( \alpha \) compare with the estimates of the same parameters from the average production function. The OLS results are also reported for each specification if they are meaningful in terms of economic theory in Appendix C. These results are discussed in the next section.

Finally, the level of inefficiency for each annual observation is calculated as in Materov, et al. (1986). The five year moving averages for these levels are then calculated and reported in Appendix D.

Section 4: Empirical Results 29

4.0 General Results

The first point to note is that frontier production functions are sometimes difficult to estimate, just as average production functions are. In addition to problems often encountered in standard, average production function estimation -- negative marginal products, autocorrelation, multicollinearity, etc. -- another difficulty appears. In a large number of cases the ordinary least squared residuals are skewed in the wrong
direction. This was labelled Type I failure in the previous section. In such cases the ordinary least squares regressions are maximum likelihood estimates and no additional information can be obtained from estimates of a production frontier. This means that when the ordinary least squares residuals are separated into random and one-sided components, the one-sided errors are such that technical inefficiency is imputed to be negative. This is generally taken to mean that no measurable technical inefficiency exists.

However, it may also mean that the functional form being estimated is misspecified. The requirements for the proper identification of the production frontier are more stringent than for the standard average production function. Essentially, the statistical technique is to find the shape of the production function from data points which are mostly inefficient relative to the frontier, and graft that shape onto the outer edge of the data points subject to the condition that no data points be above the frontier, i.e., no data points should be more than 100 percent efficient. Given a particular functional form it is often the case that no reasonably shaped production function can fulfill these conditions. For example, if the 'true' production function is characterized by constant factor productivity growth over time, then a specification which imposes variable factor productivity growth over time may not be computable. With a standard average production function such a function could be computed because the only condition is to minimize the sum of
squared errors of the regression. Of course, the estimate would not yield statistically significant results, but an estimate would be computable.

As discussed in the methodology section, estimates were made using both a log specification and a growth rate specification. In general, for all countries but the GDR and, to a lesser extent Poland, the growth rate specification seemed to fit the data better than the log specification. However, there were many cases in which the log specification produced better results. The growth rate specification worked particularly well relative to the log specification for the Soviet Union. The growth rate specification has several advantages. Levels of capital and labor tend to be correlated with each other more than input growth rates, so multicollinearity is less of a problem in the growth rate specification. This may explain why the log equations are particularly poor for the Soviet Union. In most of the East European economies labor force growth rates are very low, so trends in labor levels are not so correlated with capital levels as in the Soviet economy. Since multicollinearity increases the variance of the estimates, it may make it more difficult for the parameters of the frontier to be identified. Another benefit is that the Durbin-Watson statistic for the OLS estimates indicates that autocorrelation is, over all, less of a problem using the growth rate specification. This also makes identification easier using a growth rate specification. A drawback of the growth rate specification is that the constant
term parameter is lost. Since this is a parameter of less interest for our purposes, this is not a significant problem. An additional problem is that one observation is lost when the rates of growth are calculated. Losing one observation may be important in the case of the GDR since the data series is short.

The tables in Appendix C report only estimates of frontier production functions which produced economically meaningful parameter estimates. By economically meaningful estimates we mean first that neither a Type I or Type II failure occurred, i.e., the residuals are skewed in the correct direction, and the distribution of the error term is reasonably well behaved, and second that the estimated value of $\alpha$ is between zero and one. This latter restriction ensures that marginal products of capital and labor are positive, at least. For comparative perspective the tables also report ordinary least squares estimates, but these estimates generally are given only for those equations which correspond to the frontier estimates that are presented.

Comparisons of the OLS and frontier estimates, and comparisons of the growth rate and log specifications yield several results which are common across countries and industrial sectors. First, the parameter estimates using the log specification generally do not depend on whether estimation is OLS or frontier. Essentially, the production function has been shifted upward, reflecting the fact that we are estimating a frontier rather than an average function, but the shape of the production function is robust. Estimated capital coefficients,
α, are similar, which indicates that the shape of isoquants is unchanged, and rates and trends in factor productivity growth are nearly the same.

Second, the growth rate specification yields much greater variation between the OLS and frontier estimates. In almost all cases in which factor productivity growth is non-zero the frontier estimates produce a higher rate of factor productivity growth than the OLS estimates, but if factor productivity growth is decreasing over time then the frontier estimates indicate that the speed of decline is greater. So the frontier estimates indicate a higher level but more rapid decline in factor productivity growth than do the OLS estimates. The growth rate specification also results in a relatively large difference in the estimated capital coefficient between the OLS and frontier estimates. However, there is no particular trend. The capital coefficient in the frontier estimates is sometimes lower and sometimes higher than the capital coefficient in the OLS estimates.

Finally, the growth rate specification -- both OLS and frontier estimates -- tends to produce higher estimates of factor productivity growth and lower capital coefficients than does the log specification.

Let us now turn to the country specific discussion.

4.1 Hungary

Tables 1a through 1c of Appendix C present frontier and OLS
estimates for Hungary. A unique aspect of the Hungarian estimates is that the data could be separated into the categories of state, cooperative and socialist industries. The results for socialist industry are very similar to the state industry results. This is not surprising since socialist industry is the addition of state and cooperative industries. But, since state industry is much larger than cooperative industry the trends in state industry dominate those in cooperative industry. The discussion below will focus first on state industry. Since these data are most comparable to other countries' data, country comparisons will be based on state industry results. Then the cooperative industry results will be discussed and comparisons between state and cooperative industries will be made.

It is difficult to establish any general trends in the Hungarian results because there is a large amount of cross-sector diversity. In general, rates of inefficiency appear to be somewhat higher than in the Soviet Union, the GDR and Czechoslovakia; about the same as Yugoslavia; and somewhat lower than Poland. There is too much cross-sector diversity to make any general remarks about rates of factor productivity growth. Several sectors have very high rates of factor productivity growth -- chemicals, precision instruments and telecommunications have factor productivity growth around 10 percent per year; several sectors have decreasing factor productivity growth which is negative by the end of the period -- electric power and food processing; and seven sectors and the estimate for total state
(as well as total socialist) industry show zero rates of factor productivity growth. The zero rate of factor productivity growth for total industry appears to be an aggregate of these conflicting sectoral trends.

Rates of inefficiency, reported in Appendix D, also appear to fluctuate rather substantially over time. There seems to be a general trend of relatively high inefficiency in the early to mid-1960s, decreasing inefficiency in the late 1960s and early 1970s, and increasing inefficiency from the mid-1970s to the end of the period. For most sectors rates of inefficiency are similar at the beginning and the end of the period, with the trough occurring sometime in the early 1970s. However, there is much fluctuation and the exact timing of the change in trend varies across sectors.

Rates of factor productivity growth in cooperative industry also present a variable picture. Four sectors have constant factor productivity growth above 8 percent -- chemicals, electrical equipment, textiles and clothing; four sectors have decreasing factor productivity growth which is negative by the end of the period -- metallurgy, leather, total MBMW and total light industry; and six sectors have zero factor productivity growth.

Rates of inefficiency in cooperative industry generally are higher than in state industry, and higher than in any country in our study. However, there are a few sectors with very low rates of inefficiency -- for example, leather and food processing. The
trend in inefficiency over time is similar to that in state industry; high at the beginning and at the end of the period with the trough occurring sometime in the early 1970s. The fluctuations are much larger and just as variable in their occurrence as in state industry.

Our Hungarian results contrast rather sharply with Brada (1988). Our results for total state and total socialist industry indicate no aggregate factor productivity growth for the entire period, compared to the rather high and constant 5 percent rate found by Brada. The sectoral results indicate that this lack of productivity growth is an aggregate of sectors which are doing rather well and sectors which are doing very poorly. Our calculated rates of inefficiency show a similar trend over time, but are much lower than Brada's. Changes in inefficiency over time have had some retarding effect on growth, but appear to be much less important in explaining the slowdown in growth than Brada's results suggest. Our results indicate that poor productivity growth and decreasing rates of input growth are more important causes of the growth slowdown than decreases in efficiency.

4.2 Poland

For Poland there were only two sectors for which reasonable frontiers could not be estimated: coal and gas. The detailed results are reported in Table 2 of Appendix C. Again there was significant sectoral variation, but the results were generally
quite stable and robust for each sector individually. Also the production function parameter estimates for the logarithmic specification are rather robust moving from the average production function to the frontier specifications. Given that the time period analyzed included the late 1970s and early 1980s the general estimation results are quite good.

Table 4.2.1, below, reports the estimated value of $\lambda$ for both the average and frontier production functions along with the estimated average level of inefficiency, INEFF. The rate of growth of joint factor productivity ($100 \cdot \lambda$) ranges from 0.44 per cent in, sector 14, Ceramics and Porcelain, to a high of 12.58 per cent in sector 20, Food Processing. At the same time the average level of inefficiency ($100 \cdot$ INEFF, in percentage terms) ranged from a low of 0.87 per cent in sector 3, Electricity, to 26.47 per cent in sector 13, Glass. For total industry, sector 24, we also have a clear picture: the rate of growth of joint factor productivity for this period was 6.9 per cent and the average level of inefficiency was 4.7 per cent.

Importantly the general conclusion that may be drawn is that the average level of inefficiency is relatively high. The level of variation in output over time due to inefficiency has been significant and if eliminated could have increased industrial output by over 4.5 per cent for total industry. Of course this is a comparison made relative only to the best practice observed in Poland. Adopting management techniques and production processes not observed in Polish industry during this
period could also shift the frontier. It is also important to note though that the frontier for total industry was moving outward, as reflected by the rate of growth of joint factor productivity, at a high rate: 6.9 per cent per year.

The rates of inefficiency also exhibit significant cross sectoral variation. The five year moving averages for each sector are reported in Table 2 of Appendix D. The economic crisis of the late 1970s, early 1980s, is clearly delineated for nearly every sector appearing as a significant increase in the level of inefficiency for those years.
Table 4.2.1: Comparisons of Joint Factor Productivity Growth (λ) Inefficiency Estimates (INEFF) for Poland

<table>
<thead>
<tr>
<th>Sector Spec.</th>
<th>Average Production Function</th>
<th>Frontier Production Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.11 logs</td>
<td>λ = 0.0504</td>
<td>a</td>
</tr>
<tr>
<td>2.11 logs</td>
<td>λ = 0.00</td>
<td>a</td>
</tr>
<tr>
<td>3.11 logs w/mu</td>
<td>λ = 0.0715</td>
<td>INEFF = 0.0712 0.0087</td>
</tr>
<tr>
<td>4. logs w/mu</td>
<td>λ = 0.0418</td>
<td>INEFF = 0.0508 0.05438</td>
</tr>
<tr>
<td>5. a. logs w/o mu</td>
<td>λ = 0.0237</td>
<td>INEFF = 0.0227 0.092764</td>
</tr>
<tr>
<td>b. logs w/mu</td>
<td>λ = 0.03267</td>
<td>INEFF = 0.0345 0.033416</td>
</tr>
<tr>
<td>6. logs w/mu</td>
<td>λ = 0.0789</td>
<td>INEFF = 0.0899 0.0089</td>
</tr>
<tr>
<td>7.11 logs w/o mu</td>
<td>λ = -0.00283</td>
<td>INEFF = 0.0602 0.08228</td>
</tr>
<tr>
<td>9. pc w/o mu</td>
<td>b</td>
<td>INEFF = 0.0893 0.0521</td>
</tr>
<tr>
<td>10. pc w/o mu</td>
<td>b</td>
<td>INEFF = 0.1235 0.0714</td>
</tr>
<tr>
<td>11. pc w/o mu</td>
<td>b</td>
<td>INEFF = 0.0611 0.0491</td>
</tr>
<tr>
<td>12. pc w/ mu</td>
<td>b</td>
<td>INEFF = 0.0934 0.0517</td>
</tr>
<tr>
<td>13. logs w/o mu</td>
<td>λ = 0.05290</td>
<td>INEFF = 0.05293 0.26467</td>
</tr>
<tr>
<td>14. a. logs w/o mu</td>
<td>λ = 0.0421</td>
<td>INEFF = 0.0469 0.045535</td>
</tr>
<tr>
<td>b. logs w/mu</td>
<td>λ = 0.0406</td>
<td>INEFF = 0.00443 0.055371</td>
</tr>
<tr>
<td>15. a. logs w/o mu</td>
<td>λ = 0.0297</td>
<td>INEFF = 0.0304 0.0945686</td>
</tr>
<tr>
<td>b. logs w/mu</td>
<td>λ = 0.0313</td>
<td>INEFF = 0.0335 0.092079</td>
</tr>
<tr>
<td>16. logs w/mu</td>
<td>λ = 0.366</td>
<td>INEFF = 0.0391 0.0392</td>
</tr>
<tr>
<td>17. pc w/o mu</td>
<td>b</td>
<td>INEFF = 0.0752 0.0492</td>
</tr>
<tr>
<td>18. pc w/ mu</td>
<td>b</td>
<td>INEFF = 0.08190 0.0311</td>
</tr>
<tr>
<td>19. pc w/ mu</td>
<td>b</td>
<td>INEFF = 0.696 0.0415</td>
</tr>
<tr>
<td>20. pc w/ mu</td>
<td>b</td>
<td>INEFF = 0.1258 0.0842072</td>
</tr>
<tr>
<td>22. logs w/o mu</td>
<td>λ = 0.0131</td>
<td>INEFF = 0.0145 0.0779</td>
</tr>
<tr>
<td>24. logs w/mu mu</td>
<td>λ = 0.0646</td>
<td>INEFF = 0.06973 0.0474523</td>
</tr>
</tbody>
</table>

Note that no estimates are available for sectors eight and 23.11 because of limited data. No functions could be fit for sector 21. a. OLS results are acceptable but frontiers could not be fit. b. OLS results are acceptable and frontier results are acceptable but the specifications are not exactly comparable.
4.3 The GDR

Table 3 of Appendix C contains the detailed estimates for the GDR. Estimating average production functions and frontier production functions for GDR industry was relatively difficult. In part, this was due to the limited number of observations: 16 at most. Capital stock data was unavailable beyond 1976 and reasonable estimates of constant price capital by sector for the period beyond 1976 could not be made. Frontiers could not be estimated for four sectors: shipbuilding, electrical engineering, food processing and total industry. Unlike Poland, for those sectors in which frontiers were estimated the stability of the production function parameters when moving from the average to the frontier specifications was limited. There were significant differences in the estimated values of $a$ and $\chi$. The results should be interpreted with caution as a result.

One interesting phenomenon was the fact that the estimated rate of growth of joint factor productivity from the average production function specifications was negative for every branch. For the frontiers, however, the rate of growth was positive and inefficiency appeared. And, for several sectors relatively high rates of growth of joint factor productivity growth appear with relatively high levels of inefficiency. This is an interesting result, both in terms of its uniformity across sectors and its implications. If one concentrated on the negative rate of growth of joint factor productivity from the average production
functions one would conclude technological change in the GDR has ground to a halt - or it has even been negative. The frontier estimates imply, however, that there has been positive growth in joint factor productivity for GDR industry, but significant inefficiency. There has been significant variation in output from the best practice observed in these sectors of GDR industry which has negated the productivity growth. This conclusion must be tempered by the lack of robustness of the estimates and the limited number of observations utilized. It does deserve careful consideration and further study, however, since a similar result is found for Czechoslovakia, as discussed below.

Rates of inefficiency, reported in Table 3 of Appendix D, also exhibit considerable cross sectional variation. They are generally much lower than in Poland, but there is also a slight upward trend over time. Since the time series ends in 1976 it is difficult to state whether or not this is meaningful.
**Table 4.3.1:** Comparisons of Joint Factor Productivity Growth ($\lambda$) and Inefficiency Estimates (INEFF) for the GDR

<table>
<thead>
<tr>
<th>Sector</th>
<th>Spec.</th>
<th>$\hat{\lambda}$</th>
<th>$\hat{\mu}$</th>
<th>INEFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.11</td>
<td>logs w/mu</td>
<td>b</td>
<td>0.00</td>
<td>0.0086</td>
</tr>
<tr>
<td>2.</td>
<td>logs w/o $\mu$</td>
<td>-0.434</td>
<td>0.0137</td>
<td>0.0147122</td>
</tr>
<tr>
<td>3.</td>
<td>pc w/mu</td>
<td>b</td>
<td>0.0387</td>
<td>0.0193805</td>
</tr>
<tr>
<td>4.</td>
<td>pc w/mu</td>
<td>b</td>
<td>0.0966</td>
<td>0.0388</td>
</tr>
<tr>
<td>6.</td>
<td>logs w/o $\mu$</td>
<td>-0.0110</td>
<td>0.0154</td>
<td>0.0179124</td>
</tr>
<tr>
<td>7.5</td>
<td>logs w/o $\mu$</td>
<td>-0.0122</td>
<td>0.0142</td>
<td>0.020</td>
</tr>
<tr>
<td>8. a.</td>
<td>logs w/o $\mu$</td>
<td>-0.0204</td>
<td>0.0240</td>
<td>0.0273966</td>
</tr>
<tr>
<td>b.</td>
<td>logs w/mu</td>
<td>-0.0392</td>
<td>0.0422</td>
<td>0.0202008</td>
</tr>
<tr>
<td>9.</td>
<td>logs w/o $\mu$</td>
<td>-0.0301</td>
<td>0.0583</td>
<td>0.0116173</td>
</tr>
</tbody>
</table>

Note that no estimates are available for sectors 5, 7, 10 and 11. In several instances reasonable estimates were made but they were not robust.

a. OLS results are acceptable but frontiers could not be fit.
b. OLS results are acceptable and frontier results are acceptable but the specifications are not exactly comparable.
4.4 Czechoslovakia

For Czechoslovakia frontiers could be estimated for all sectors except sector 7, Construction Materials, and sector 16, Other Industry. The estimates are reported in detail in Table 4 of Appendix C. For seven of the individual sixteen sectors the log specification is the preferred specification and again the coefficient estimates were quite stable when comparing the OLS average production function estimates with the frontier estimates. The percentage change specifications for the remaining nine sectors and total industry do not exhibit this stability to the same degree as the log specification.

Like the other countries discussed above there is a significant amount of cross sectoral variation in rates of growth of joint factor productivity in both the OLS and frontier specifications and a significant amount of variation in the estimated level of inefficiency across sectors. Below, Table 4.4.1 provides a summary of the estimates of the rate of growth of joint factor productivity for both the average and frontier specifications and the average level of inefficiency for each sector. For the frontier production function the rate of growth of joint factor productivity ranges from a low of 2.2 per cent for sector 9, Paper and Cellulose, to a high of 15.49 per cent in sector 3, Ferrous Metals. The estimated levels of inefficiency ranged from a low of 0.52 per cent for one of the log specifications for sector 8, Wood products, to a high of 10.3 per cent for sector 15.11, Food Processing. Also of interest is the
fact that for several sectors exhibiting high rates of growth of joint factor productivity, for example sectors 3, Ferrous Metals, and 15.11, Food Processing, there is also a high level of inefficiency present. This finding is similar to that of the GDR and deserves more careful analysis.

Table 4 of Appendix D reports the five year moving average of the rate of inefficiency for each observation for each sector. Again the cross sectoral variation, comparable to the variation in average levels of inefficiency reported in Table 4.4.1, is evident. Changes over time differ markedly from sector to sector. For example, there is virtually no change in the year to year levels of inefficiency for sector 3, Ferrous Metals, and sector 7, Construction Materials, but for most other sectors and Total Industry the level of inefficiency began rather high in the early 1960s, declined reaching a low in the early 1970s and then began to increase, reaching a high in the 1980s. This pattern is quite pronounced and very similar to that of Hungarian industry.
Table 4.4.1: Comparisons of Joint Factor Productivity Growth ($\lambda$) and Inefficiency Estimates (INEFF) for Czechoslovakia

<table>
<thead>
<tr>
<th>Sector Spec.</th>
<th>Function</th>
<th>Average Production</th>
<th>Frontier Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.11 pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0463</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>2.11 pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0684</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>3.00 pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>b</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>4.11 pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.1496</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>5. a. pc w/o</td>
<td>$\hat{\lambda}$</td>
<td>0.0575</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>b. pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0804</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>6.11 logs w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0606</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>7. pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>a</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>8. a. logs w/o</td>
<td>$\hat{\lambda}$</td>
<td>0.0285</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>b. logs w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0735</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>c. pc w/o</td>
<td>$\hat{\lambda}$</td>
<td>0.151</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>mu</td>
<td>$\hat{\lambda}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. logs w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0312</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>10. logs w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0656</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>11. a. logs w/o</td>
<td>$\hat{\lambda}$</td>
<td>0.0314</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>b. logs w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0733</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>c. pc w/o mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0319</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>d. pc w/ mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0386</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>12. a. logs w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0320</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>b. pc w/o</td>
<td>$\hat{\lambda}$</td>
<td>0.0346</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>mu</td>
<td>$\hat{\lambda}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0497</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>13.11 pc w/o</td>
<td>$\hat{\lambda}$</td>
<td>0.0067</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>14. a. logs w/o</td>
<td>$\hat{\lambda}$</td>
<td>0.0301</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>b. logs w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0556</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>15.11 pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>b</td>
<td>$\hat{\lambda}$</td>
</tr>
<tr>
<td>17. pc w/mu</td>
<td>$\hat{\lambda}$</td>
<td>0.0868</td>
<td>$\hat{\lambda}$</td>
</tr>
</tbody>
</table>

Note that no estimates are available for sector 16.

a. OLS results are acceptable but frontiers could not be fit.
b. OLS results are acceptable and frontier results are acceptable but specifications are not exactly comparable.
4.5 Yugoslavia

Tables 5a and 5b of Appendix C present OLS and frontier estimates for Yugoslavia. Estimates for Yugoslavia were made using both the number of workers and hours worked as measures of labor input. The following will focus on estimates using hours worked, since that is the preferred measure of labor and is the measure used for most of the countries in this study.

Yugoslavia seems to have less cross-sectoral variation in the growth of factor productivity than other East European countries. Four sectors -- metal working, chemical, construction materials and tobacco -- have constant factor productivity growth between 4 and 6 percent per year. Electric power and electric machinery have decreasing factor productivity growth but it is still positive at the end of the period, and five sectors have zero factor productivity growth. Only non-ferrous metallurgy has decreasing factor productivity which is negative at the end of the period. The estimate for total industry shows decreasing factor productivity growth, but it is still about 4 percent at the end of the period. These results are similar to other East European economies in the sense that there are several well performing sectors and several poorly performing sectors. But the extremes do not appear to be so large. The high performance sectors are not so spectacular, and the poorest performing sectors are not declining so precipitously.

There is greater cross-sectoral variation in inefficiency.
Several sectors -- such as gas and electric machinery -- have rather high rates of inefficiency, but other sectors -- such as chemicals, printing and tobacco -- have very low rates of inefficiency. As in other countries, there is a general trend of high inefficiency in the early 1960s, decreasing inefficiency in the late 1960s and early 1970s, and increasing inefficiency in the late 1970s. Also comparable to other countries is the fact that there are individual year fluctuations in this trend, and the exact timing of the trend varies across sectors. In contrast to most other countries, however, many sectors have lower inefficiency at the end of the period than at the beginning of the period.

The implication of these results for the growth slowdown also is similar to the other countries in this study. Increasing inefficiency in the late 1970s has contributed to the slowdown, but this effect has been small. Decreases in growth have also come from decreasing factor productivity growth, but this effect also seems to be small. Therefore, decreasing rates of input growth still appear to be the most important cause of the growth slowdown in Yugoslavia. This is consistent with Sapir (1980) and Whitesell (1985).

One caveat about the Yugoslav results should be noted. Because capital data were unavailable after 1980 we were not able to extend the estimates into the early 1980s. Since performance has deteriorated in Yugoslavia in the 1980s, as it has in the rest of Eastern Europe, this may affect significantly the
comparison of Yugoslav results with those of the other countries.

Special note must be taken of the results for the shipbuilding industry because it appears to be a particularly extreme indicator of how the Yugoslav economy operates -- as well as the other East European economies. No frontier using hours worked could be calculated. The estimate using the number of workers implies a zero rate of factor productivity growth and the implied inefficiency is extremely unusual. The average rate of inefficiency is 29 percent, which is much larger than anything else calculated in this study. But the trend over time is even more extraordinary. Inefficiency increases from 13 percent in 1960 to 53 percent in 1964, decreases to 5 percent in 1972, and then increases to 46 percent in 1980. Our interpretation is that there probably were significant increases in factor productivity growth (or technical change) in the 1960s and early 1970s. But from the mid-1970s shipbuilding was a depressed industry worldwide. The data for this industry show that after 1972 output growth diminished and actually fell after 1976, but capital and labor inputs continued to grow. Since this was a high priority industry, inputs continued to expand in spite of insufficient demand to keep up production. Therefore, inefficiency increased dramatically. This is an extreme occurrence of a process that seems to have occurred throughout Eastern Europe and the Soviet Union in the late 1970s and 1980s.
4.6 The U.S.S.R

Tables 6a and 6b of Appendix C present frontier and OLS results for the Soviet Union. For the Soviet Union we have CIA estimates of value-added as well as official gross value of output, and we have data from 1951. Since several countries have data only from 1960, the following will focus on the results for the latter period in order to increase comparability across countries. Generally the CIA data result in lower estimates of both factor productivity growth and technical inefficiency. The only major exception is the fuel industry, where both results are reversed. Regardless of data used the Soviet results appear to imply lower rates of factor productivity growth and lower inefficiency than the East European countries. For comparability the following will focus on the results using the gross value of output, since we have only gross value of output data for the East European countries.

Compared to standard OLS estimates the results seem to imply better factor productivity performance than earlier studies. Four sectors have constant and respectable or high rates of factor productivity growth – electric power, MBMW, wood-working and light industry. Three sectors have decreasing factor productivity growth, but it is still positive at the end of the period in two of these sectors – construction materials and food processing. Only the fuel sector is an exception. It has rapidly decreasing factor productivity growth which is negative throughout most of the period. Its exceptional behavior is
probably due to the peculiarities of this industry and its overly rapid development in the 1970s and 1980s.\textsuperscript{31} These results present a more favorable view of Soviet productivity growth than previous research (for example, Desai, 1985), which has stressed the significant decreases in factor productivity growth over time. One disturbing result is that the estimate for total industry implies a zero rate of factor productivity growth. This is difficult to explain given the individual sector results.

Rates of inefficiency are rather low but their trend over time appears to explain the difference between our frontier results and earlier OLS estimates. Generally, rates of inefficiency tend to be relatively high in the 1960s until about 1968, then decrease through the early 1970s until about 1976, then increase to their highest levels in the late 1970s and early 1980s until about 1983 or 1984, and finally appear to decrease again in the last two or three years. The highest rates of inefficiency are found in the early 1980s. This is the same pattern exhibited by Poland and with the exception of the last two or three years this is the same trend exhibited in Hungary, Czechoslovakia, and to a lesser extent the GDR. The increase in inefficiency in the late 1970s and early 1980s is the major difference between our results and the results of previous studies. Poor Soviet performance in the late Brezhnev period has been caused partially by a decrease in efficiency.

The results also imply that the Khrushchev and Kosygin reforms of the 1960s did not result in good efficiency
performance, but that once the attempts at reforms ended, the early Brezhnev period performed relatively well. This indicates that the attempts at reform probably disrupted the normal operation of the system, and gains were made by reducing that disruption during the late 1960s and early 1970s. However, by the late 1970s the increase in corruption, the decrease in pressure from above, and the decrease in investment rates and labor growth rates increased bottlenecks. Since these bottlenecks do not cause unemployment in the Soviet-type system, they must result in lower input utilization rates. This appears as a decrease in efficiency in our estimates. However, the decrease in efficiency during this period appears to be smaller than the anecdotal evidence about the 'era of stagnation' would suggest. Thus, the results indicate that, although decreasing efficiency has been a contributing factor in declining growth, poor and decreasing factor productivity growth and declining input growth still appear to be more important causes of the growth slowdown.

Finally, the improvement in the last two or three years of the period probably reflect short-term gains made by crackdowns on discipline during the Andropov and early Gorbachev eras. These campaigns are likely to generate increases in input utilization rates, and therefore, increases in efficiency.
Section 5: Conclusions

In this study frontier production functions have been estimated for industrial sectors in five East European countries and the Soviet Union, for the period from 1960 to the mid-1980s. The major purpose has been to identify more fully than in previous research the factors leading to the slowdown in industrial growth. Previous studies have identified declining rates of factor productivity growth and decreasing rates of input growth as primary causes of this slowdown in growth. However, decreasing rates of factor productivity growth, when defined as the Solow residual, may be caused by many factors other than decreasing technological change. One possibility is that there has been a decrease in the efficiency with which inputs are used. For example, capital and labor inputs may be idle much of the time so that input levels may not reflect actual input services. The estimation of frontier production functions allows us to separate the effects of changing efficiencies in the use of inputs from other influences on factor productivity growth such as technological change.

Before concluding remarks are made, two caveats need to be reemphasized. First, the inefficiency which has been calculated in this study -- which, in general has been referred to as technical inefficiency -- actually is the result of both technical and allocative inefficiency, as these terms are normally used in microeconomic theory. Production is technically
efficient if the maximum achievable output is produced with a given level of inputs. Production is allocatively efficient if inputs are allocated among competing uses such that the production of no output can be increased without decreasing the production of some other output. Our estimates calculate technical efficiency if one assumes that each industrial sector represents one firm producing a single homogeneous product. Since each sector actually produces many individual products by many different firms, our estimates will be affected by how well inputs are allocated among firms and among individual products within the sector, as well as by how efficiently each firm uses its given inputs.

Second, efficiency is not calculated in an absolute sense, i.e., it is not calculated relative to an engineering norm or relative to best practice in market economies. Rather, efficiency in a particular industrial sector is calculated relative to best practice in that sector. For example, a three percent rate of inefficiency in a particular industry for a particular year means that year's production was three percent less efficient than the most efficient level of production achieved by the industry through the period observed. This most efficient level of production or 'best practice' may be substantially less efficient than the best practice elsewhere, in a Western market type economy, for instance. The methodology we employed cannot determine whether or not this latter comparison is valid. The frontier approach is capable of identifying
changes in efficiency over time relative to the most efficient observations in the data set, but is not capable of identifying the absolute level of efficiency.

Generally, our results support the hypothesis that there has been an increase in inefficiency throughout Eastern Europe and the Soviet Union in the late 1970s and 1980s. The results also indicate that factor productivity growth has been somewhat higher than reported in studies using standard ordinary least squares (OLS) estimation techniques. The combination of these two results implies that the industrial growth rate decline has been more effected by increases in inefficiency and less effected by decreases in the rate of technological change than can be inferred from previous studies.

However, with the possible exception of Poland and Czechoslovakia, the increase in inefficiency appears to be rather small. Rates of inefficiency are generally about 3 or 4 percent, even in the most inefficient period in the early 1980s. Only a few industrial sectors in each country have higher rates of inefficiency. These seem to be small rates of technical inefficiency relative to our prior expectations based on anecdotal evidence of rampant inefficiency in Soviet and East European economies.\textsuperscript{33} The anecdotal evidence indicates substantial overuse of labor, low labor and capital utilization rates, input bottlenecks, etc. The results in this study indicate that, although the level of technical inefficiency may be high, changes in inefficiency over time - from year to year -
are small. In other words, the absolute level of inefficiency may be high, in accordance with anecdotal evidence, but we find that it does not vary much from year to year.

These rates of inefficiency also are small relative to those calculated by Brada (1988). The primary difference between his study and ours is that he used a non-stochastic linear programming technique for fitting a production frontier while we used a stochastic frontier production function technique, and we tested more functional forms. We find substantially lower rates of inefficiency in the late 1970s and 1980s, and lower rates of factor productivity growth than Brada. Relative to Brada, our results indicate that the growth slowdown has been much less influenced by increasing inefficiency and much more influenced by low and declining factor productivity growth. We suspect that his results may be affected by measurement error since his technique is non-stochastic.

Another finding is that there is substantial cross-sectoral variation in both rates of factor productivity growth and rates of inefficiency within all the countries studied. Generally, the variation in factor productivity growth tends to conform with prior expectations. High priority sectors, such as machine building and chemicals, tend to have high rates of factor productivity growth. Low priority sectors, such as the light industrial sectors and food processing, tend to have low rates of factor productivity growth. Also, sectors with particularly difficult technical problems, such as fuels, tend to have very
low (often negative) factor productivity growth. Rates of factor productivity growth for total industry appear to be averages of these strong and weak performing industrial sectors.

Cross-sectoral variations in inefficiency seem to have no identifiable pattern. High priority sectors with high factor productivity growth sometimes appear to be relatively inefficient and sometimes appear to be relatively efficient, and the same is true for low priority sectors.

A final important result is that Soviet inefficiency estimates appear to be somewhat lower, have less cross-sectoral variation, and fluctuate less over time than in the East European countries. This does not imply that production in the Soviet Union is more efficient, but it does imply that levels of inefficiency are less variable among sectors and over time than in Eastern Europe. We interpret this result and the general finding of low estimated rates of inefficiency similarly.

Generally, the Soviet-type economic system achieves macroeconomic stability at the expense of microeconomic efficiency and technological innovation. The system maintains full (or over-full) employment and price stability, but the rules and incentives which achieve those results also lead to weak incentives for technical efficiency and technological innovation. If the system works in the textbook manner, we would expect to see low rates of factor productivity growth. We also would expect to see large amounts of technical inefficiency, but we would expect to find that changes in technical inefficiency were
small over time. Since planning is 'from the achieved level' and is based on quantitative targets rather than monetary incentives, performance should be rather consistent, albeit poor, over time. Furthermore, the macroeconomic stability of the system should reinforce this consistency. Put another way, firms face demands which are designed by the state in a manner which does not vary significantly over time, compared to the vagaries of consumer demands in a market economy. Therefore, significant fluctuations over time are mitigated by the planning process.

For several reasons, this description of the system applies more strictly to the Soviet Union itself than the East European economies. First, the Soviet economy is much more isolated from the international market and can better absorb shocks induced by that market. This increases the macroeconomic stability of the system because planners, and therefore firms, have less need to make plans respond to occurrences in the world market. If the international market is a disruptive influence on the stability of the planning mechanism, macroeconomic stability should be inversely related to the importance of international trade in a Soviet-type economy. Second, because the Soviets have had very little experimentation with economic reform the system has been relatively stable. Further, there have been fewer changes in policy. This also increases the macroeconomic stability of the economy. In the 1970s the East European countries engaged in an investment binge financed by Western loans, but the Soviet Union did not pursue such a policy. This policy resulted in the well-
known debt problems and subsequent fluctuations in macroeconomic policies in Eastern Europe. Overall macroeconomic stability in Eastern Europe was adversely affected by the greater influence of international trade, more systemic experimentation and detrimental macro-policy decisions. None of these factors had as significant an impact upon the macroeconomic stability of the Soviet Union.

How does macroeconomic stability relate to our measures of efficiency in industrial production? In market economies (if they operate as microeconomic textbooks indicate) fluctuations in macroeconomic activity should result in changes in the employment of labor and other inputs, but efficiency should not be affected. In Soviet-type economies, however, the planning mechanism and individual firm incentives work to keep employment and investment rates high. Fluctuations in macroeconomic activity -- i.e., fluctuations in aggregate demand -- will tend to reduce output, but input employment levels will tend to remain high. Therefore, macroeconomic fluctuations will result in changes in the efficiency of production rather than changes in employment.

The implication of these considerations for our results is that the finding of generally low rates of inefficiency are a reflection of the macroeconomic stability properties of the Soviet-type economic system. The finding that these rates of inefficiency are smaller and less variable in the Soviet Union is a consequence of greater East European vulnerability to the world market, and East European economic policies which have reduced
the effectiveness of the macroeconomic stability properties of the system.
References


Cameron, N.E., "Economic Growth in the USSR, Hungary and East and


____, "The Rate of Return on Foreign Capital Inflow to the Soviet Economy," in JEC (1979), 396-413.


____, "Technical Change, Factor Elasticity of Substitution and Returns to Scale in Branches of Soviet Industry in the


Green, Donald W. and Herbert S. Levine, "Implications of Technology Transfer to the USSR," in NATO (1976), 43-67.


Hanson, Philip, Trade and Technology in Soviet-Western Relations, New York: Columbia University Press, 1981.


Promishlennost' SSSR (Moscow: Central Statistical Administration, 1956 and 1958).


Shephard, R.H. Theory of Cost and Production Functions.  

Shephard, R.H. "Semi-Homogeneous Production Functions and  
Scaling of Production," in Eichorn, W., Henn, R.,  
Opitz, O., and Shephard, R.W. eds. Production Theory  
(Berlin: Springer Verlag) 1974.

Solow, Robert M., "Technical Change and the Aggregate Production  
Function," Review of Economics and Statistics, August 1957,  
312-20.

Statisticka Rocenka Ceskoslovenske Socialisticke Republicy  

Statistisches Jahrbuch der Deutschen Demokratischen Republik  
(Berlin: Staatsverlag der Deutschen Demokratischen  

Statisticki Godisnjak Jugoslavije, Beograd: Savezni zavod za  
Statistiku, 1961-85.

Thomas, John R. and V.M. Kruse-Vaucienne, eds., Soviet Science  
and Technology: Domestic and Foreign Perspectives,  

Thornton, Judith, ed., Economic Analysis of the Soviet-Type  

——, "Differential Capital Changes and Resource Allocation in  
May/June 1971.

——, "Value-Added and Factor Productivity in Soviet Industry,"  

Timmer, C.P. "Using a Probabilistic Frontier Production  
Function to Measure Technical Efficiency." Journal of  

Toda, Yasushi, "Estimation of a Cost Function in the state of  
Structural Disequilibrium: The Case of Soviet Manufacturing  
58(2), May 1976.

——, "Technology Transfer to the USSR: The Marginal-  
Productivity Differential and the Elasticity of IntraCapital  
Substitution in Soviet Industry," Journal of Comparative  
Economics, 3(2), 1979, 181-94.

——, "Capital-Labor Substitution in Production Functions: The

Toumanoff, Peter, "The Use of Production Functions to Investigate Soviet Industrial Reform," Comparative Economic Studies, 29(3), Fall 1987, 94-111.


Notes

1. The problem may also be phrased in terms of absolute levels of inputs and outputs.

2. Most productivity studies estimate average production functions rather than frontiers. See Goldberger (1968) for a discussion of this point. Forsund, Lovell and Schmidt (1980) provides an illuminating survey of the frontier production function approach which is pursued in this paper.

3. It should be emphasized here that the Solow residual is truly an "everything else" category and it is too aggregated to distinguish between technological change and efficiency changes - either technical or allocative. Explanations of changes in overall rates of growth employing changes in the Solow residual as an explanatory factor usually turn to other evidence or speculative hypotheses about the productivity of individual factors or output elasticities which are dependent upon the functional form of the production function and estimation technique. We briefly survey this work in section three, below.


5. Changes in overall efficiency are important. Overall efficiency may be decomposed into allocative and technical efficiency. Below we concentrate on estimating technical efficiency via the frontier production function approach.

6. See Kemme and Neufeld (1988) for an example of the non-parametric approach and Brada and Totev (1988) for an example of the parametric linear programming approach to East European countries.

7. For example, the import of a new production process or technique will quickly shift the frontier. However, it is an altogether different matter to insure the diffusion of that process or technique to other enterprises or branches.

8. The rate of growth of factor productivity is also known as the Solow residual. It is often equated with technological change. It actually includes anything which increases output with a fixed level of inputs. This includes technological change but also includes other influences not usually considered to be technological change. For example, changes in technical efficiency, changes in allocative efficiency in a multi-product firm context or in the context of a sector of the economy, non-constant returns to scale, changes in the organization of management or labor, etc.
9. Low growth rates of the labor force have several causes. Particularly important are: the inability to transfer labor from agriculture to industry because of low agricultural productivity, high female-labor force participation rates because of low real wages which result in low birth rates, and increasing death rates because of health problems.

10. Actually, Blitzer (1970) showed earlier that the Soviet data implied a low elasticity of substitution, but he did not estimate the value of the elasticity of substitution. Another early article by Brubaker (1968) used the aggregate production function to analyze Soviet growth, but he did not focus on the growth slowdown. His main conclusion was that the rate of growth of factor productivity was a less important cause of growth than input accumulation relative to what had been found by Solow (1957) and others for the United States. Most of the subsequent analyses imply a similar conclusion.

11. Income shares in a Soviet-type economy may not reflect marginal productivities because of the rules for the formation of wages and prices. This is a serious qualification to Thornton's approach.


13. An earlier study by Kaplan (1968) came to the same conclusion but did not actually estimate the parameters of the production function. He shows that, regardless of the value of capital and labor shares, the rate of growth of factor productivity must be decreasing.

14. Most Western research has estimated disembodied Hicks-neutral technical change. Embodied technical change means that new technology is embodied within new inputs. For example, new more productive machines or a more educated labor force. Disembodied would be something outside these inputs such as a better organization of work. In practice disembodied technical change is estimated because the data necessary to measure embodied technical change is unavailable. The factor productivity residual should include the influence of both embodied and disembodied technical change, but we cannot separate them. Hicks-neutral technical change implies that technical change does not alter the marginal rate of technical substitution between capital and labor at a fixed capital-labor ratio. Harrod-neutral technical change means that new technology does not alter the marginal rate of technical substitution at a fixed capital-output ratio. This is equivalent to labor-augmenting or capital-saving technical change in the Hicks sense, i.e., the marginal productivity of labor is increased relative to the
marginal productivity of capital at a fixed capital-labor ratio.

15. Recent estimates, including those presented here, extending the data into the 1980s indicate that this may no longer be true.


17. See Weitzman quote below which implies that the specific functional form may not be important, at least for some questions.

18. Weitzman (1983), 188.


21. See the earlier discussion of econometric techniques for a description of this methodology.

22. For some industrial branches and countries slight variations of these six were also estimated.

23. Note though, that the residual for the percentage change specification will be interpreted slightly differently than for the logarithmic specification.


25. See Aigner, Lovell and Schmidt (1977), inter alia, for an explanation. If the third moment is negative the frontier is being fitted to the wrong side of the data. In software packages like LIMDEP the resulting frontier is not reported. It is then assumed that the entire set of observations make up the frontier isoquant - there is no inefficiency - and the OLS estimates are accurate estimates of the stochastic frontier.

26. Again see Olson, Schmidt and Waldman (1980) on the Type I and Type II errors.

27. This parameter was labelled $\lambda$ in the discussion of the previous section.

28. Below the $^*$ refers to an estimated value of the parameter.

29. An expanded version of this section will be found in the book length version of this report in process.
30. Actually, given the large changes taking place in Polish industry during the later part of the 1970s and early 1980s this should probably be regarded as a low level of inefficiency. Since it is an average for the entire period, however, the disturbances of the later part of the period are dampened by the stability of the earlier period. Nonetheless, the average level of inefficiency is higher than most of the other countries analyzed.

31. The increasingly costly exploration for new reserves and the deeper and more difficult exploitation of those resources should show up as decreases in factor productivity.

32. See Hewett (1988), 76-77, for a discussion of anecdotal evidence of a decrease in capital and labor utilization during this period.

33. See, for example, Hewett (1988), 76-77, where he cites Soviet sources indicating much higher and increasing inefficiency in the Soviet industry.

34. The following interpretation is consistent with Brada's (1988) interpretation of changes in efficiency in Eastern Europe.