POLICY RESEARCH WORKING PAPER 1284

The Soviet Economic Decline

Historical and Republican Data

William Easterly
Stanley Fischer

What led to the relative Soviet decline was reliance on capital accumulation and a low elasticity of substitution between capital and labor. Planned economies are apparently less successful at replacing labor effort with capital. Tentative evidence indicates that the burden of defense spending also contributed to the Soviet debacle.

The World Bank
Policy Research Department
Macroeconomics and Growth Division
April 1994

POLICY RESEARCH WORKING PAPER 1284

Summary findings

Soviet growth for 1960–89 was the worst in the world, after controlling for investment and human capital. And relative performance worsens over time.

Easterly and Fischer explain the declining Soviet growth rate from 1950 to 1987 by the declining marginal product of capital. The rate of total factor productivity growth is roughly constant over that period.

Although the Soviet slowdown has conventionally been attributed to extensive growth (rising capital-to-output ratios), extensive growth is also a feature of market-oriented economies like Japan and Korea. One message from Easterly's and Fischer's results could be that Soviet-style stagnation awaits other countries that have relied on extensive growth. The Soviet experience can be read as a particularly extreme dramatization of the long-run consequences of extensive growth.

What led to the relative Soviet decline was a low elasticity of substitution between capital and labor, which caused diminishing returns to capital to be especially acute. (The natural question to ask is why Soviet capital-labor substitution was more difficult than in Western market economies, and whether this difficulty was related to the Soviets' planned economic system.)

Tentative evidence indicates that the burden of defense spending also contributed to the Soviet debacle.

Differences in growth performance between the Soviet republics are explained by the same factors that figure in the empirical cross-section growth literature: initial income, human capital population growth, and the degree of sectoral distortions. The results Easterly and Fischer got with the Soviet Union in the international cross-section growth regression indicate that the planned economic system itself was disastrous for long-run economic growth in the Soviet Union.

This point may now seem obvious but was not so apparent in the halcyon days of the 1950s, when the Soviet case was often cited as support for the neoclassical model's prediction that distortions do not have steady-state growth effects. Since a heavy degree of planning and government intervention exists in many countries, especially developing countries, the ill-fated Soviet experience continues to be of interest.

This paper — a product of the Macroeconomics and Growth Division, Policy Research Department — is part of a larger effort in the department to study the determinants of long-run growth. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Rebecca Martin, room N11-043, extension 31320 (56 pages). April 1994.

Produced by the Policy Research Dissemination Center

THE SOVIET ECONOMIC DECLINE: HISTORICAL AND REPUBLICAN DATA*

William Easterly
World Bank, Room N-11-043
1818 H Street NW
Washington DC 20433

and

Stanley Fischer
Department of Economics
MIT
Cambridge MA 02139

* Easterly is in the Macroeconomics and Growth Division at the World Bank, and Fischer in the Department of Economics at MIT, and a Research Associate of the NBER. Views expressed here are not to be attributed to the World Bank.We are grateful to Karen Brooks, Alan Gelb, Eugene Gravilenkov, Barry Ickes, Barry Kostinsky, Martha de Melo, Gur Ofer, Sergio Rebelo, Bryan Roberts, Marc Rubin, Randi Ryterman, Martin Schrenk, Marcelo Selowsky, Michael Walton, and Alwyn Young for comments and useful discussions while writing this draft, to seminar participants at MIT, the University of Michigan, the Federal Reserve Board, and the World Bank, to Professor Mark Schaffer of the London School of Economics for kindly making his historical Western, official, and Khanin data available in machine readable form, and to Elana Gold and Mary Hallward for diligent research assistance.

While the final collapse of the Soviet Union and Soviet communism now appears to have been inevitable, it is essential to try to pinpoint the causes of the economic decline, without which the Soviet Union would still exist. The different accounts of the causes of declining Soviet economic growth developed by Bergson (1987b), Desai (1987), Ofer (1987), Weitzman (1970) and others emphasize: the Soviet reliance on extensive growth which, given the slow growth of the labor force and the falling marginal productivity of capital, eventually ran out of payoff; the declining rate of productivity growth or technical progress associated with the difficulties of adopting and adapting to the sophisticated technologies being introduced in the West (including East Asia as part of the West); the defense burden; and a variety of special factors relating to the absence of appropriate incentives in the Soviet system, including corruption and demoralization.

In this paper, we first place the Soviet growth performance in an international context using the empirical cross-section growth literature. In section I, we start with an overview of the data and of the Soviet growth record, comparing it to other countries using a standard growth regression. We compare the Soviet pattern of extensive growth (rising capital to output ratios) to other countries. We reexamine and update Soviet-level production function estimates based on the official, unofficial (by the Russian economist Khanin)[1] and western data, as well as examining other historical indicators of the Soviet growth pattern. In section II, we turn to a new data set: official data on republican output, capital stocks (both in constant, or as the Soviets called it, comparable prices), and employment by sector. These data have not previously figured in the Western literature on Soviet growth[2]. The fact that the republics will now have to operate as independent economic units adds interest to our republican-level

[1]Ericson (1990) argues that the Khanin data are preferable to the western data created by Bergson and others; Bergson (1991a, 1987a) criticizes the Khanin data for a poorly documented methodology and the apparent use of unweighted averages of physical indicators. Harrison (1993) provides a more sympathetic analysis of Khanin's data, emphasizing his attempts to adjust for the reporting biases inherent in the Soviet statistical system. We are grateful to Professor Mark Schaffer for making the Khanin data available.

[2]The republican data were provided by Goskomstat of the Commonwealth of Independent States and by the Center for Economic Analysis and Forecasting at the Ministry of Economics, and are available from Easterly at the World Bank, 1818 H Street NW, Washington, DC 20433. We rescaled the data to reconcile different base years for the data in comparable prices.

results. We discuss the patterns of growth by sector and republic, exploring cross-section correlations between growth of the Soviet republics or sectors and conventional right-hand side variables used in growth regressions. In the conclusion, we offer some thoughts on interpretation of our results.

I. The Soviet Growth Record

The fundamental problem in evaluating Soviet growth is data quality.[3] Official Soviet output data overstate growth, as a result of both methodological problems -- particularly in deflating nominal data, and incentives to misreport output within the Soviet system. Western analysis of Soviet growth relies on the classic studies of Bergson (1961), and others, as well as the CIA, which makes the working assumption that physical quantities as presented in the official data were not systematically misreported. Thus the difference between the western estimate that per capita Soviet GNP increased between 1928 and 1987 by 3.0 percent per annum (4.3 percent for aggregate GNP) and the official estimate for NMP per capita of 6 percent per annum results mostly from pricing corrections, and also from differences in the coverage of NMP and GNP.[4] The classic western estimates generally assume that Soviet investment and capital data are more accurate than output data (Bergson (1987a), a view disputed by Wiles (1982)). The western data through 1985 are conveniently summarized in Ofer (1987).

We use four different data sets in the empirical work in this paper:

(1) The official Soviet Union-wide data on real output, industrial production, employment, and the capital stock in the material sector in 1973 rubles, taken from official sources;

(2) Western data on output, industrial production, employment, and the capital stock, for the Soviet Union as a whole: including

(a) the Powell(1963)/CIA(1982)/CIA (various years) series on value added and capital stocks in industry, and

[3] This discussion draws on material in Fischer (1992).

[4] The Soviet concept of Net Material Product omitted from GNP services not directly related to production, such as passenger transportation, housing, and the output of government employees not producing material output.

(b) the Moorsteen-Powell(1966)/Powell(1968)/CIA(1982)/CIA (various years)/Kellogg(1989) series on GNP, labor input, and capital stock for the entire economy. These series are chain linked, using 1937 rubles for 1928-60, in 1970 rubles for 1960-80, and 1982 rubles for the 1980s.

(3) Khanin's data, from Khanin (1988), also at Soviet Union-wide level, for output, employment and the capital stock in the material sector; and

(4) Republic-level data on aggregate and sectoral output and inputs in the material sectors for 1970-90 in constant rubles, which were made available by Goskomstat.

The direct source of our datasets (1) through (3) is Gomulka and Schaffer (1991), who spliced together series from the sources described. Note that the Khanin data are presented for the material sectors (i.e. not including consumer services), as are the official data. Our preferred dataset for the aggregate data will be (2); the others are presented to test the robustness of the conclusions to alternative estimates of outputs and inputs.

A) SOVIET GROWTH IN INTERNATIONAL COMPARISON

Growth rates of series in the first three data sets for different periods are presented in Table 1. The Western output per worker growth rates are well below the official rates, with the Khanin data in turn below the Western data. All series show growth declining sharply since the 1950s.

How does the Soviet growth record compare to the rest of the world? We use the Western GDP series to compare Soviet per capita growth over 1960-89 with World Bank per capita growth rates for 102 countries (we look here at per capita rather than per worker growth to enlarge the sample of comparators and make it consistent with the cross-section growth literature). The first column of Table 2 shows that Soviet per capita growth has been slightly above the global average over both 1960-89 and 1974-89.

However, Soviet growth no longer looks respectable once we control for the standard growth determinants from the empirical literature. The last column of Table 2 shows the residual from inserting the Soviet Union into the core regression of Levine and Renelt (1992), which relates growth to initial income, population growth, secondary enrollment, and the investment ratio to GDP. The Levine-Renelt regression including the Soviet Union is as follows:

Per capita growth 60-89= -0.83 + 17.49 Investment 60-89 - .35 GDP per capita 1960 +
(.85) (2.68) (.14)

*3.16 * Secondary enrollment 1960 - .38 Population growth 60-89 - 2.34 Dummy for USSR*
(1.29) (.22) (1.43)

103 observations, R2=.46. (standard errors in parentheses)

Except for population growth, Levine and Renelt showed these variables to be robust to alternative specifications in growth regressions (although concerns about endogeneity remain). The regression results are identical to the Levine-Renelt original since we are dummying out the Soviet observation.

Excepting initial income, the values of the Soviet right-hand side variables should have implied very rapid growth--population growth was low, and secondary education and the investment ratio were near the top of the distribution. Growth was only average, hence the large negative residual of 2.3 percentage points in 1960-89. It is notable that the only countries with worse residuals are generally both small and poor: Suriname, Jamaica, Guinea-Bissau, Liberia, Zambia, and Peru. Soviet per capita income in 1989 was only half of what it would have been if the average relationship between growth and the right-hand side variables had held over 1960-89.

The Soviet residual in this OLS regression is not actually significant in a two-sided test at the 5 percent level. However, the presence of so many small and poor countries among the large outliers makes us suspect heteroskedasticity. The suspicion is justified. We split the 1960-89 sample into thirds on the basis of total real GDP (i.e. population times PPP per capita income) and rerun the above regression for the top and bottom thirds ranked by total GDP. (The USSR is included in the top third ranked by total GDP and we continue to dummy it out.) The Goldfeld-Quandt test statistic for heteroskedasticity -- which is equal to the ratio of the sum of squared residuals in these two subsample regressions and is distributed as an F statistic with the number of degrees of freedom of the numerator and denominator corresponding to the degrees of freedom in the subsample regressions -- indicates that we can reject homoscedasticity. The test results are as follows:

Sum of squared residuals in third of sample with lowest real GDP: 88.3
Sum of squared residuals in third of sample with highest real GDP: 33.9
F (29, 28) = 2.61 (significant at 1 percent level)

Based on the test results, we now perform weighted least squares using the log of total real GDP as the weighting series. The results are now as follows:

Per capita growth 60-89= -0.43 + 15.93 Investment 60-89 - .28 GDP per capita 1960 +
(.73) (2.19) (.08)

*2.56 * Secondary enrollment 1960 - .24 Population growth 60-89 - 2.28 Dummy for USSR*
(0.73) (.16) (0.48)

102 observations, R2 (weighted) =.84, R2 (unweighted) =.41.

The Soviet dummy becomes highly significant with weighted least squares, with a t-statistic of 4.8. Taking into account that only countries doing worst than the USSR were small economies makes the Soviet performance look even worse. After correcting for heteroskedasticity, the Soviet economic performance conditional on investment and human capital accumulation was the worst in the world over 1960-89.

How does the comparative Soviet performance evolve over time? Since the World Bank data used by Levine and Renelt begins only in 1960, we compare the Soviet performance also with the cross-country Summers-Heston (1991) dataset that extends back to 1950. We perform a pooled time-series, cross-section regression using decade averages for the same specification as before (except that we have to unfortunately omit the secondary enrollment variable for lack of reliable Soviet data for the 1950s). We use the same Soviet data as in the previous regression, but now broken down by decade. We put intercept dummies for each decade, as well as a separate Soviet dummy for each decade. We continue to use weighted least squares with the weighting series being the log of total GDP, as the Goldfeld-Quandt statistic still indicates a significantly larger variance for small economies.[5] The results are:

[5]The F-statistic for the ratio of the sum of squared residuals in the bottom third to that in the top third of the sample ranked by total GDP (in PPP prices from Summers-Heston (1991)) is F(124,121)=2.03, which is significant at the 1 percent level.

Per capita growth by decade = 0.022 +.120 Investment/GDP by decade - 1.5E-06 GDP per capita, initial year
(.005) (.016) (3.6E-07)

-.626 Population growth by decade + .005 60s dummy - .005 70s dummy - .015 80s dummy
(.143) (.004) (.003) (.003)

+.024 Dummy for USSR 50s - .008 Dummy for USSR 60s - .017 Dummy for USSR 70s
(.011) (.010) (.009)

-. 023 Dummy for USSR 80s
(.009)

391 observations, R2 (weighted) =.54, R2 (unweighted) =.26

As is well known, world economic growth decelerated in the 70s and even more in the 80s. However the Soviet growth deceleration is notable even by comparison with the world pattern: Soviet economic growth was significantly *above* the world average in the 1950s, and significantly *below* even the poor world growth of the 1980s. Note especially the good performance of the Soviet Union in the 1950s, even controlling for high investment: it suggests that whatever the weaknesses of Soviet central planning in hindsight, these weaknesses were unlikely to have been apparent prior to 1960.

B) POSSIBLE EXPLANATIONS FOR POOR AND DECLINING SOVIET GROWTH

We now consider other possible factors in the relative Soviet decline, including the defense burden, demoralization, and Soviet disincentives for innovation. Could the poor and declining growth performance be explained by the burden of defense on the Soviet economy? Although measurement is problematic, the burden seems to have been high and rising. In Table 3, we show some estimates of the Soviet defense burden as a share of GDP. Over the entire period since 1928, Soviet defense spending has risen from 2 percent of GDP to the much higher levels of the mid-and late-1980s, of around 15-16 percent of GDP. Over the period 1960-89 in which the Soviet growth decline occurred, the rise in the defense burden is more modest -- from 10-13% in 1960 to 12-16% in the 1980s.

The international evidence for adverse effects of defense spending on growth is ambiguous -- see Landau (1993) for a recent survey. Landau (1993) himself finds an inverted U relationship: military spending below 9 percent of GDP has a positive effect on growth, but defense above 9 percent of GDP has a negative effect on growth. To see whether this affects the Soviet dummy in the growth regressions, we insert defense spending into the decade-average growth regressions performed earlier.

We also include a variable measuring war casualties per capita on national territory to insure that the military spending variable is not simply proxying for wars. Because the military spending data is only available for recent periods, we use data from the 1980s only.[6] The regression including a quadratic function of military spending is as follows:

Per capita growth 1980-88 = -0.003 + .127 Investment/GDP 1980-88 - 2.7E-06 GDP per capita, 1980 +
(.017) (.038) (1.1E-06)

-1.34 Population growth, 1980-88 + .007 Secondary enrollment 1970 + .0081 Military spending/GDP
(.38) (.017) (.0024)

-.00041 (Military spending/GDP)^2 - 0.746 War casualties per capita -.0155 Dummy for USSR
(.0001) (0.343) (.0268)

LS weighted by log of total GDP, 77 observations, R2 (weighted) =.59, R2 (unweighted) =.30 Standard errors in parentheses.

We confirm Landau's result of an inverted U-shaped relationship between growth and defense spending. Military spending reduces the magnitude and significance of the Soviet dummy. However, as Landau also noted this result is not very robust -- omitting Syria and Israel from our sample eliminates the significance of military spending. The defense explanation for the Soviet decline is plausible but not firmly established with cross-section data. We will test the defense hypothesis further with the Soviet time series in the production function estimates below.

Another hypothesis about the Soviet growth decline is that it was related to the increasing demoralization of the population, or alternatively to the increasing breakdown of worker discipline. This breakdown of discipline could have resulted from the gradual opening up of the Soviet system, and the declining reliance on state terror.

Demoralization is obviously hard to measure, but we present some fragments of evidence. One statistic relevant to demoralization is shown in Figure 1, which represents the results of a survey of emigres which asked how satisfied they had been with the standard of living in the USSR. The young had been less satisfied than the old. Among the many possible explanations for these results is that

[6]Landau only covers developing countries, so we use instead data from Hewitt (1993) that covers all countries (including the USSR itself). The data for both Landau and Hewitt is mainly from SIPRI (the Stockholm International Peace Research Institute). The data on war casualties is from Easterly, Kremer, Pritchett, and Summers (1993).

declining growth and disappointed expectations among the young were mutually reinforcing.[7]

Other indicators of life in the Soviet Union also support the idea of a system breaking down. Western specialists were amazed to learn that Soviet male life expectancy actually declined in the 1970s while other countries' (male) life expectancy rates were rising(Figure 2). Soviet life expectancy was declining even though per capita income growth was slightly above the world average, as we have seen. There was a recovery in Soviet life expectancy in the 80s, but the USSR was still surpassed during the decade by developing countries like Mexico.[8]

Another possible explanation for poor and declining Soviet growth could be adverse incentives under central planning for technological innovation (Berliner (1976)). A recent theoretical and empirical literature argues that endogenous technological innovation, as measured by resources devoted to research and development (R&D), significantly explains relative growth performance across countries (Coe and Helpman (1993), Lichtenburg (1992), Romer (1989); see Birdsall and Rhee (1993) for a dissenting view).

Western estimates of the Soviet research effort, presented in Figure 3, show R&D spending rising as a share of GNP. The R&D share is above the 2-3 percent in the leading industrialized countries. In 1967, about 1.5 percentage points of this was estimated to be for defense and space (Bergson, 1983). The share of defense and space R&D in total R&D is believed to have fallen over 1959-84 (Acland-Hood (1987)), implying an even steeper rise in civilian R&D. The data on Soviet R&D thus go in the wrong direction to explain either poor Soviet growth on average or the fall of Soviet growth over time.

[7]Among the other explanations: the young are chronic complainers; the old remember the period of much lower consumption before the rapid Soviet growth of the 1950s; the authorities resisted emigration by the young, so that any young emigre had to be more determined and disgruntled than the average emigre. Also, since the original source did not report standard deviations within the sample groups, we are unsure whether the differences are statistically significant.

[8]One factor could have been the sharply rising consumption of alcohol in the 60s, 70s, and early 1980s, which itself may be an independent indicator of demoralization (Treml 1991). However, we are reluctant to make too much of this since some countries with rapid income increases -- like Korea -- also had sharply rising alcohol consumption.

C) THE EXTENSIVE GROWTH HYPOTHESIS

As noted, in the introduction, the conventional hypothesis for the Soviet growth decline is the pattern of extensive growth, defined by Ofer (1987) as a rising capital-output ratio. Figure 4 shows the evolution of the capital-output ratios implied by the alternative data series for 1950-87.[9] The western series shows the capital-output ratio increasing two and a half times between 1950 and 1987. The official series also rises steadily beginning at the end of the 50s, more than doubling between 1958 and 1987. The Khanin data, by contrast with the other two series, show only a small increase in the capital-output ratio between the early 1950s and 1987. The capital-output ratios in industry first decline in the 50s and then rise sharply after 1960, according to both Western and official estimates.

The behavior of the capital-output ratio is central to the debate about whether reliance on extensive growth was the Achilles' Heel of Soviet industrialization, as the conventional wisdom has it. In the neoclassical model, a rising capital-output ratio implies capital deepening during the transition to a higher steady state, but this capital deepening will sooner or later run into diminishing returns that will cause growth to slow or stop. The Soviet reliance on capital deepening is implicitly contrasted with market economies, where according to the famous Kaldor stylized fact, capital-output ratios remain relatively stable (recently reaffirmed by Romer (1990)). A constant capital-output ratio is consistent with neoclassical steady state growth with labor-augmenting technical change. King and Rebelo (1993) argue that capital deepening cannot account for much of sustained economic growth in the neoclassical model without implying implausibly high rates of return to capital early in the transition process.

Nevertheless, recent research on capital accumulation in market economies casts doubt on whether the Soviet extensive growth experience was unique. Appendix 1 lists the per annum growth rates of the capital-output ratios in a selection of recent growth accounting studies and a few older ones. All studies agree that the capital-output ratio in the U.S. has remained remarkably constant, which

[9]We begin the graphs in 1950 because we are puzzled by the extreme volatility of all of the capital-output series before 1950. We conclude that more even than the usual caution should be attached to results that rely on pre-1950 data.

perhaps accounts for the conventional wisdom that Kaldor's stylized fact holds. However, a number of recent studies point to capital-output ratios rising at Soviet-style rates in Japan and in some of the East Asian NICs such as Korea (Young (1993b), Kim and Lau (1993), King and Levine (1994), Benhabib and Spiegel (1992), Nehru and Dhareshwar (1993)).

Moreover, the latter three, cross-country, studies show that rising capital-output ratios are a feature of growth for many countries.[10] The three studies compute capital stocks for a large sample of countries, using a variety of data sources (Summers-Heston versus World Bank) and a variety of assumptions about initial capital stocks and depreciation rates. The three concur that rising capital-output ratios are by no means rare: the median capital-output ratio growth of their respective samples is around 1 percent per annum, and fully a quarter of the samples' capital-output ratio growth rates are over 1.7 percent per annum.[11] Nor is it only developing countries that are shown to have rapid capital-deepening. For example, the studies concur that capital-output ratios in Austria and France increased at over 1.5 percent per annum. The literature on extensive growth as the bane of Soviet development did not recognize that extensive growth also occurred in market economies, and sometimes with striking results as in Japan and Korea. What is notable about the Soviet experience was not the extensive growth, but the low payoff to the extensive growth.

As either a cause or a consequence of the low payoff, the *level* of the Soviet capital-output (K-Y) ratio had become extreme by the 1980s. The K-Y ratio as measured by the Western GDP and total capital stock series was 4.9 in 1985, which is higher than any of the 1985 K-Y ratios in the Benhabib-Spiegel and King-Levine exercises. In the Nehru-Dhareshwar sample, there are only four countries with a K-Y ratio above the Soviets in 1985, none of which seem especially relevant as comparators -- Guyana, Zambia, Jamaica, and Mozambique.

One other implication of the extensive growth model is that investment ratios have to rise over

[10]See also Judson (1994), who shows the capital-output ratio rising systematically with income.

[11]For the two studies that use Summers-Heston data (Benhabib and Spiegel 1993 and King and Levine 1994), we omit Africa from the sample because investment to GDP ratios are implausibly extreme (both high and low) in the 1950s.

time if growth is to be maintained while the capital output ratio rises. As has previously been highlighted in the literature (see Ofer (1987)) the Soviet investment share doubled between 1950 and 1975, as can be seen in the CIA estimates presented in Figure 5. After 1975, the investment share continued to increase, but more slowly.

How unusual is the doubling of the investment rate over a 25 year period? In the Summers and Heston (1991) international database for 1950-75, 8 out of 52 countries -- most notably Japan and Taiwan -- had a doubling or more of investment rates.[12] Shifting the sample period forward by 10 years to expand the sample, 6 out of 72 countries had a more than doubling of investment over 1960-85, among which Korea and Singapore are of particular interest. Soviet investment mobilization was at a level that was above average, but not unknown, among market economies.

The stand-by of Soviet industrialization, machinery and equipment investment, also increased sharply as growth declined. The importance of this sector to growth has been emphasized by de Long and Summers (1991, 1992, 1993); the Soviet data suggest a high ratio of machinery investment to GNP is not sufficient to generate growth.

D) PRODUCTION FUNCTIONS AND EXTENSIVE GROWTH

Another way to evaluate the extensive growth hypothesis is to do the traditional total factor productivity calculation. For the TFP calculation, there is little difference between the official and western data on factor input growth while Khanin shows substantially lower rates of growth of capital (Table 1). This is a consequence in part of Khanin's view that hidden inflation is as serious in capital goods industries as in consumer goods, a view shared by the "British school" of Hanson (1984), Nove (1981), and Wiles (1982).

In Table 4 we show summary statistics for productivity growth for the USSR, calculated assuming a Cobb-Douglas production function with labor's share equal to .6 and the share of capital equal to .4 (slightly above that used by Bergson and the CIA, but within the conventional range for

[12]We continue to exclude African countries from this and the following sample.

developing countries) for alternative data series.[13] With the assumption of Cobb-Douglas production (unit elasticity of substitution between capital and labor) we see a strongly declining trend in TFP growth after the 1950's.

The most interesting aspect of Table 4 is that the 1950s once more stand out as an exceptional period in Soviet growth. It is especially striking that even the western data for the industrial sector imply productivity growth in that decade of more than 6 percent per annum. Note the remarkable divergences of views about performance in the 1930s that emerge from Table 4, with official Soviet data showing extraordinary rates of productivity growth and Khanin and western GNP data implying negative rates.

Western GNP data present the most pessimistic assessment of Soviet productivity performance, implying that productivity growth in the Soviet Union was positive only in the 1950s. The Khanin data, which uniformly exhibit lower overall growth than western GNP data, by contrast imply positive post-1950 productivity growth, a result of the lower rates of growth of capital in the Khanin series.

The data in Table 4 point to one extremely important feature of the Soviet growth slowdown: estimated productivity growth for the industrial sector was positive until the 1980s. This locates the major slowdown of productivity in the non-industrial sector. Looking ahead to Table 7, using the aggregate of the republican data for 1970-90, the biggest problem was in agriculture, where productivity appears to have declined by 4 percent per annum, with construction and trade and procurement showing small positive rates of productivity growth.[14]

Following the pioneering work of Weitzman (1970, 1983) and later contributions (Desai (1976,

[13]It has long been a stylized fact in the development literature that capital shares are higher in developing than developed countries (see for example De Gregorio's (1992) estimate that the capital share is between .4 and .55 for Latin America). Western estimates of Soviet per capita income suggest it was a developing rather than a developed country.

[14]Previous estimates of productivity growth in agriculture were less drastic but still showed poor performance. Diamond, Bettis, and Ramson (1983) show productivity growth in agriculture of 0.2 percent over 1971-79. Brooks (1983) showed zero agricultural productivity growth over 1960-80. We are not sure how our calculation of negative agricultural productivity growth relates to Desai's (1992) evidence that weather-adjusted grain yields were rising rapidly in the 1980s, unless the increase in yields was obtained through massive increases in inputs.

1987), Bergson (1979), and others), we also investigate whether CES functions provide a better representation of the data than the Cobb-Douglas production function imposed in calculating the TFP estimates in Table 4.

Weitzman's basic finding was that a CES production function with a low elasticity of substitution of 0.4 fit the data better than the Cobb-Douglas, and that the hypothesis that the elasticity of substitution was one could be rejected. Bergson (1983) criticized this result, on the grounds that it implied implausibly high estimates of the marginal product of capital in earlier years. Desai (1987) concurred with Weitzman's finding for aggregate industry, but claimed that Cobb-Douglas was an adequate representation for some branches of industry.

Estimation of production functions in industrial countries is the subject of a large literature. The usual method is to estimate parameters of factor demands derived from the cost function, the dual of the production function (see Jorgenson (1983) for a survey). This is obviously inappropriate for a non-market economy like the Soviet Union. Direct estimation of production functions is usually thought to be tainted by endogeneity of the factor supplies, particularly capital; we believe this would be much less of a problem in the non-market system of the USSR. Table 5 shows elasticities of substitution estimated by nonlinear least squares (see Appendix 2 for the regressions), and recalculated TFP growth rates for 1950-87 (assuming Hicks-neutral technical progress) for subperiods with the CES form:

$$\ln(Y/L) = c1 * Time * D5059 + c2 * Time * D6069 + c3 * Time * D7079 + c4 * Time * D8087 + c5 * \ln[c6 * (K/L)^{1/c5} + (1-c6)] + c7$$

We find indeed that, with the exception of the estimates based on the Khanin data, all of the alternative estimates of Soviet output and capital growth per worker lend themselves to the CES form with low elasticities of substitution between capital and labor (significantly below one).[15] The results are less

[15]A classic article by Diamond, McFadden, and Rodriguez (1967) shows that it is in general impossible to identify separately a time-varying elasticity of substitution parameter and the bias of technical change (neutral versus labor-augmenting etc.) We identify the substitution parameter by presuming that it is constant over time and that technical change is neutral.

sharp when we use the entire sample 1928-87, where as indicated earlier the data before 1950 are volatile. Serial correlation is a problem for most of the estimates, with the significant exception of the results using our preferred Western GDP series for 1950-87.

The results with the Khanin data are intriguing because they support a story of unit elasticity of substitution and poor (though not necessarily declining) productivity growth. According to the Khanin data, growth declines mainly because capital growth slowed (see Table 1 again). Given Bergson's criticisms and the limited information about the methodology behind the Khanin data, these differing results can only point to the need for further research into Khanin's approach to see whether his work represents a valid criticism of the Western estimates. For the moment, we are forced to regard the Khanin story as unproven.[16]

The low elasticity of substitution from the other data series gives us an important insight into the lack of success of the Soviet extensive growth strategy compared to the high payoffs from capital deepening in Japan, Korea, and other market economies. The literature does not find the elasticity of substitution between capital and labor in market economies to be greatly below one (see for example, Berndt and Wood (1975) and Prywes (1983) for discussion of theirs and other results for U.S. manufacturing). A recent study estimating the elasticity parameter from the convergence behavior of the cross-sectional national per capita income data even argues that the elasticity of substitution is slightly ABOVE one (Chua (1993)). Diminishing returns to extensive growth were much sharper in the USSR than in market economies because the substitutability of capital for labor was abnormally low. In the concluding section, we will speculate why substitutability may have been low in a planned economy.

Another striking feature of Table 5 is that the implied rates of TFP growth show no significant decline between the 50s and 80s. Thus, freeing up the functional form of the production function rules

[16]We would have liked to examine the implications of the "British school" of Hanson (1984), Nove (1981), and Wiles (1982), who somewhat similar claims to Khanin's. However, we cannot do so since those researchers do not provide alternative time series for output and capital. Note that a lower estimate for the growth rate of capital over the entire period, as implied by the "British" arguments, would imply higher TFP growth but does not imply anything about the estimated elasticity of substitution that would result from using such data.

out the collapsing productivity growth explanation for declining growth: in Table 4, both extensive growth and declining productivity growth account for the overall fall in growth; in Table 5 the fault lies entirely with diminishing returns to capital.

Table 5 also shows that the level of TFP growth is more plausible after we control for the sharply falling marginal product of capital with a low elasticity of substitution. Our preferred estimates are those yielded by the Western GDP estimates in the last column in Table 5 for the 1950-87 sample. Those estimates yield a constant TFP growth rate of 1 percent per annum, in contrast to the negative TFP growth implied by the Cobb-Douglas estimates in Table 4 for the 60s through the 80s. We find a positive rate of TFP growth with falling returns to capital more plausible than a negative rate of TFP growth.

In Figure 6 we examine a second implication of the estimates in Table 5: these are estimates of the "share of capital" implied by the alternative columns in Table 5 for 1950-87, assuming marginal productivity pricing. In the graph, we present only the more reliable western data. For total GNP, the share of capital falls steadily throughout. For industrial output, the implied share of capital would have been close to one until the mid-50s, and it then would have begun a sharp decline to close to zero by 1980.

In Figure 7 we present closely related data, on the marginal product of capital implied by the CES estimates. The western GNP data imply high rates of return to capital in the early 50s, declining to about 3 percent in 1987. The 1950 marginal product of capital in industry is lower than that implied by the GDP estimates. It stays constant throughout the 50s, then declines sharply to zero by the late 70s.

The data presented in Figures 6 and 7 suggest that a market economy could not have gone through the growth process of the Soviet economy between 1928 and 1987. The very low wage shares in the early period would probably have prevented any but a subsistence wage equilibrium in those periods. The essentially zero marginal product of capital in industry (estimated using western data) by the mid-80s would have been inconsistent with equilibrium, and would have meant that investment in industry and the capital-labor ratio would have been lower.

What would have happened in the early years if there had been a market economy? One possibility is that some method--such as trade unions--would have been found to divorce factor payments from marginal productivities. Another possibility is that different technologies would have been adopted. Similarly, in the later period, there may well have been other technologies available that yielded a positive return to capital. It is also possible that if the extensive growth route had been closed off in a market economy, there would have been more incentive for Soviet entrepreneurs to attempt to improve technology.

The high capital share in the CES production functions before 1960 has one other implication we find interesting. A CES function with a high capital share acts much like a linear function of capital, so that the marginal product of capital can stay flat for as long as the capital share is high (see the line for industrial capital's marginal product in the 50s in figure 7). With a very capital-intensive production of goods, including capital goods, the Soviets were close for a while to the model of growth through rapid reproduction of capital -- described by Feldman in the 1920s as using "machines to make more machines" (see Domar (1957)).[17]

However, as the capital share begins to fall, the marginal product will begin to decline. The decline can be precipitous when the elasticity of substitution is particularly low (see the industrial marginal product in the late 50s and early 60s). While we find the extreme values of the marginal product of capital and capital's share in Figures 6 and 7 surprising, they do not logically rule out the CES form--the capital-labor ratio in a non-market economy could be driven to levels that would not be observed in a market economy.

E) COMBINING REGRESSION EVIDENCE WITH PRODUCTION FUNCTION ESTIMATES

As a final exercise, we insert the other apparent correlate of declining growth -- defense spending -- into our production function estimates (we take the midpoint of the Brada and Graves estimates in Table 3 spliced together with the Steinberg estimate for 1985-87). Specifically, we allow

[17]Rebelo (1991) shows formally that constant returns to reproducible factors in the capital goods sector is sufficient to generate a constant, sustained rate of growth even without TFP growth.

the Hicks-neutral rate of technological progress to depend linearly on the share of defense spending in GDP in the production function estimated with Western GDP and capital stock data:

$$\ln(Y/L) = c1*Time + c2*Time*(Defense\ Spending) + c3*\ln[c4*(K/L)^{1/c3} + (1-c4)] + c5$$

The results are shown in Appendix 2. We find defense spending does indeed have a significant and negative effect on the rate of increase in the total productivity term in the production function. However, the effect is not very quantitatively important: every additional 1 percent of GDP spent on defense lowered productivity growth by .07 percent. The increase over 1960-87 of 2.2 percentage points in the defense share thus would have lowered growth by .15 percentage points. Moreover, the parameters of the CES function are virtually unchanged from our earlier regression so the low substitutability, diminishing returns story still holds. We also tried equipment investment and R&D spending as independent influences on the technical progress term, but both gave insignificant results.

How do we reconcile our production function estimates with our earlier cross-section growth regression evidence using the Levine-Renelt specification? The Soviets' high capital-output ratio and low substitutability of capital for labor implies a lower derivative of growth with respect to the investment rate than in other countries with lower K-Y ratios and more substitutable capital for labor. To see this, assume zero depreciation and labor growth for simplicity and set labor $=1$ by choice of units. Assume a CES function $Y=A(\gamma K^{\rho}+1-\gamma)^{(1/\rho)}$. Growth will be given as a function of the investment ratio ($I/Y = \Delta K/Y$) as follows:

$$\Delta Y/Y = \gamma\ (I/Y)\ [\,(K/Y)\ (\gamma+(1-\gamma)K^{-\rho})\,]^{-1}$$

As is well known, a higher K/Y implies a lower marginal effect of the investment ratio on growth simply because a given investment rate translates into lower capital growth. With a unit elasticity of substitution ($\rho=0$), this is the only way that the level of capital influences the marginal effect of investment. With a less than unit elasticity of substitution ($\rho<0$), higher capital has an even stronger negative effect on the coefficient on investment in a growth equation. Although obviously not the only explanation, this is consistent with the large negative residual for the USSR -- and increasingly negative residuals over time -- in the cross-section regressions. (With only one observation, we cannot distinguish between a Soviet slope dummy on the investment coefficient and a Soviet intercept dummy.)

We conclude from our reexamination of the aggregate data that the original Weitzman story holds up. Soviet growth declined because of diminishing returns to capital accumulation, and not because of a slowdown in TFP growth. The average growth performance was poor when we take into account the rapid capital growth and high education levels. The general extensive growth hypothesis of the literature on Soviet growth is not sufficient explanation by itself, because in a comparative context we find that Soviet extensive growth was not that unusual. It was the low substitutability of capital for labor, rather than extensive growth per se, that was the fatal weakness of the Soviet development strategy.

II. Republican Results -- Capital Growth and Low TFP Growth

The republican time series cover the period 1970-90, and provide detailed data to describe the economic decline in the final years of the Soviet system, by republic and by sector. The data are for NMP. Table 6 shows least-squares estimates of real NMP growth per worker in the USSR and the republics, overall, and by branch of industry, for the years 1970-90. Growth rates in the Central Asian republics were well below those in the rest of the Soviet Union, with Belarus and Georgia having the highest rates of output growth. Among the Central Asian republics, Turkmenistan experienced negative growth of per worker output over the 20-year period; the growth rate of per worker output of Kyrgyzstan, the most rapidly growing of the Central Asian republics was nonetheless a full percentage point below that of the slowest-growing of the other republics, Azerbaijan. Growth performance in the Baltics does not stand out relative to the Soviet average.

Across branches, output per worker grew most rapidly in industry, and at a negative rate in agriculture; output growth in the service sectors, transport and communications, and trade and procurement, was positive. Belarus shows the highest rate of growth of output per worker in industry; Lithuania, where aggregate growth was relatively low, also shows rapid output growth in industry. The slow growth of output in the Central Asian republics clearly owes much to the poor performance of agriculture in these relatively agricultural republics.

Table 7 shows estimates of TFP growth (computed assuming a 0.4 capital share for all sectors and a Cobb-Douglas form) by sector and by republic.[18] Judging by TFP growth, industry did relatively better than other sectors in the European USSR (just as industrial productivity growth is usually higher than other sectors in the West), while agriculture was a disaster everywhere. Transport and communications did well in the border regions of Belarus and the Baltics. Productivity growth in construction and in trade is uneven and generally close to zero. Central Asia is an almost unrelieved tale of woe for all sectors, with Kyrgyzstan standing out again as having the best performance in that region.

For the entire material sector's TFP growth, Georgia and Belarus did the best over 1970-90, Armenia, Azerbaijan, Latvia, and Estonia, the next best, and Central Asia the worst. The relative success of Belarus and Georgia was due entirely to industry, with productivity performance in agriculture still disastrous, and performance in the transport/communications/construction sectors generally poor.

The relative performance of the republics shown here is broadly consistent with previous studies focusing on earlier periods. The ranking of TFP growth by republic for the period 1960-75 in Koropeckyj (1981) is similar to that in Table 7: Belarus is at the top, and Central Asia at the bottom. Whitehouse (1984) presents similar findings for 1961-70: Belarus and Georgia are third and fourth in productivity growth (Latvia and Estonia are at the top), with Central Asia again firmly ensconced at the bottom. The bad Central Asian outcome is well known in the literature (for example, Rumer(1989)).

A) EXPLAINING RELATIVE PERFORMANCE WITHIN THE USSR

Growth by republic is correlated with some of the same factors -- human capital, initial income, and population growth -- that have been singled out in recent cross-sectional growth regressions (Barro (1991), Barro and Lee (1993), Levine and Renelt (1992)). We first examine simple correlations between estimated productivity growth over the period and these factors, and then present the results of a multiple regression.

[18] We are rather embarrassed to resort to the Cobb-Douglas form for the republican sectors after rejecting it for the Soviet Union as a whole in section 1. The republican data series are too short to lend themselves to CES estimation of individual production functions. The Cobb-Douglas TFP growth rates are still useful descriptive statistics.

Figure 8 shows the association between one measure of human capital -- the percentage of specialists with higher education per capita -- and productivity growth. The negative productivity growth of the Central Asian republics is associated with a low level of higher education, while the relatively high growth of Georgia, Latvia, Estonia, and Armenia is strikingly correlated with a high proportion of highly-trained specialists. Belarus is well above the implied regression line, reflecting its relatively low share of higher education specialists. Similarly, the Central Asian republics' poor record is associated with rapid population growth (Figure 9).

We have also run a standard cross-sectional growth regression for the fifteen republics. While we have not found republican data to match the international data in the Levine-Renelt regression we presented in Section 1, we can do a similar cross-section across republics. The results, presented in Table 8, are similar to those obtained in the standard cross-country regressions. The educational variable has a positive coefficient, while those on initial income (relative to the Soviet average) and population growth are negative. The coefficient on population growth is much larger than is normal in cross-country regressions.

The coefficient on initial relative income implies that the rate of convergence between the Soviet republics is over 4 percent per year (taking the derivatives at the Soviet average). This implies a rate of internal convergence for the Soviet republics considerable faster than the convergence coefficients found by Barro and Sala i Martin (1992), which are around 2 percent per annum for both US states and a sample of 98 countries. Chua (1993) shows that convergence is more rapid the lower is the elasticity of substitution between capital and labor. The rapid convergence of Soviet republics to each other (though admittedly based on the tenuous evidence of 15 observations) is yet another confirmation of the stronger force of diminishing returns (and possibly the lower elasticity of substitution) in the Soviet Union compared to market economies.[19]

[19] An alternative explanation for faster convergence among Soviet republics is that Soviet policymakers placed more emphasis on regional redistribution than did Western policymakers.

B) SECTORAL PATTERNS AND PRODUCTIVITY GROWTH IN THE REPUBLICS

Table 7 shows enormous variations in productivity growth between sectors and republics; in this section, we examine whether these variations are related to degrees of sectoral distortion. It is well known that the Soviet Union (and socialist economies in general) had distorted sectoral structures of production (Ofer (1987)). Ofer compared the sector employment and output shares in the Soviet Union to those that would have been expected for a country of its per capita income level, using the patterns of sectoral shares and income established by Chenery, Robinson, and Syrquin (1986). He showed that the Soviet services sector was smaller than normal, Soviet agriculture was larger than normal, and Soviet industry roughly normal for a country of its per capita income level. The atrophied service sector has been documented also with recent data (Easterly, de Melo, and Ofer (1994)).

Table 9 shows the difference between the sectoral shares of employment that would have been predicted by the republics' respective per capita incomes and their actual sectoral shares. The per capita incomes are derived from the estimates of relative incomes by the World Bank, and then applied to the per capita income for the Soviet Union as a whole in Bergson (1991b). The employment shares of the comparators are taken from International Labor Organization (various years) for a sample of about 70 developing and developed countries. We see the basic pattern confirmed: agriculture is larger than average in all of the republics for their respective income levels, and trade is smaller. Transport is larger than expected in the republics. Industry and construction do not diverge as sharply from the expected patterns.[20]

Are the sector imbalances related to relative productivity growth performance? The answer is yes -- sectors that were "too large" had poor productivity growth. Figure 10 shows a scatter of productivity growth 1970-90 for the 5 sectors and 15 republics against the sectoral employment

[20]These measures are extremely crude and obviously reflect other factors besides "distortions". For example, the fertile soils of Ukraine and Moldova might imply a larger agriculture share than per capita income alone would predict. The variation in employment shares in the international data set is enormous and the residuals shown in Table 10 are generally not statistically significant in OLS regressions (with the exception of many of the deviations in republican trade shares). The sectoral employment deviations nevertheless remain useful descriptive statistics for the nature of the republican economies. Note that employment statistics cover the entire economy, and so are preferable to NMP shares that only cover the material sector (not to mention the pricing problems).

deviations in 1970. Republican agricultural sectors that were above the predicted employment shares also had poor (negative) TFP growth, while industrial and trade sectors below predicted shares of employment had positive TFP growth. The slope coefficient in figure 10 is -.11 (ten percentage points excess employment share lowers TFP growth in that sector by 1.1 percentage points). The coefficient is strongly significant. This result is reminiscent of the finding in market economies that distorted sectoral price incentives or other measures of departure from comparative advantage are negatively related to growth (Barro (1991), Easterly (1993), Edwards (1989), Fischer (1993)).

III. Conclusion: interpreting the results on Soviet Growth

Our results confirm and update the results of Weitzman (1970) on the low Soviet elasticity of substitution between capital and labor, which combined with the Soviet attempt at extensive growth, is sufficient to explain the decline of Soviet growth. The natural question to ask is why Soviet capital-labor substitution was more difficult than in Western market economies, and whether this difficulty was related to the Soviets' planned economic system.

Recent work on models of endogenous economic growth stresses the notion of a broad concept of capital, including human capital, organizational capital, and the stock of knowledge, which can substitute easily for raw labor and perhaps replace it altogether (Rebelo 1991, Jones and Manuelli 1992, Parente and Prescott 1991). Conversely, one possible explanation for the Soviets' substitution problems would be that, under an autocratically directed economic system, they accumulated a narrow rather than a broad range of capital goods. Some forms of physical or human capital that were missing would have been market-oriented entrepreneurial skills, marketing and distributional skills, and information-intensive physical and human capital (because of the restrictions on information flows). It is more difficult to substitute more and more drill presses for a laborer than it is to substitute a drill press plus a computerized inventory and distribution system for a laborer. There is nothing that explicitly supports this conjecture in our results, but it is an interesting direction for further research.

The other message from our results could be that Soviet-style stagnation awaits other countries that have relied on extensive growth, a point that has been made forcefully for those extensive growers, the East Asian Tigers, in several articles by Young (1992, 1993a, 1993b). After all, the USSR had its period of rapid growth in the 30s through 50s when it appeared to be following a linear output-capital production function, as we have shown. If East Asian capital-output ratios keep rising until they reach the extreme Soviet levels, they too could experience a drastic slowdown. Even if diminishing returns are weaker in the East Asian economies (if, following our conjecture, they have been accumulating a broader range of capital goods and experiencing higher substitutability between capital and labor), diminishing returns would still eventually cause a growth slowdown. The Soviet experience can be read as a particularly extreme dramatization of the long-run consequences of extensive growth.[21]

The cross-section results on republics, although based on a small number of datapoints, support the idea that some of the same factors that are argued to determine growth in the recent empirical cross-section literature -- human capital, population growth, initial income, sectoral distortions -- also mattered under Soviet central planning. Our results with the Soviet Union in the international cross-section growth regression indicate that the planned economic system itself was disastrous for long-run economic growth in the USSR. While this point may now seem obvious, it was not so apparent in the halcyon days of the 1950s, when the Soviet case was often cited as support for the neoclassical model's prediction that distortions do not have steady-state growth effects. Since a heavy degree of planning and government intervention exists in many countries, especially in developing ones, the ill-fated Soviet experience continues to be of interest.

[21] Weitzman (1990) describes Soviet growth (as analyzed by Ofer (1990)) as the best application of the Solow neoclassical model ever seen.

BIBLIOGRAPHY

Acland-Hood, Mary. 1987. "Estimating Soviet Military R&D Spending" in Jacovsen, ed., The Soviet Defence Enigma page 136-147.

Anderson, Barbara and Brian Silver (1990). "Trends in Mortality of the Soviet Population", Soviet Economy. Vol. 6, No. 3, pp. 191-251.

Barro, Robert J. (1991). "Economic Growth in a Cross Section of Countries", Quarterly Journal of Economics, 106, 2 (May), 407-444.

----- and Jong-wha Lee (1993), "International Comparisons of Educational Attainment", Journal of Monetary Economics 32(3), 363-393.

Barro, R.J. and X. Sala-i-Martin. 1992. "Convergence", Journal of Political Economy 100, 223-251.

Benhabib, Jess and Mark Spiegel. 1993. "The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-country and Regional U.S. Data", forthcoming, Journal of Monetary Economics.

Berndt, Ernst and David O. Wood. 1975. "Technology, Prices, and the Derived Demand for Energy", The Review of Economics and Statistics, Vol. LVII, No. 3, 259-268.

Bergson, Abram (1979). "Notes on the Production Function in Soviet Postwar Industrial Growth", Journal of Comparative Economics, 3, 2 (June), 116-126.

----- (1983). "Technological Progress" in A. Bergson and H. Levine (eds), The Soviet Economy: Toward the Year 2000. London: Allen & Unwin.

----- (1987a). "On Soviet Real Investment Growth", Soviet Studies, 39, 3, (July), 406-424.

----- (1987b). "Comparative Productivity: The USSR, Eastern Europe, and the West. American Economic Review, vol. 77, no. 3, pp. 342-357.

----- (1991a). "Real National Income Measurement In Soviet Perspective", paper prepared for the Bureau of Labor Statistics (BLS) and Eurostat conference on economic statistics for Economies in Transition. Washington DC, February.

----- (1991b). "The USSR Before the Fall: How Poor and Why", Journal of Economic Perspectives, 5, 4 (Fall), 29-44.

Berliner, Joseph S. (1976). The Innovation Decision in Soviet Industry. Cambridge, MA: MIT Press.

Birdsall, Nancy and Changyong Rhee, 1993, "Does Research and Development Contribute to Economic Growth in Developing Countries?", Policy Research Working Paper 1221 (World Bank: Washington D.C.)

Brada, Josef C. and Ronald L. Graves. "Slowdown in Soviet Defense Expenditures." Southern Economic Journal. vol. 54 pp. 969-84, 1988

Brooks, Karen McConnell. 1983. "Productivity in Soviet Agriculture". in D. Gale Johnson and Karen Brooks, eds., Prospects for Soviet Agriculture in the 1980s.

Chenery, Hollis, Sherman Robinson and Moshe Syrquin (1986). Industrialization and Growth. New York: Oxford University Press.

Chua, Hak. 1993. "Factor Substitution and Slow Convergence", Economic Growth Center Discussion Paper, Yale University.

CIA (1982), USSR: Measures of Economic Growth and Development (Washington DC: US Government Printing Office)

CIA (various years), Handbook of Economic Statistics (Washington DC: US Government Printing Office)

Coe, David T. and Elhanan Helpman (1993), "International R&D Spillovers", NBER Working Paper No. 4444, August.

De Gregorio, Jose. 1992. "Economic Growth in Latin America" Journal of Development Economics, Vol. 39 No.1, pp. 59-85.

De Long, J. Bradford and Lawrence Summers. 1991. "Equipment, Investment, Relative Prices, and Economic Growth." Quarterly Journal of Economics, May 1991, Vol CVI, Issue 2, pp. 445-502.

_______ and _______ (1992). "Equipment Investment and Economic Growth: How Robust is the Nexus?" Brookings Papers on Economic Activity, 2, 157-211.

_______ and _______ (1993). "How Strongly Do Developing Countries Benefit from Equipment Investment?", Journal of Monetary Economics 32, 395-415.

Desai, Padma (1976). "The Production Function and Technical Change in Postwar Soviet Industry: A Reexamination", American Economic Review, 66, 3 (June), 372-381.

---- (1987). The Soviet Economy, Problems and Prospects. Oxford: Basil Blackwell.

---- (1992). "Reforming the Soviet Grain Economy: Performance, Problems, and Solutions", American Economic Review, vol. 82, no. 2, pp. 49-54

Diamond, Douglas, Lee Bettis, and Robert Ramsson, "Agricultural Production" in A. Bergson and H.S. Levine, eds., The Soviet Economy: Toward the Year 2000, Allen & Unwin, Boston.

Diamond, Peter, Daniel McFadden, and Miguel Rodriguez, 1967, "Measurement of the Elasticity of Factor Substitution and Bias of Technical Change", in...

Domar, Evsey (1957). "A Soviet Model of Growth", in Essays in the Theory of Economic Growth. New York: Oxford University Press.

Easterly, William, Martha de Melo, and Gur Ofer. 1994. "Services as a Growth-Promoting Sector in the Former Soviet Union", in Mario Blejer, ed. Macroeconomic and Structural Aspects of Russian Economic Reform, International Center for Economic Growth.

Easterly, William. 1993. "How Much Do Distortions Affect Growth?" Journal of Monetary Economics 32: 187-212.

_____, Michael Kremer, Lant Pritchett, and Lawrence H. Summers, 1993, "Good policy or good luck? Country growth performance and temporary shocks", Journal of Monetary Economics 32, 459-483.

Edwards, Sebastian. 1992. "Openness, Outward Orientation, Trade Liberalization, and Economic Performance", NBER working paper.

Elias, Victor J. Sources of Growth: a Study of Seven Latin American Economies, International Center for Economic Growth, 1992.

Ericson, Richard E. (1990a). "The Soviet Statistical Debate: Khanin vs TsSU", in H.S. Rowen and C. Wolf, Jr. (eds) The Impoverished Superpower. San Francisco, CA: ICS Press.

Feschbach, Murray. 1983. "Population and Labor Force" in A. Bergson and H.S. Levine, eds., The Soviet Economy: Toward the Year 2000, Allen & Unwin, Boston.

Fischer, Stanley (1992). "Russia and The Soviet Union: Then and Now", NBER Conference on Transition in Eastern Europe.

_______. (1993) "The Role of Macroeconomic Factors in Growth", Journal of Monetary Economics 32 (3), 485-511.

Gomulka, S. and M. Schaffer "A New Method of Long-Run Growth Accounting, with Applications to the Soviet Economy 1928-87 and the US economy 1949-78. Centre for Economic Performance Discussion Paper 14. January 1991.

Hanson, Phillip (1984). "New Evidence about Soviet Investment", Radio Liberty Research, 13 September.

Harrison, Mark (1993). "Soviet Economic Growth Since 1928: The Alternative Statistics of G.I. Khanin", Europe-Asia Studies, 45,1, pp. 141-167.

Hewitt, Daniel (1993). "Military Expenditures 1972-1990, The Reasons Behind the Post 1985 Fall in World Military

Spending, IMF WP/93/18

International Labor Organization (various years), Handbook of Labor Statistics

IMF, World Bank, OECD, and EBRD. 1991. A Study of the Soviet Economy (3 volumes).

Jones, L. and R. Manuelli, "A Convex Model of Equilibrium Growth", Journal of Political Economy 98, 1008-1038.

Joint Economic Committee (1990), Measures of Soviet GNP (U.S. Government Printing Office: Washington D.C.)

Jorgensen, Dale. 1986 "Econometric Methods for Modeling Producer Behavior", in Z. Griliches and M. Intriligator, Handbook of Econometrics, Vol. 3, Amsterdam: North-Holland.

Judson, Ruth. 1994. "Do Low Human Capital Coefficients Make Sense? A Puzzle and Some Answers", mimeo, Department of Economics, MIT.

Kellogg, Robert L. "Inflation in Soviet Investment and Capital Stock data and its impact on measurement of total factor productivity", CIA Office of Soviet Analysis, May 1989.

Khanin, G. 1988. "Ekonomicheskii Rost: Al'ternativnaia Otsenka", Kommunist, (No. 17)

Kim, Jong-Il and Lawrence J. Lau, 1993. "The Sources of Economic Growth of the East Asian Newly Industrialized Countries", Stanford University Mimeo.

King, Robert and Ross Levine. (1994). "Capital Fundamentalism, Economic Development, and Economic Growth" , forthcoming, Carnegie-Rochester Series on Public Policy, forthcoming.

King, Robert and Sergio Rebelo (1993), "Transitional Dynamics and Economic Growth in the Neoclassical Model", American Economic Review, September, Vol. 83, No. 4, pp. 908-931.

Kingkade, W.W. (1987) "Demographic Trends in the Soviet Union", in Joint Economic Committee, Gorbachev's Economic Plans, Volume 1, U.S. Government Printing Office, Washington D.C.

Koropeckyj, I.S. (1981). "Growth and Productivity" in I.S. Koropeckyj and Gertrude Schroeder (eds), Economics of Soviet Regions. New York: Praeger.

Landau, Daniel. 1993. "The Economic Impact of Military Expenditures". Policy Research Working Paper 1138, World Bank.

Levine, Ross and David Renelt (1992). "A Sensitivity Analysis of Cross-Country Growth Regressions", American Economic Review, 82, 4 (Sept), 942-963.

Lichtenberg, Frank R., "R&D Investment and International Productivity Differences," NBER Working Paper #4161, September 1992.

A. Maddison, The World Economy in the 20th Century. Development Center of the Organization for Economic Cooperation and Development, Paris, 1989

Marer, Paul, Janos Avray, John O'Connor, Martin Schrenk, and Daniel Swanson, 1992, Historically Planned Economies. A Guide to the Data, World Bank: Washington D.C.

Millar, J.R. and E. Clayton. 1987.Quality of life: subjective measures of relative satisfaction, in J.R. Millar, ed. Politics, work, daily life in the USSR, Cambridge University Press.

Moorsteen, Richard H. and Raymond P. Powell (1966). The Soviet Capital Stock, 1928-1962. Homewood, IL: Irwin.

Nehru, Vikram and Ashok Dhareshwar (1993), "A New Database on Physical Capital Stock: Sources, Methodology, and Results." Revista de Analisis Economico Vol. 8, No. 1, 37-59.

Nove, Alec (1981). "A Note on Growth, Investment, and Price Indices", Soviet Studies, 23, 1 (Jan), 143-145.

Ofer, Gur (1987). "Soviet Economic Growth: 1928-85", Journal of Economic Literature, 25, 4 (Dec), 1767-1833.

----- (1990). "Macroeconomic Issues of Soviet Reforms", NBER Macroeconomic Annual, 297-339.

Parente, Stephen L., and Edward C. Prescott, 1991. "Technology Adoption and Growth", NBER Working Paper No. 3733.

Powell, Raymond P. (1968) "The Soviet Capital Stock and Related Statistical Series for the War Years", The Economic Growth Center, Yale University.

_____(1963). "Industrial Production" in Abram Bergson and Simon Kuznets, eds., Economic Trends in the Soviet Union, Cambridge MA: Harvard University Press.

Prywes, Menahem. 1983. "A Nested CES Approach to Capital-Energy Substitution", Federal Reserve Bank of New York.

Rebelo, Sergio (1991). "Long-Run Policy Analysis and Long-Run Growth", Journal of Political Economy, 99, 3 (June), 500-521.

Romer, Paul (1990). "Capital Accumulation in the Theory of Long-Run Growth", in R. Barro (ed), Modern Business Cycle Theory. Cambridge, MA: Harvard University Press.

________. (1989). "What Determines theRate of Growth and Technical Change?", World Bank PRE Working Paper #279, September 1989.

Rumer, Boris Z. (1989). Soviet Central Asia, A Tragic Experiment. Boston, MA: Unwin Hyman.

Solow, Robert M. (1956). "A Contribution to the Theory of Economic Growth", Quarterly Journal of Economics, 70, 1 (Feb), 65-94.

Summers, Robert and Alan Heston (1991). "The Penn World Table (Mark 5): An Expanded Set of International Comparisons 1950-88", Quarterly Journal of Economics CVI, 369-406.

Steinberg, Dmitri. 1987. "Estimating Total Soviet Military Expenditures: an Alternative Approach Based on Reconstructed Soviet National Accounts." in Jacobsen, ed., The Soviet Defence Enigma

Treml, Vladimir G. 1991."Alcohol Abuse".in Jones, Connor and Powell, eds. Soviet Social Problems

UNESCO (1975), UNESCO Statistical Yearbook (United Nations: New York)

Weitzman, Martin L. (1970). "Soviet Postwar Economic Growth and Capital-Labor Substitution", American Economic Review, 60, 5 (Dec), 676-692.

----- (1983) "Industrial Production" in A. Bergson and H.S. Levine, eds., The Soviet Economy: Toward the Year 2000, Allen & Unwin, Boston.

----- (1990). "Comment", NBER Macroeconomics Annual, 339-342

Whitehouse, F. Douglas (1973). "Demographic Aspects of Regional Economic Development in the USSR" in V.N. Bandera and Z.L. Melnyk (eds), The Soviet Economy in Regional Perspective. New York: Praeger.

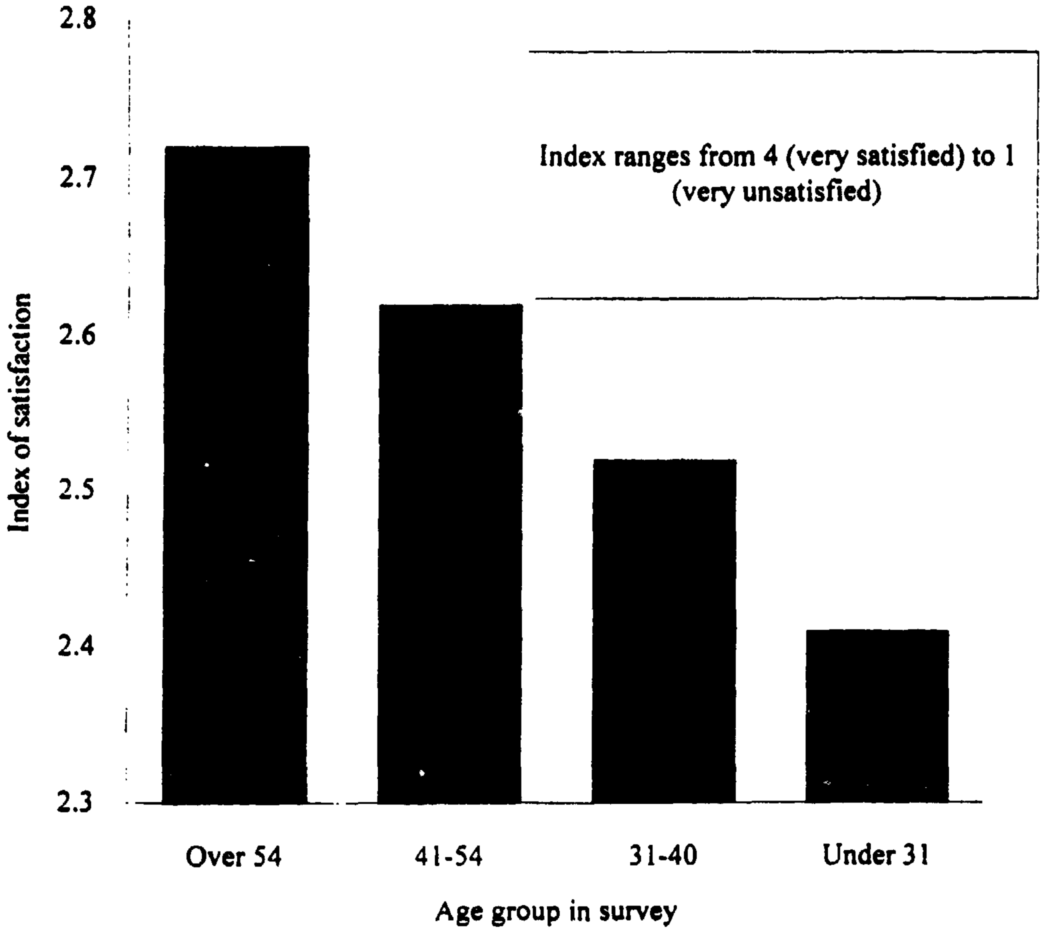
Wiles, Peter (1982). "Soviet Consumption and Investment Prices and the Meaningfulness of Real Investment", Soviet Studies, 24, 2 (April), 289-295.

Young, Alwyn. 1993b,"The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience", mimeo MIT

__________, 1993a, "Lessons from the East Asian NICs: A Contrarian View", forthcoming, European Economic Review.

__________, 1992, "A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore", In Olivier J. Blanchard and Stanley Fischer, eds., NBER Macroeconomics Annual 1992, Cambridge MA: MIT Press.

Figure 1: Index of satisfaction with standard of living in USSR reported in survey of emigres, 1983



Source: Millar and Clayton (1987)

Figure 2: Male life expectancy at birth: USSR and world median

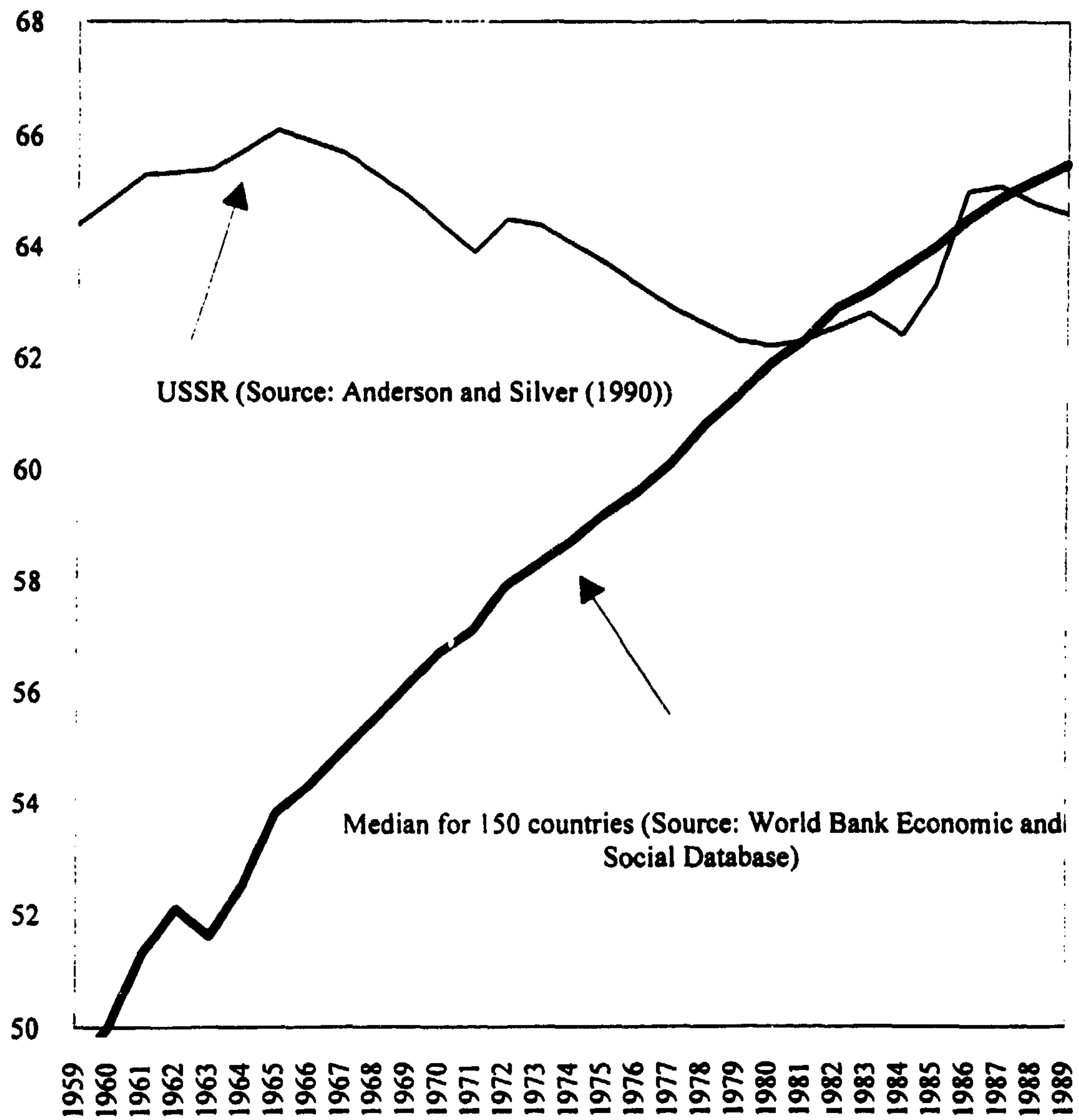
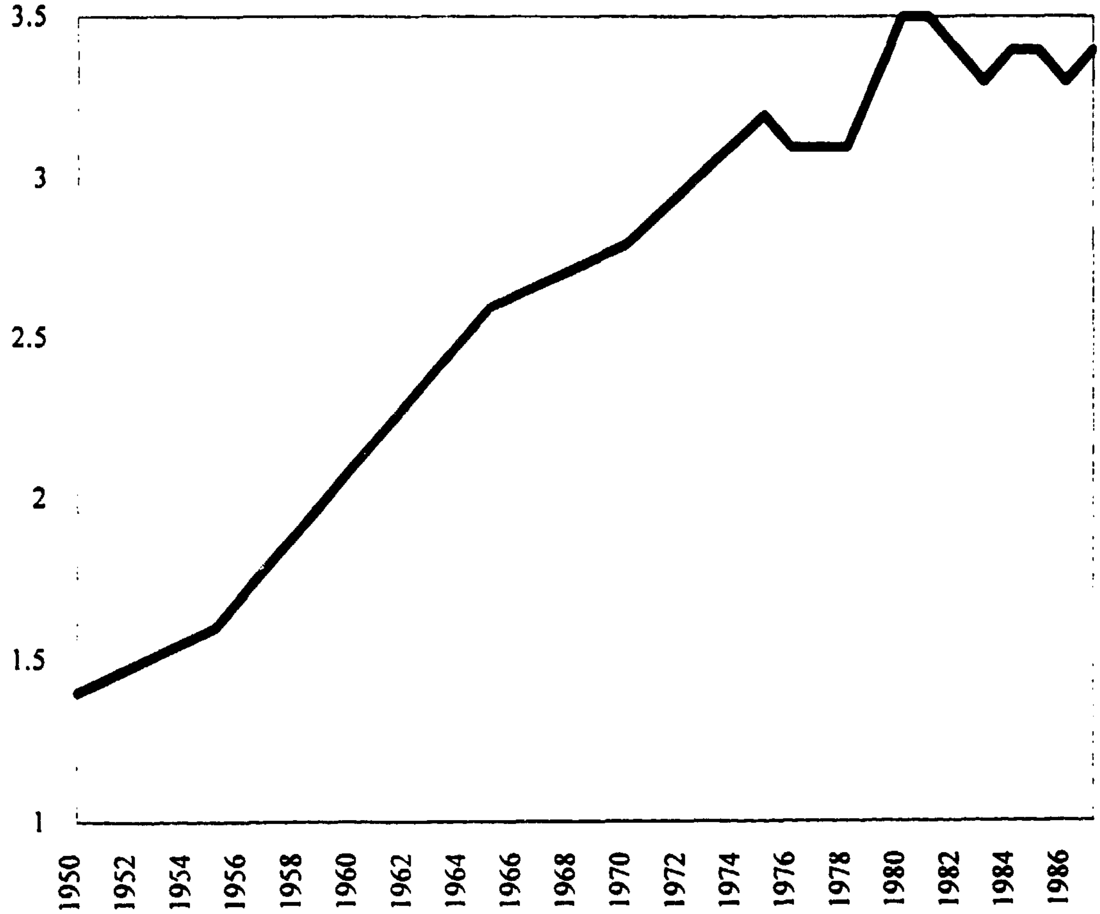
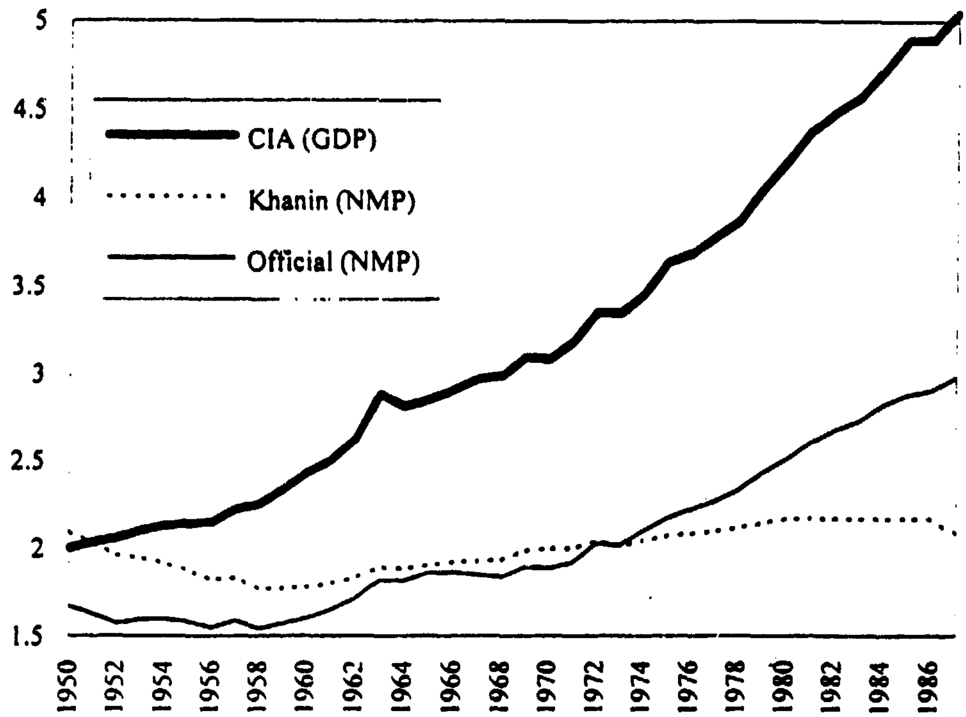


Figure 3: Soviet research and development expenditures as percent of GDP



Source: Joint Economic Committee (1990)

Figure 4: Capital-output ratios, Alternative Estimates



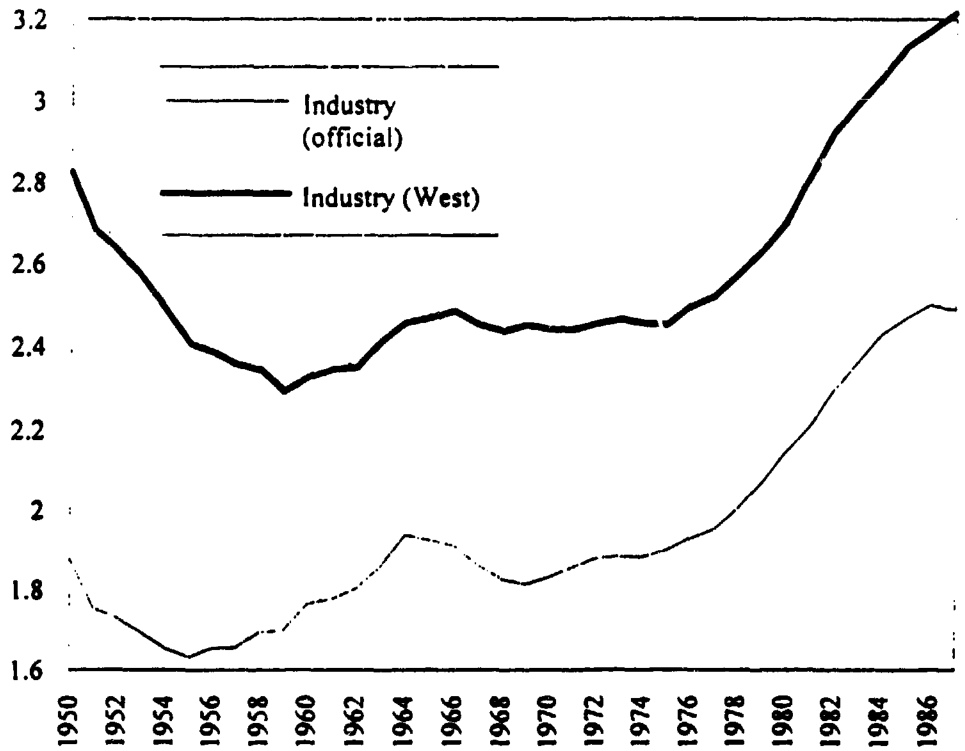
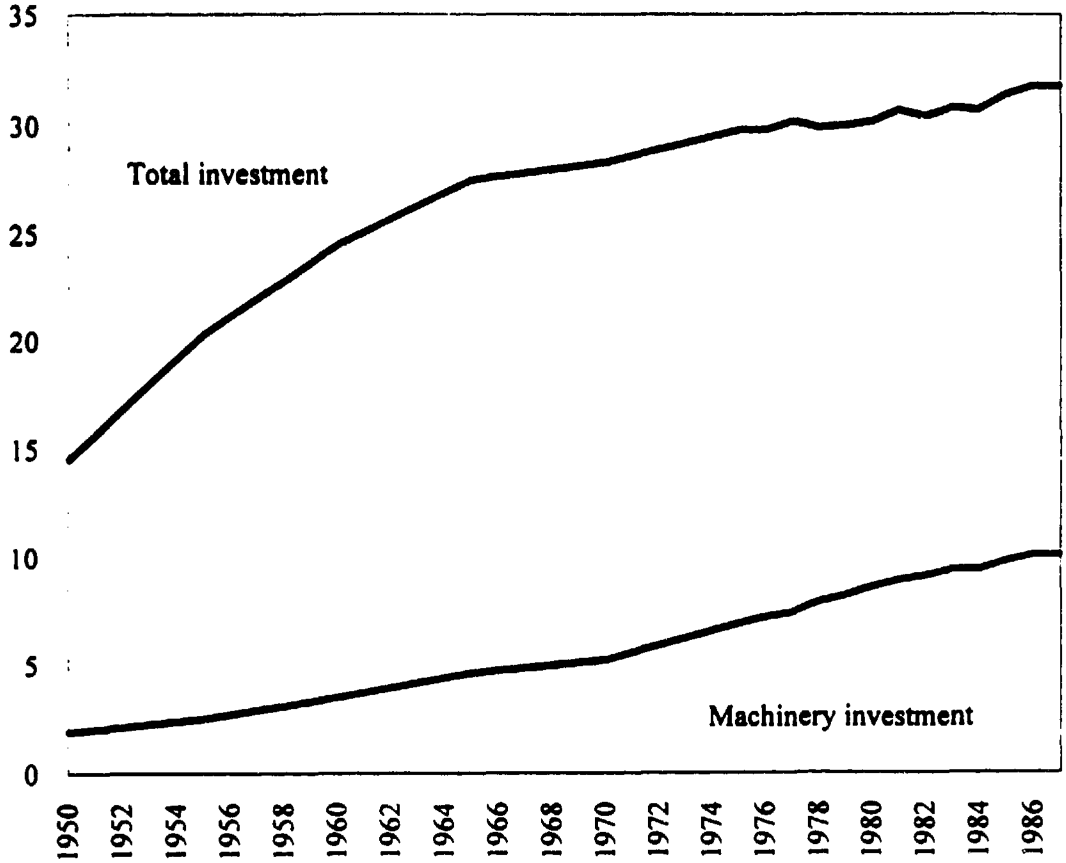


Figure 5: Shares of total investment and machinery investment in Soviet GNP



Source: Joint Economic Committee (1990)

Figure 6: Share of capital in output if marginal product pricing were observed, industry and total economy

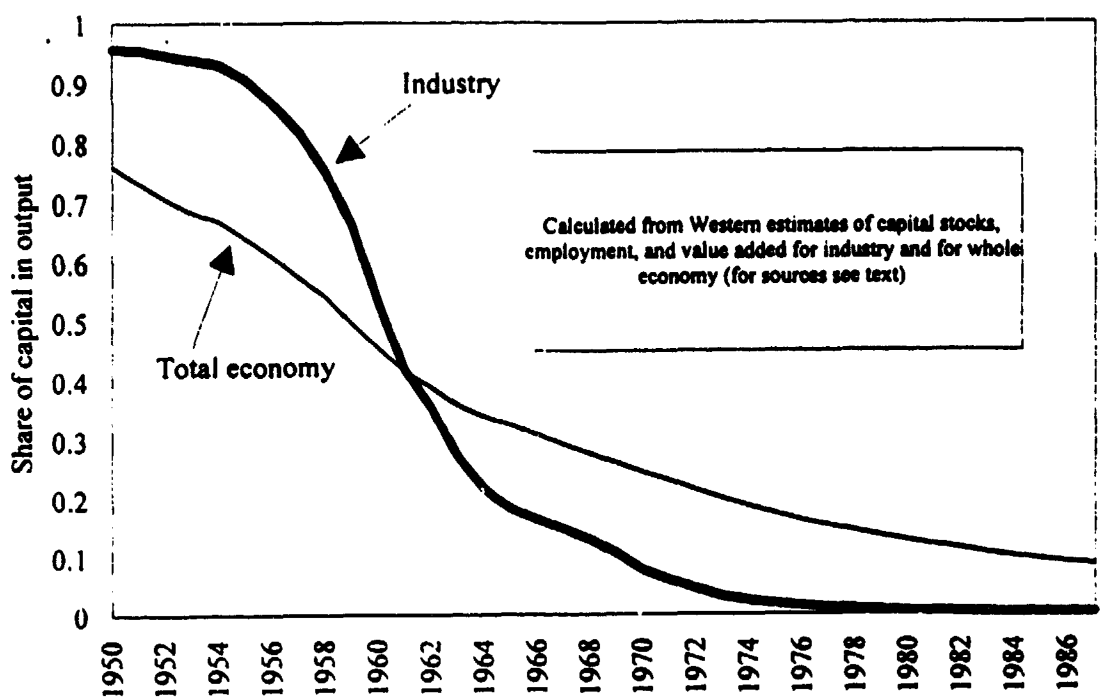


Figure 7: Marginal products of capital in industry and total economy, calculated from regressions on Western data

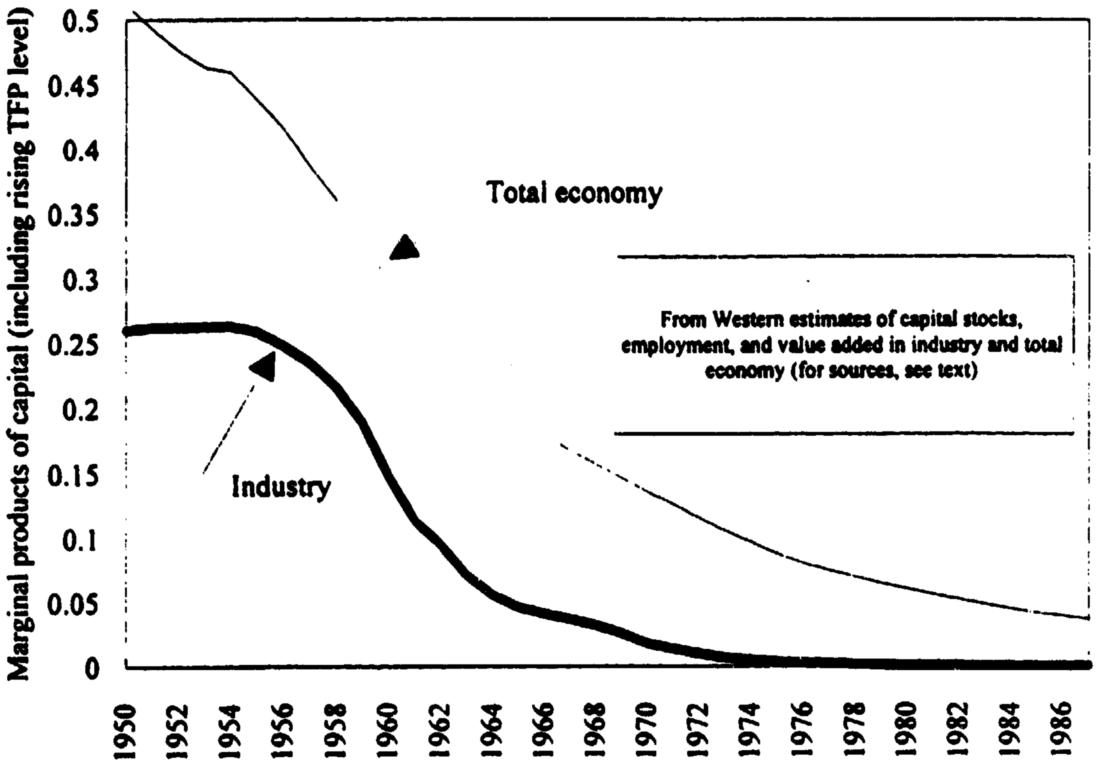


Figure 8: Growth and Human Capital, Soviet Republics

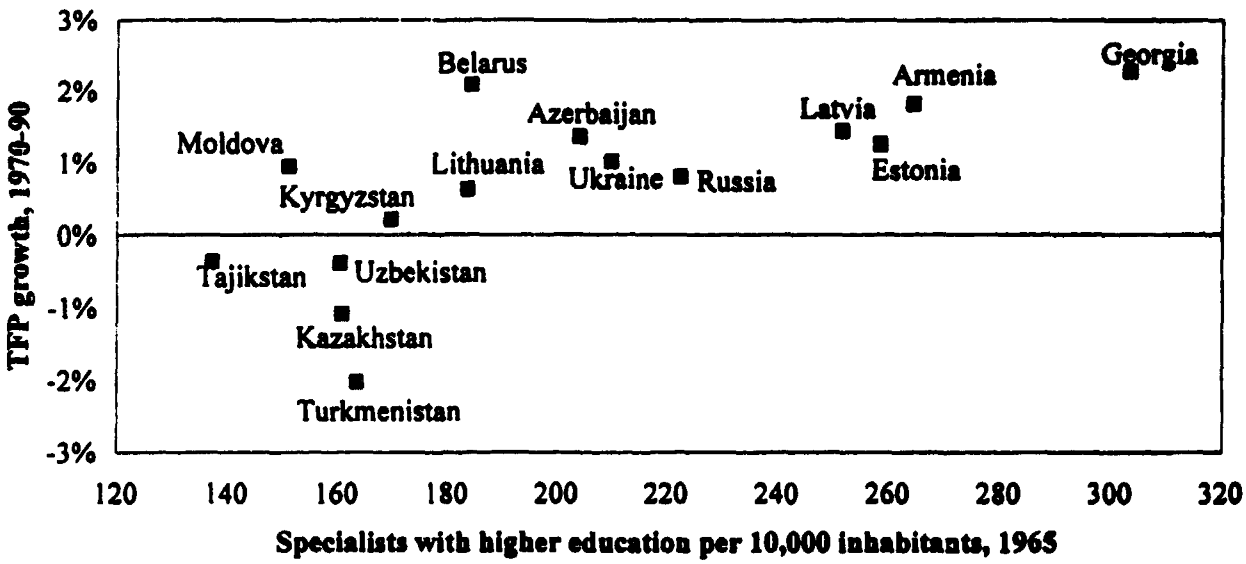


Figure 9: Growth and Population Growth, Soviet Republics

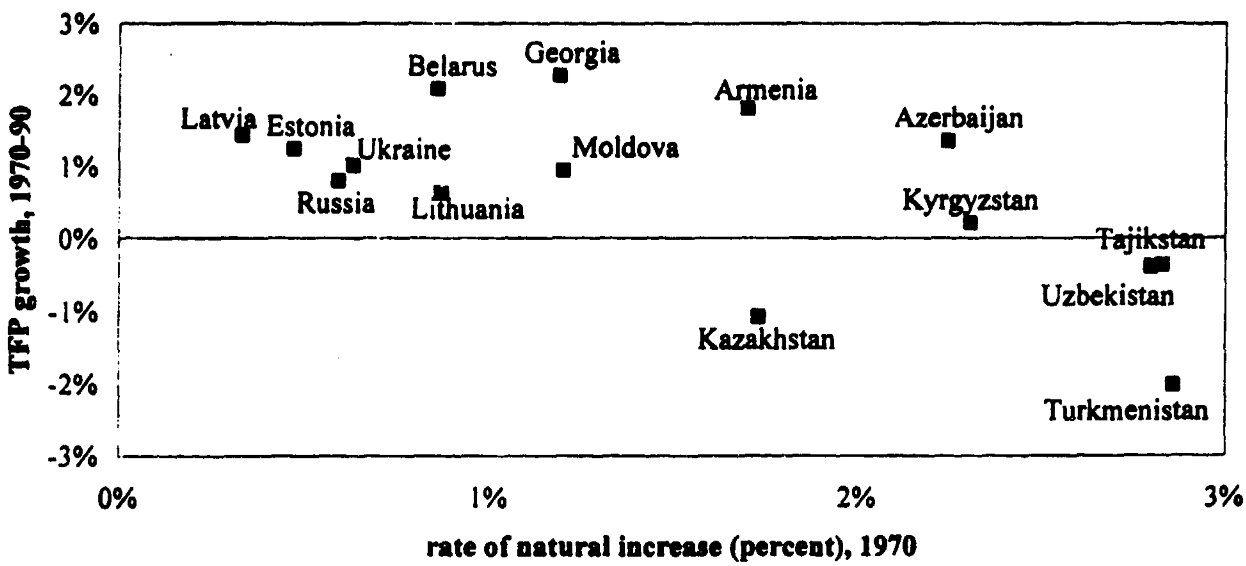


Figure 10: Sectoral employment shares and TFP growth, 5 sectors and 15 republics

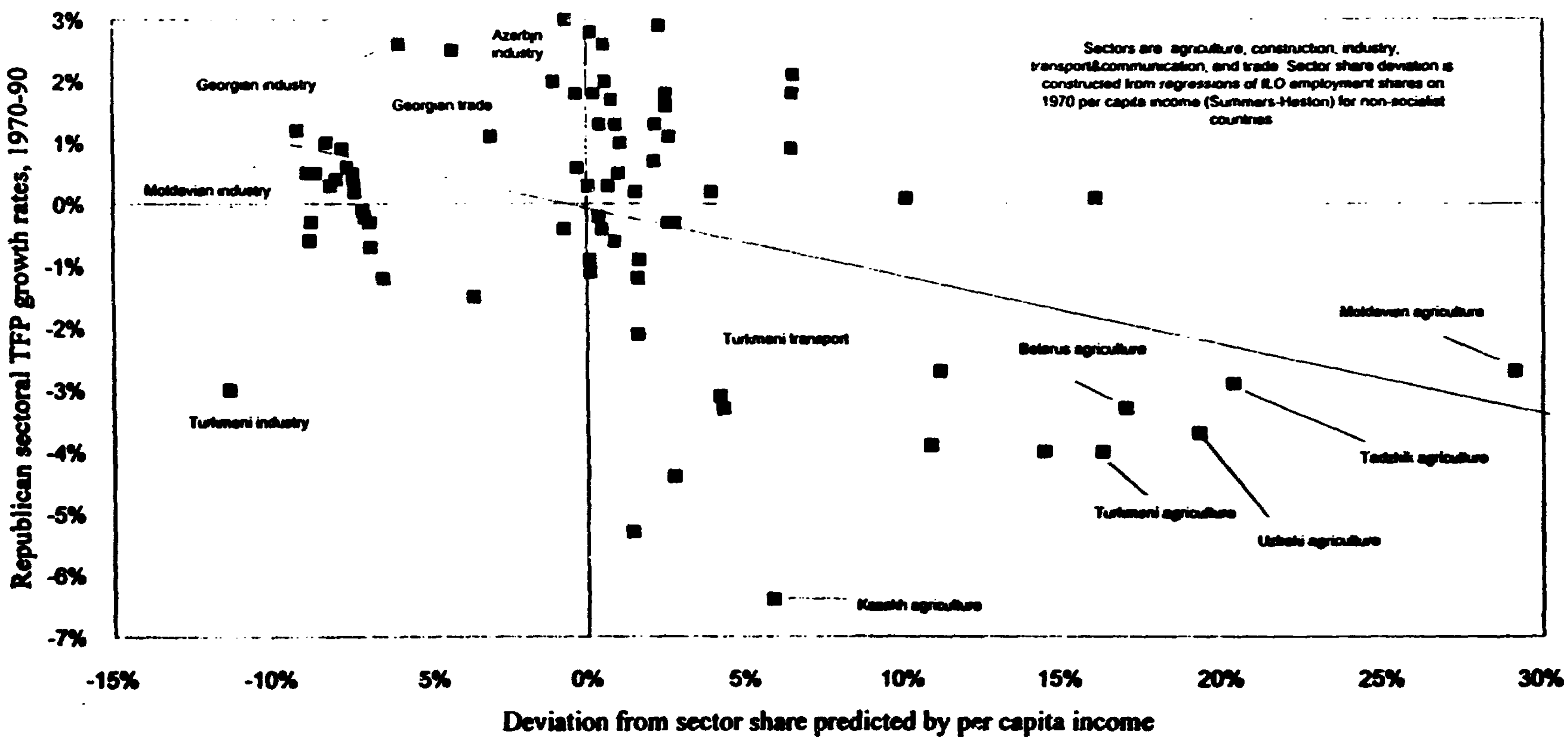


Table 1: Soviet Growth Data, 1928-87

Period	Industry, official	Industry, Western	Material sectors, Khanin	Material sectors, official	Total economy, Western
Growth rates of output per worker, alternative estimates					
1928-87	6.3%	3.4%	2.1%	6.0%	3.0%
1928-39	12.5%	5.0%	0.9%	11.4%	2.9%
1940-49	0.1%	-1.5%	-1.0%	2.1%	1.9%
1950-59	8.9%	6.2%	5.3%	8.3%	5.8%
1960-69	5.7%	2.8%	2.7%	5.4%	3.0%
1970-79	5.2%	3.4%	1.2%	4.1%	2.1%
1980-87	3.4%	1.5%	0.2%	3.0%	1.4%
Growth rates of capital per worker, alternative estimates					
1928-87	6.2%	3.2%	2.3%	6.1%	4.9%
1928-39	11.9%	6.5%	5.9%	8.7%	5.7%
1940-49	1.5%	-0.1%	-1.3%	2.7%	1.5%
1950-59	8.0%	3.9%	3.5%	7.7%	7.4%
1960-69	6.1%	3.4%	3.8%	7.1%	5.4%
1970-79	6.3%	4.1%	1.9%	6.8%	5.0%
1980-87	5.6%	4.0%	-0.1%	5.3%	4.0%

Note: growth rates ar: logarithmic least-squares estimates.

Table 2: The Soviet Union in the Levine-Renelt (1992) Growth Regression, 1960-89

	Per capita growth, 1960-89	*Per capita income, 1960 (Summers - Heston PPP)*	*Population growth,1960-89*	*Secondary enrollment, 1960*	*Investment ratio to GDP, 1960-89*	*Growth residual*
Average for sample excluding Soviet Union	2.00	1792	2.07	21%	21%	
Soviet Union	2.36	2796	1.05	58%	29%	-2.34
Rank of Soviet Union in sample (out of 103 observations)	45	24	81	10	7	97

Sources: Data for all countries except Soviet Union from Levine and Renelt (1992).
Soviet data: Per capita growth--Western GDP described in text, updated to 1988-89 with Marer et al. (1992)
Per capita income--Bergson(1991b) for 1985 PPP, backcast to 1960 with per capita growth in first column
Population growth: Feschbach (1983), Kingkade (1987), IMF et al. (1991), Marer et al. (1992)
Secondary education: UNESCO (1975 Statistical Yearbook), 1970 from Marer et al. (1992)
Investment rate: Joint Economic Committee (1990), updated for 1988-89 with Marer et al. (1992) (JEC series available at 5 yr intervals from 1960-75, interpolated in between)
Growth residual: Residual from Levine-Renelt regression of first column on other columns

Table 3: Soviet defense burden as share of GDP

	Ofer (1987) (current rubles)	*Brada and Graves (1988) -- High (constant rubles)*	*Brada and Graves (1988) -- Low (constant rubles)*	*Steinberg (1990) (constant rubles)*
1928	2%			
1950	9%			
1960	12%	13.34%	9.90%	
1961		13.86%	10.60%	
1962		14.93%	11.39%	
1963		15.49%	12.32%	
1964		15.03%	12.17%	
1965		14.49%	11.79%	
1966		14.11%	11.54%	
1967		14.40%	11.95%	
1968		14.45%	12.14%	
1969		14.61%	12.08%	
1970	13%	13.83%	11.48%	13.28%
1971		13.56%	11.30%	13.76%
1972		13.80%	11.34%	13.61%
1973		13.33%	11.03%	13.14%
1974		13.71%	11.28%	13.15%
1975		14.14%	11.53%	13.57%
1976		14.32%	11.62%	13.30%
1977		14.07%	11.26%	12.98%
1978		14.00%	11.09%	13.08%
1979		14.53%	11.43%	13.05%
1980	16%	15.06%	11.82%	13.91%
1981		15.48%	11.75%	14.03%
1982		15.36%	11.70%	14.58%
1983		15.51%	11.63%	14.36%
1984		15.55%	11.57%	14.37%
1985				14.79%
1986				14.49%
1987				14.63%

Table 4: Total factor productivity growth rates, alternative series, USSR

period	Khanin material sectors	Official material sectors	Western est industrial sector	Official industrial sector	Western est. GNP
1928-40	-1.7	7.2	1.7	7.2	-1.2
1940-50	-0.2	2.5	-1.1	1.7	-0.2
1950-60	3.8	6.0	6.1	4.1	1.3
1960-70	1.5	2.9	1.9	3.4	-0.1
1970-80	0.4	1.4	2.4	1.7	-0.8
1980-87	0.4	0.7	-0.1	1.1	-1.2

Sources: see earlier description in text

Table 5: Elasticities of substitution and TFP growth with estimated CES functions

	Khanin material sectors	*Official material sectors*	*Western estimates industrial sector*	*Official industrial sector*	*Western GNP*
For 1950-87 sample:					
Elasticity of substitution	1.11	0.37 *	0.13 *	0.40 *	0.37 *
TFP growth in :					
1950-59	0.11%	2.93% *	2.40% *	3.72% *	1.09% *
1960-69	-0.07%	2.88% *	2.36% *	3.60% *	1.10% *
1970-79	-0.30%	2.98% *	2.51% *	3.74% *	1.16% *
1980-87	-0.35%	2.92% *	2.43% *	3.62% *	1.09% *
For entire sample period, 1928-87					
Elasticity of substitution	1.11	0.38 *	0.22	0.45 *	0.81
TFP growth in :					
1928-39	-2.03% *	3.34% *	-1.38%	0.72%	-0.52%
1940-49	-1.17% *	2.18% *	-0.72%	0.51%	-1.32% *
1950-59	-0.18%	2.96% *	0.36%	1.48% *	-0.21%
1960-69	0.33%	2.97% *	0.40%	1.27%	-0.15%
1970-79	0.30%	3.05% *	0.43%	1.38%	-0.18%
1980-87	0.22%	2.97% *	0.37%	1.28%	-0.33%

Notes: * indicates elasticity of substitution significantly different than one or TFP growth rates significantly different than zero. Full regression results given in appendix.

Table 6: Growth rates of NMP per worker 1970-90 constant prices						
	Total	Industry	Agriculture	Transport & Communication	Construction	Trade & Procurement
USSR	2.8%	3.4%	-1.3%	3.1%	2.7%	2.1%
Slavic:						
Russia	3.0%	3.5%	-2.1%	3.2%	3.1%	2.4%
Ukraine	2.9%	3.2%	0.3%	3.1%	2.2%	2.2%
Belarus	4.5%	5.4%	0.3%	3.5%	2.9%	2.4%
Baltic/Moldavian:						
Estonia	3.1%	3.8%	-1.7%	3.6%	2.6%	2.5%
Latvia	3.3%	4.3%	-0.8%	5.6%	1.0%	2.0%
Lithuania	2.8%	4.9%	-0.6%	3.9%	1.4%	1.0%
Moldova	3.3%	3.3%	0.5%	4.1%	2.2%	2.4%
Transcaucasian:						
Georgia	3.9%	4.5%	2.5%	3.1%	2.0%	2.5%
Armenia	3.4%	3.4%	-0.8%	5.2%	2.7%	2.5%
Azerbaijan	2.7%	3.9%	1.9%	0.7%	2.7%	1.6%
Central Asian:						
Kazakhstan	0.7%	0.6%	-4.4%	1.9%	1.9%	0.4%
Turkmenistan	-0.3%	-0.6%	-2.8%	0.9%	1.6%	1.4%
Uzbekistan	1.2%	2.2%	-1.8%	2.7%	1.0%	1.8%
Tajikstan	1.0%	1.7%	-1.8%	3.1%	0.6%	1.8%
Kyrgyzstan	1.7%	3.1%	-2.4%	3.8%	1.4%	1.1%

Table 7: Total factor productivity growth by sector and republic, 1970-90

	Total	Industry	Agriculture	Transport & Communication	Construction	Trade & Procurement
USSR	0.8%	1.1%	-4.1%	0.8%	0.2%	0.3%
Slavic:						
Russia	0.8%	0.9%	-5.3%	0.7%	0.5%	0.4%
Ukraine	1.0%	1.3%	-2.7%	1.0%	-0.4%	0.6%
Belarus	2.1%	3.0%	-3.3%	1.3%	1.8%	0.3%
Baltic/Moldavian:						
Estonia	1.3%	1.8%	-4.4%	1.6%	0.2%	0.5%
Latvia	1.4%	2.1%	-3.3%	2.9%	-0.9%	0.2%
Lithuania	0.6%	2.6%	-4.0%	2.0%	-0.9%	-0.6%
Moldova	1.0%	1.2%	-2.7%	2.0%	-0.4%	0.5%
Transcaucasian:						
Georgia	2.3%	2.6%	0.1%	1.3%	0.3%	1.0%
Armenia	1.8%	1.8%	-3.1%	2.8%	1.1%	0.4%
Azerbaijan	1.4%	2.5%	0.1%	-1.2%	0.3%	-0.2%
Central Asian:						
Kazakhstan	-1.1%	-1.5%	-6.4%	0.2%	-0.3%	-1.2%
Turkmenistan	-2.0%	-3.0%	-4.0%	-2.1%	-0.3%	-0.3%
Uzbekistan	-0.4%	0.5%	-3.7%	0.6%	-0.6%	-0.1%
Tajikstan	-0.4%	-0.3%	-2.9%	1.8%	-1.1%	0.9%
Kyrgyzstan	0.2%	1.1%	-3.9%	1.7%	-0.2%	-0.7%

Table 8: Cross-sectional growth regression, 15 Soviet republics

LS // Dependent Variable is Total Factor Productivity Growth,1970-90
Number of observations: 15

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	0.0303710	0.0244123	1.2440874	0.2393
SPECHI65	0.0001098	5.011E-05	2.1910647	0.0509
INCOM60	-0.0002895	0.0001477	-1.9598548	0.0758
NATINC70	-1.4371064	0.5552033	-2.5884325	0.0252

R-squared	0.686424	Mean of dependent var	0.006709
Adjusted R-squared	0.600904	S.D. of dependent var	0.012018
S.E. of regression	0.007592	Sum of squared resid	0.000634
Log likelihood	54.25[illegible]78	F-statistic	8.026420
		Prob(F-statistic)	0.004105

Variables:

SPECHI65 -- number of specialists with higher education per 10,000 inhabitants, 1965
INCOM60 -- income per capita relative to USSR, 1960
NATINC70 --rate of natural increase of population, 1970

Source: official data.

Table 9: Sectoral employment imbalances by republic
Deviation from employment shares predicted by per capita income, 1970

	Industry	Construction	Agriculture	Transport and comm	Trade
USSR	3%	1%	6%	2%	-7%
Slavic:					
Russia	6%	1%	1%	2%	-7%
Ukraine	2%	0%	11%	1%	-8%
Belarus	-1%	0%	17%	0%	-8%
Baltic/Moldavian:					
Estonia	7%	2%	3%	3%	-7%
Latvia	7%	0%	4%	2%	-7%
Lithuania	1%	2%	14%	1%	-9%
Moldova	-9%	-1%	29%	-1%	-9%
Transcaucasian:					
Georgia	-6%	0%	16%	1%	-8%
Armenia	3%	3%	4%	0%	-8%
Azerbaijan	-4%	1%	10%	2%	-7%
Central Asian:					
Kazakhstan	-4%	3%	6%	4%	-7%
Turkmenistan	-11%	3%	16%	2%	-7%
Uzbekistan	-9%	1%	19%	0%	-7%
Tajikstan	-9%	0%	20%	0%	-8%
Kyrgyzstan	-3%	0%	11%	1%	-7%

Sources: International Labor Organization (various years) for international employment data; see text for sources on Soviet republics

Note: Share deviations are calculated by regressing employment shares in 1970 for non-socialist countries on 1970 per capita income (Summers-Heston), dummying out the Soviet republics.

Appendix 1: Trends in capital-output ratios in growth accounting studies

Country	*Period*	*Per annum percent change in capital output ratio*
	This paper	
USSR (Western GDP and Capital Stock Estimates)	1950-87	2.53%
	Maddison (1989)	
France	1950-84	-0.45%
Germany	1950-84	0.16%
Japan	1950-84	-0.91%
United Kingdom	1950-84	0.62%
United States	1950-84	-0.07%
China	1950-84	2.48%
India	1950-84	1.54%
Korea	1950-84	0.03%
Taiwan	1950-84	-0.34%
Argentina	1950-84	0.61%
Brazil	1950-84	0.86%
Chile	1950-84	-0.22%
Mexico	1950-84	0.50%
USSR	1950-84	3.75%
	Young (1993)	
Hong Kong	1966-91	0.84%
Singapore	1970-90	2.79%
South Korea (excluding agriculture)	1966-90	3.62%
Taiwan (excluding agriculture)	1966-90	2.55%
	Kim and Lau (1993)	
Hong Kong	66-90	1.11%
Singapore	64-90	1.38%
South Korea	60-90	3.50%
Taiwan	53-90	3.13%
France	57-90	0.68%
W. Germany	60-90	1.16%
Japan	57-90	3.19%
U.K.	57-90	0.68%
U.S.	48-90	-0.19%
	Elias (1992)	
Argentina	1950-80	0.39%
Brazil	1950-80	-0.54%
Chile	1950-80	-0.39%
Colombia	1950-80	-0.79%
Mexico	1950-80	0.44%
Peru	1950-80	1.22%
Venezuela	1950-80	0.75%

Trends in capital-output ratios in growth accounting studies (Appendix 1 cont.)

Country	*Period*	*Per annum percent change in capital output ratio*
	Chenery, Robinson, and Syrquin (1986)	
Canada	47-73	0.66%
France	50-73	0.13%
Germany	50-73	0.33%
Italy	52-73	-0.63%
Netherlands	51-73	0.17%
United Kingdom	49-73	0.69%
United States	49-73	0.00%
	Benhabib and Spiegel (1992) (using Summers-Heston data)	
United States	1965-85	0.63%
Japan	1965-85	2.56%
Hong Kong	1965-85	-0.20%
Korea	1965-85	2.78%
Singapore	1965-85	2.41%
Taiwan	1965-85	2.97%
75th percentile of sample (77 countries in sample, excluding Africa)	*1965-85*	*1.72%*
50th percentile	*1965-85*	*0.80%*
25th percentile	*1965-85*	*0.21%*
	Nehru and Dhareshwar (1993) (World Bank data)	
United States	1950-90	0.20%
Japan	1950-90	2.70%
Korea	1950-90	3.70%
Singapore	1960-90	-1.09%
Taiwan	1950-90	-2.08%
75th percentile of sample (72 countries in sample)	*1950-90*	*1.64%*
50th percentile	*1950-90*	*1.06%*
25th percentile	*1950-90*	*0.38%*
	King and Levine (1994) (Summers-Heston data)	
United States	1950-88	0.40%
Japan	1950-88	2.33%
Hong Kong	1950-88	-0.80%
Korea	1950-88	3.05%
Singapore	1950-88	2.94%
Taiwan	1950-88	2.63%
75th percentile of sample of 74 countries excluding Africa	*1950-88*	*1.69%*
50th percentile	*1950-88*	*0.95%*
25th percentile	*1950-88*	*0.23%*

Appendix 2: Nonlinear least squares estimation of CES functions

Variable names for nonlinear regressions

dummy for 1928-39	D2839
dummy for 1940-49	D4049
dummy for 1950-59	D5059
dummy for 1960-69	D6069
dummy for 1970-79	D7079
dummy for 1980-87	D8087
Capital-labor ratio, industry, official	KLINO
Capital-labor ratio, industry, Western est	KLINW
Capital-labor ratio, Khanin	KLKHAN
Capital-labor ratio, material sectors, official	KLOFF
Capital-labor ratio, whole economy, Western	KLWES
Log of output per worker, industrial sector, official numbers	LYLINO
Log of output per worker, industrial sector, Western estimates	LYLINW
Log of output per worker, material sectors, Khanin	LYLKHAN
Log of output per worker, material sectors, official	LYLOFF
Log of output per worker, whole economy, Western estimates	LYLWES
TIME*D2839	T2839
TIME*D4049	T4049
TIME*D5059	T5059
TIME*D6069	T6069
TIME*D7079	T7079
TIME*D8087	T8087
Ratio of defense spending to GDP	DEFGDP
TIME (1,2,3,4,ETC.)	TIME

(1) Results for 1928-87 sample

NLS // Dependent Variable is LYLKHAN
SMPL range: 1928 - 1987
Number of observations: 60
LYLKHAN=C(1)*T2839+C(2)*T4049+C(3)*T5059+C(4)*T6069+C(5)*T7079+C(6)*T8087+C(7)*LOG(C(8)*KLKHAN^(1/C(7))+1-C(8))+C(9)

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	-0.0202626	0.0073460	-2.7583265	0.0080
C(2)	-0.0116552	0.0034600	-3.3685319	0.0014
C(3)	-0.0017588	0.0025248	-0.6966280	0.4892
C(4)	0.0033136	0.0029598	1.1195481	0.2682
C(5)	0.0030160	0.0031696	0.9515282	0.3458
C(6)	0.0022460	0.0029139	0.7707873	0.4444
C(7)	9.8304594	113.76212	0.0864124	0.9315
C(8)	0.6102850	0.1464251	4.1678994	0.0001
C(9)	0.0916414	0.0363921	2.5181703	0.0150

R-squared	0.983100	Mean of dependent var	0.471133
Adjusted R-squared	0.980450	S.D. of dependent var	0.397586
S.E. of regression	0.055592	Sum of squared resid	0.157612
Log likelihood	93.12259	F-statistic	370.8535
Durbin-Watson stat	1.024675	Prob(F-statistic)	0.000000

NLS // Dependent Variable is LYLOFF
SMPL range: 1928 - 1987
Number of observations: 60
LYLOFF =C(1)*T2839+C(2)*T4049+C(3)*T5059+C(4)*T6069+C(5)*T7079+C(6)*T8087+C(7)*LOG(C(8)*KLOFF^(1/C(7))+1-C(8))+C(9)

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0333843	0.0080809	4.1312477	0.0001
C(2)	0.0218378	0.0044657	4.8901520	0.0000
C(3)	0.0296170	0.0047890	6.1844430	0.0000
C(4)	0.0296679	0.0059473	4.9884344	0.0000
C(5)	0.0304758	0.0058937	5.1708799	0.0000
C(6)	0.0297401	0.0054773	5.4296908	0.0000
C(7)	-0.6260722	0.1706363	-3.6690441	0.0006
C(8)	0.5403918	0.1322528	4.0860527	0.0002
C(9)	1.3706613	0.1645207	8.3312377	0.0000

R-squared	0.996612	Mean of dependent var	2.117937
Adjusted R-squared	0.996080	S.D. of dependent var	1.061674
S.E. of regression	0.066469	Sum of squared resid	0.225327
Log likelihood	82.40014	F-statistic	1875.115
Durbin-Watson stat	1.101054	Prob(F-statistic)	0.000000

NLS // Dependent Variable is LYLWES
Date: 7-20-1993 / Time: 23:35
SMPL range: 1928 - 1987
Number of observations: 60
LYLWES =C(1)*T2839+C(2)*T4049+C(3)*T5059+C(4)*T6069+C(5)*T7079+C(6)*T8087+C(7)*LOG(C(8)*KLWES^(1/C(7))+1-C(8))+C(9)
Convergence achieved after 2 iterations

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	-0.0051988	0.0086239	-0.6028340	0.5493
C(2)	-0.0131666	0.0045147	-2.9163642	0.0053
C(3)	-0.0020808	0.0048916	-0.4253758	0.6724
C(4)	-0.0014649	0.0058862	-0.2488673	0.8045
C(5)	-0.0018068	0.0059853	-0.3018751	0.7640
C(6)	-0.0033362	0.0060313	-0.5531465	0.5826
C(7)	-4.1327746	5.8211962	-0.7099528	0.4810
C(8)	0.7331452	0.1523563	4.8120442	0.0000
C(9)	-0.2293690	0.0861945	-2.6610638	0.0104

R-squared	0.989484	Mean of dependent var	0.934737
Adjusted R-squared	0.987835	S.D. of dependent var	0.549799
S.E. of regression	0.060641	Sum of squared resid	0.187543
Log likelihood	87.90639	F-statistic	599.8574
Durbin-Watson stat	1.118814	Prob(F-statistic)	0.000000

NLS // Dependent Variable is LYLINW
SMPL range: 1928 - 1987
Number of observations: 60
LYLINW =C(1)*T2839+C(2)*T4049+C(3)*T5059+C(4)*T6069+C(5)*T7079+C(6)*T8087+C(7)*LOG(C(8)*KLINW^(1/C(7))+1-C(8))+C(9)

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	-0.0137604	0.0079630	-1.7280338	0.0900
C(2)	-0.0071615	0.0038608	-1.8549179	0.0694
C(3)	0.0035802	0.0026946	1.3286169	0.1899
C(4)	0.0040201	0.0038213	1.0520246	0.2977
C(5)	0.0043616	0.0051544	0.8461905	0.4014
C(6)	0.0036720	0.0054903	0.6688182	0.5066
C(7)	-0.2743993	0.3211317	-0.8544760	0.3968
C(8)	0.3542810	0.3325082	1.0654807	0.2917
C(9)	-1.2839549	0.3090338	-4.1547401	0.0001

R-squared	0.979397	Mean of dependent var	-1.911255
Adjusted R-squared	0.976165	S.D. of dependent var	0.610544
S.E. of regression	0.094259	Sum of squared resid	0.453126
Log likelihood	61.44156	F-statistic	303.0437
Durbin-Watson stat	1.034563	Prob(F-statistic)	0.000000

```
NLS // Dependent Variable is LYLINO
Date: 7-20-1993 / Time: 23:38
SMPL range: 1928  -  1987
Number of observations: 60
LYLINO =C(1)*T2839+C(2)*T4049+C(3)*T5059+C(4)*T6069+C(5)*T7079+C(6)*T808
7+C(7)*LOG(C(8)*KLINO^(1/C(7))+1-C(8))+C(9)
Convergence achieved after 2 iterations
```

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0072341	0.0086047	0.8407205	0.4044
C(2)	0.0051121	0.0053042	0.9637879	0.3397
C(3)	0.0148348	0.0050212	2.9544124	0.0047
C(4)	0.0126798	0.0064987	1.9511147	0.0565
C(5)	0.0137831	0.0069631	1.9794368	0.0532
C(6)	0.0128241	0.0069723	1.8392831	0.0717
C(7)	-0.8243762	0.3706599	-2.2240773	0.0306
C(8)	0.4472637	0.1562502	2.8624840	0.0061
C(9)	-1.4963393	0.3791015	-3.9470674	0.0002

R-squared	0.996675	Mean of dependent var	-2.191933
Adjusted R-squared	0.996154	S.D. of dependent var	1.111757
S.E. of regression	0.068948	Sum of squared resid	0.242448
Log likelihood	80.20302	F-statistic	1911.111
Durbin-Watson stat	1.317886	Prob(F-statistic)	0.000000

(2) Results for 1950-87 sample

```
NLS // Dependent Variable is LYLKHAN
SMPL range: 1950  -  1987
Number of observations: 38
LYLKHAN=C(1)*T5059+C(2)*T6069+C(3)*T7079+C(4)*T8087+C(5)*LOG(C(6)*KLKHAN
^(1/C(5))+1-C(6))+C(7)
```

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0011270	0.0048291	0.2333864	0.8170
C(2)	-0.0006563	0.0051628	-0.1271136	0.8997
C(3)	-0.0030198	0.0050557	-0.5972997	0.5546
C(4)	-0.0034716	0.0045055	-0.7705352	0.4468
C(5)	9.7629283	220.16876	0.0443429	0.9649
C(6)	1.1237026	0.2228861	5.0415996	0.0000
C(7)	-0.1735591	0.1109200	-1.5647225	0.1278

R-squared	0.987796	Mean of dependent var	0.707439
Adjusted R-squared	0.985434	S.D. of dependent var	0.305213
S.E. of regression	0.036836	Sum of squared resid	0.042064
Log likelihood	75.39730	F-statistic	418.1935
Durbin-Watson stat	0.505965	Prob(F-statistic)	0.000000

NLS // Dependent Variable is LYLOFF
SMPL range: 1950 - 1987
Number of observations: 38
LYLOFF =C(1)*T5059+C(2)*T6069+C(3)*T7079+C(4)*T8087+C(5)*LOG(C(6)*KLOFF^(1/C(5))+1-C(6))+C(7)

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0292335	0.0027887	10.482690	0.0000
C(2)	0.0288169	0.0029999	9.6060223	0.0000
C(3)	0.0297372	0.0030072	9.8888315	0.0000
C(4)	0.0291584	0.0028214	10.334843	0.0000
C(5)	-0.5812015	0.0565917	-10.270078	0.0000
C(6)	0.5715239	0.0456052	12.531981	0.0000
C(7)	1.3912334	0.0869462	16.001090	0.0000

R-squared	0.999488	Mean of dependent var	2.812825
Adjusted R-squared	0.999389	S.D. of dependent var	0.594913
S.E. of regression	0.014707	Sum of squared resid	0.006705
Log likelihood	110.2862	F-statistic	10084.79
Durbin-Watson stat	1.390053	Prob(F-statistic)	0.000000

NLS // Dependent Variable is LYLWES
SMPL range: 1950 - 1987
Number of observations: 38
LYLWES =C(1)*T5059+C(2)*T6069+C(3)*T7079+C(4)*T8087+C(5)*LOG(C(6)*KLWES^(1/C(5))+1-C(6))+C(7)

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0109709	0.0032629	3.3623384	0.0021
C(2)	0.0109651	0.0035797	3.0631462	0.0045
C(3)	0.0116165	0.0035835	3.2417041	0.0028
C(4)	0.0109505	0.0034259	3.1963828	0.0032
C(5)	-0.5958245	0.0966218	-6.1665625	0.0000
C(6)	0.9598616	0.0134483	71.373976	0.0000
C(7)	-0.8162872	0.0832581	-9.8042949	0.0000

R-squared	0.998747	Mean of dependent var	1.285964
Adjusted R-squared	0.998505	S.D. of dependent var	0.356312
S.E. of regression	0.013777	Sum of squared resid	0.005884
Log likelihood	112.7701	F-statistic	4119.769
Durbin-Watson stat	1.922959	Prob(F-statistic)	0.000000

NLS // Dependent Variable is LYLINW
SMPL range: 1950 - 1987
Number of observations: 38

```
LYLINW =C(1)*T5059+C(2)*T6069+C(3)*T7079+C(4)*T8087+C(5)*LOG(C(6)*KLINW^
(1/C(5))+1-C(6))+C(7)
```

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0240169	0.0021467	11.187968	0.0000
C(2)	0.0236218	0.0023585	10.015738	0.0000
C(3)	0.0251244	0.0021509	11.681057	0.0000
C(4)	0.0243103	0.0018522	13.124830	0.0000
C(5)	-0.1441544	0.0330823	-4.3574480	0.0001
C(6)	0.0020469	0.0031944	0.6407644	0.5264
C(7)	-2.4449147	0.1045291	-23.389801	0.0000

R-squared	0.997683	Mean of dependent var	-1.535708
Adjusted R-squared	0.997234	S.D. of dependent var	0.417767
S.E. of regression	0.021971	Sum of squared resid	0.014965
Log likelihood	95.03323	F-statistic	2224.312
Durbin-Watson stat	0.506999	Prob(F-statistic)	0.000000

NLS // Dependent Variable is LYLINO
SMPL range: 1950 - 1987
Number of observations: 38

```
LYLINO =C(1)*T5059+C(2)*T6069+C(3)*T7079+C(4)*T8087+C(5)*LOG(C(6)*KLINO^
(1/C(5))+1-C(6))+C(7)
```

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0371878	0.0049959	7.4436178	0.0000
C(2)	0.0359650	0.0053985	6.6619911	0.0000
C(3)	0.0373821	0.0054797	6.8219713	0.0000
C(4)	0.0361438	0.0052913	6.8308024	0.0000
C(5)	-0.6618038	0.1296726	-5.1036531	0.0000
C(6)	0.1022757	0.0669595	1.5274265	0.1368
C(7)	-2.7672364	0.2907247	-9.5184097	0.0000

R-squared	0.999228	Mean of dependent var	-1.481138
Adjusted R-squared	0.999079	S.D. of dependent var	0.657494
S.E. of regression	0.019953	Sum of squared resid	0.012342
Log likelihood	98.69529	F-statistic	6690.964
Durbin-Watson stat	1.008779	Prob(F-statistic)	0.000000

(3) Regression with Defense Spending/GDP

NLS // Dependent Variable is LYLWES
SMPL range: 1960 - 1987
Number of observations: 28
LYLWES=C(1)*TIME+C(2)*TIME*DEFGDP+C(3)*LOG(C(4)*KLWES^(1/C(3))+1-C(4))+C(5)

	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C(1)	0.0207134	0.0059611	3.4747771	0.0021
C(2)	-0.0727455	0.0108381	-6.7120112	0.0000
C(3)	-0.5785414	0.2470464	-2.3418330	0.0282
C(4)	0.9690962	0.0396033	24.470094	0.0000
C(5)	-0.8963781	0.2645463	-3.3883604	0.0025

R-squared	0.996629	Mean of dependent var	1.468442
Adjusted R-squared	0.996042	S.D. of dependent var	0.179790
S.E. of regression	0.011310	Sum of squared resid	0.002942
Log likelihood	88.52034	F-statistic	1699.821
Durbin-Watson stat	2.232942	Prob(F-statistic)	0.000000

Policy Research Working Paper Series

	Title	Author	Date	Contact for paper
WPS1264	A Rock and a Hard Place: The Two Faces of U.S. Trade Policy Toward Korea	J. Michael Finger	March 1994	M. Pateña 37947
WPS1265	Parallel Exchange Rates in Developing Countries: Lessons from Eight Case Studies	Miguel A. Kiguel Stephen A. O'Connell	March 1994	R. Luz 34303
WPS1266	An Efficient Frontier for International Portfolios with Commodity Assets	Sudhakar Satyanarayan Panos Varangis	March 1994	D. Gustafson 33732
WPS1267	The Tax Base in Transition: The Case of Bulgaria	Zeljko Bogetic Arye L. Hillman	March 1994	F. Smith 36072
WPS1268	The Reform of Mechanisms for Foreign Exchange Allocation: Theory and Lessons from Sub-Saharan Africa	Eliana La Ferrara Gabriel Castillo John Nash	March 1994	N. Artis 38010
WPS1269	Union-Nonunion Wage Differentials in the Developing World: A Case Study of Mexico	Alexis Panagides Harry Anthony Patrinos	March 1994	I. Conachy 33669
WPS1270	How Land-Based Targeting Affects Rural Poverty	Martin Ravallion Binayak Sen	March 1994	P. Cook 33902
WPS1271	Measuring the Effect of External Shocks and the Policy Response to Them: Empirical Methodology Applied to the Philippines	F. Desmond McCarthy J. Peter Neary Giovanni Zanalda	March 1994	M. Divino 33739
WPS1272	The Value of Superfund Cleanups: Evidence from U.S. Environmental Protection Agency Decisions	Shreekant Gupta George Van Houtven Maureen L. Cropper	March 1994	A. Maranon 39074
WPS1273	Desired Fertility and the Impact of Population Policies	Lant H. Pritchett Lawrence H. Summers	March 1994	P. Cook 33902
WPS1274	The New Trade Theory and Its Relevance for Developing Countries	Asad Alam	March 1994	A. Alam 87380
WPS1275	Female-Headed Households, Poverty, and the Welfare of Children in Urban Brazil	Ricardo Barros Louise Fox	March 1994	K. Binkley 81143
WPS1276	Is There Persistence in the Growth of Manufactured Exports? Evidence from Newly Industrializing Countries	Ashoka Mody Kamil Yilmaz	March 1994	M. Pateña 37947
WPS1277	Private Trader Response to Market Liberalization in Tanzania's Cashew Nut Industry	Steven Jaffee	March 1994	C. Spooner 32116

Policy Research Working Paper Series

	Title	Author	Date	Contact for paper
WPS1278	Regulation and Commitment in the Development of Telecommunications in Chile	Ahmed Galal	March 1994	B. Moore 38526
WPS1279	Optimal Hedging Strategy Revisited: Acknowledging the Existence of Nonstationary Economic Time Series	Ying Qian Ronald Duncan	March 1994	S. Lipscomb 33718
WPS1280	The Economic Impact of Export Controls: An Application to Mongolian Cashmere and Romanian Wood Products	Wendy E. Takacs	March 1994	M. Pateña 37947
WPS1281	Human and Physical Infrastructure: Public Investment and Pricing Policies in Developing Countries	Emmanuel Jimenez	April 1994	L. Longo 37786
WPS1282	Copper and the Negative Price of Storage	Donald Frederick Larson	April 1994	A. Kim 33715
WPS1283	Interest Rates in Open Economies: Real Interest Rate Parity, Exchange Rates, and Country Risk in Industrial and Developing Countries	Dipak Das Gupta Bejoy Das Gupta	April 1994	B. Kim 82467
WPS1284	The Soviet Economic Decline: Historical and Republican Data	William Easterly Stanley Fischer	April 1994	R. Martin 31320