The Determinants of International Variation in Technical Efficiency: Estimates from a Stochastic Frontier Function

To be presented at the Southern Economics Association Meetings
Baltimore, MD
November 8 - November 10, 1998

Version: November 19, 1998

Lee C. Adkins
Professor
Department of Economics
Oklahoma State University
Stillwater, OK 74075
Phone: 1-405-744-8637
Internet: Ladkins@okway.okstate.edu

Ronald L. Moomaw
Regents Professor
Department of Economics
Oklahoma State University
Stillwater, OK 74075

Andreas Savvides
Associate Professor
Department of Economics
Oklahoma State University
Stillwater, OK 74075

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Abstract

Economists increasingly are studying the effects of institutions on countries economic performance. Rodrik [24] for instance, argues that democracies are associated with better economic performance then other types of governments. Dawson [10] finds that economic freedom–not political freedom–is associated with more rapid growth. Other research [6, 7, 8, 17, 19] indicates that planned economies are less efficient than unplanned ones. These studies compare the performance of centrally planned economies to that of western market economies. None account for the sources of inefficiency other than the differentiating planned vs. market via dummy variables. In addition, they focus on OECD countries versus the former USSR or Eastern European economies. Edwards [11] uses a much broader panel to study the determinants of TFP growth, finding that initial levels of GDP and human capital as well as degree of trade openness are important contributors. In this study, the sources of technical inefficiency are examined both within the OECD and among a much broader set of countries using panel data and assuming a stochastic production frontier. Data on human capital, political and economic freedom are used to determine specific sources of technical inefficiency. The parameters of the stochastic production frontier and the determinants of X inefficiency are estimated simultaneously using a maximum likelihood estimator proposed by [2].

1 Introduction

Institutions can have large affects on economic performance. In this paper we examine empirically a specific mechanism through which institutional and other variables can affect a country's economic performance. It is generally accepted [1] that different countries operate at different distances from the frontier and that "catch up" can account for some of the differences in economic growth. We postulate that deviations from the production possibility frontier are functions of certain economic and institutional variables. The unique contribution of this paper is that it provides econometric parameter estimates of several determinants of these deviations.

Economists have demonstrated that institutions may have large affects on economic performance. For instance, Rodrik [24] provides evidence that democracies are associated with (1) more stable long-run growth rates, (2) greater short-run stability, (3) better ability to deal with adverse shocks, (3) and with higher wages. He proposes three explanations of these empirical regularities. First, democracies may have greater stability because the preferences of the median voter inhibit radical policy actions that would yield extreme results. Second, voice in the political process reduces the amount of internal conflict. And, third, losers in political battles are more likely to avoid economic loss in a democracy than in other types of government.

Dawson [10] examines the effects of economic and political freedom on economic growth. His estimates of cross-county growth and investment equations indicate that economic growth is associated with economic freedom because of a positive effect of such freedom on investment and the level of total factor productivity. Aspects of political freedom are associated with investment, but there is no indication that they are associated with total factor productivity. In a sense, our paper is an attempt to determine the extent to which findings like Dawson's indicate that total factor productivity effects of institutions are associated with deviations from a frontier.

Edwards [11], using the same capital stock data as we use, first estimates a production function for a panel of 93 advanced and developing countries and calculates total factor productivity (TFP). He then estimates the relationship between the degree of trade openness and TFP growth. He finds that initial per capita GDP, initial level of human capital and openness are important determinants of TFP growth.

Other research, which is more closely related to that here, indicates that planned economies are less efficient than unplanned ones; in particular Bergson [6, 7, 8], Marer [17], Moroney and Lovell [19] and others compare the performance of centrally planned economies to that of western market economies. Bergson [6, 7] finds that the planned economies tend to use capital and land less efficiently than market economies using ordinary least squares estimation of a constant-returns-to-scale production function, with dummy variables identifying planned economies. Moroney [18] uses a similar approach to show that a larger set of planned economies used capital and energy less efficiently than West European economies from 1978-1980.

Moroney and Lovell [19] were the first to use a stochastic production frontier panel data techniques to compare the productive performance of market and planned economies. Their goal was to quantify the extent to which market economies are more efficient than planned ones. They find a group of West European market economies to have been much more productive than the group of seven East European planned economies from 1978-1980. They attribute most of the difference to the use of better technology in the market economies. The Eastern European economies were no more than 76 percent as efficient as the Western European economies during this period. None of these studies account for the sources of inefficiency other than with dummy variables indicating planned or market economies. In addition, they focus on OECD countries versus the former USSR or Eastern European economies. In this study, we use panel data to estimate a production frontier and examine the sources of productive inefficiency both within the OECD and among a much broader set of countries than previously considered. Data on human capital, political and economic freedom are used to determine specific sources of technical inefficiency. In addition, our study differs from Dawson, Edwards and related studies in that we model the TFP effect as a deviation from a stochastic frontier. Unlike Edwards, we specify that the TFP effect is associated with economic and political freedom, in general, rather than liberal trade and foreign investment regimes.

Therefore our goal and our approach are different from earlier research. In this paper we estimate a stochastic production frontier where technical inefficiency is modeled as a specific function of various economic and political variables. Our intent is to determine whether the stage of economic development, the level of human capital, and the degrees of political and economic freedom account for observed variation in technical inefficiencies across a wide range of countries.

Our findings are based upon the use of an estimator proposed by Battese and Coelli [2] to simultaneously estimate the parameters of the stochastic frontier and the determinants of X inefficiency. The results suggest that even among the members of the OECD, variations in development, human capital, economic freedom, and tax burden are linked to economic efficiency. Among the broader set of countries, which include ones from Africa, Asia, and South America, we find evidence that political freedom is also important to economic efficiency.

2 The Stochastic Frontier Model

A number of studies have estimated stochastic production frontiers and used the predicted efficiencies in a second stage regression to determine reasons for differing efficiencies. In the first stage the predicted inefficiencies are estimated under the assumption that they are independently and identically distributed. Regressing other variables on the inefficiencies in a second stage is a clear violation of the independence assumption. Kumbhakar, Ghosh, and McGuckin [16] find at least two serious problems with such a procedure. First, technical inefficiency may be correlated with the inputs; if so the inefficiencies and the parameters of the second stage regression are inconsistently estimated. Second, the use of OLS in the second stage ignores the fact that the dependent variable (technical inefficiency) is inherently one-sided. OLS may yield predictions that are inconsistent with this fact and it is therefore not appropriate.[1]

Kumbhakar, Ghosh, and McGuckin [16], Reifschneider and Stevenson [23], and Huang and Liu [14] have proposed models of technical inefficiency in the context of stochastic frontier models. In these cross-sectional models, the parameters of the stochastic frontier and the determinants of inefficiency are estimated simultaneously given appropriate distributional assumptions about the model's errors.

Battese and Coelli [2] proposed a stochastic frontier model for use with panel data in which the inefficiencies can be expressed as specific functions of explanatory variables. The model can be expressed as

$$Y_{it} = x_{it}\beta + (V_{it} - U_{it}) \qquad i = 1, \ldots, N \quad t = 1, \ldots, T \tag{1}$$

where Y_{it} is the production of firm i in time period t; x_{it} is a $kx1$ vector of inputs; β is a vector of unknown parameters; V_{it} are random variables which are assumed to be independently and identically distributed $N(0, \sigma_v^2)$ and independent of U_{it} which are non-negative random variables that account for technical inefficiencies in production; U_{it} are assumed to be independently distributed as truncations at zero of the $N(m_{it}, \sigma_U^2)$ distribution. The mean inefficiency is a deterministic function of p explanatory variables:

$$m_{it} = z_{it}\delta \tag{2}$$

where δ is a $px1$ vector of parameters to be estimated. Following Battese and Corra [4] let $\sigma^2 = \sigma_V^2 + \sigma_U^2$ and $\gamma = \sigma_U^2/(\sigma_V^2 + \sigma_U^2)$.

The inefficiencies, U_{it}, in equation (1) can be specified as:

$$U_{it} = z_{it}\delta + W_{it} \tag{3}$$

[1] See [16] for discussion.

where W_{it} is defined by the truncation of the normal distribution with mean zero and variance, σ^2. Then, the technical inefficiency of the ith country at time t is

$$\mathrm{TE}_{it} = \exp(-U_{it}) = \exp(-z_{it}\delta - W_{it}) \tag{4}$$

The conditional expectation of TE_{it} is given in equation (A.10) of Battese and Coelli [3] which can be used to produce predictions for each country for each time period.

The parameters of the model (β, δ, σ^2, and γ) are estimated using the maximum likelihood estimator (MLE); the likelihood function can be found in the appendix of [3].[2]

Translog Production

The translog functional form is used because it offers great flexibility in specifying the nature of production. The translog model can be interpreted as a second-order approximation to the unknown, but true, functional form.[3]

In this paper output (Y) is a function of capital (K) and labor (L). The basic translog model is:

$$\ln Y_{it} = \beta_0 + \ln(L)\beta_1 + \ln(K)\beta_2 + .5[\ln(L)]^2\beta_3 + .5[\ln(K)]^2\beta_4 + \ln(L)\ln(K)\beta_5 + (V_{it} - U_{it}) \tag{5}$$

Equation (5), however, ignores the role of technological change in each economy. This is normally accounted for by using functions of time in the production function. We account for this in 2 ways in the results that follow. For the panels having only 3 time periods, we create dummy variables that allow for shifts in production, possibly due to overall worldwide economic conditions at time. In the longer panel, which extends from 1965-1987, we include a quadratic time trend to permit technological change.

Modeling Inefficiency

The inefficiencies are modeled as functions of other exogenous variables. These variables are observed factors that we have hypothesized explain differences in

[2]Computations were performed using FRONTIER 4.1 [9].

[3]Most other authors in this literature have adopted the constant returns to scale Cobb-Douglas model (see [6, 7, 10, 19, 18] *inter alia*). We test the null hypothesis of the Cobb-Douglas versus the alternative translog specification and reject the Cobb-Douglas at the 5% level in every instance.

technical efficiency across the countries in our samples. The factors affecting the technical efficiency of country are of several types. First, are data on the degree of economic freedom experienced by citizens of a country. As Gwartney et al. [13] note "[t]he central elements of economic freedom are personal choice, protection of private property, and freedom of exchange." The absence of restrictions on the freedom to choose goods, to supply resources, to compete in business and in trade has been considered at least since Adam Smith as central to economic prosperity. As Gwartney et al. suggest "[a]n index of economic freedom should measure the extent to which rightly acquired property is protected and individuals are free to engage in voluntary transactions." Consequently, we anticipate that the economic freedom index is an important determinant of economic efficiency. Certainly if one believes in Adam Smith's *invisible hand*, one would expect no less.

Political freedom is a different, if no less valuable, commodity. Political freedom has more to do with how the rules of the economic game are determined than with the actual rules themselves. Political liberty exists where adult citizens are free to vote, lobby, choose candidates, and make political contributions of time and resources. In politically free countries elections are fair, the press is free, expression of religion is unencumbered, criminal and civil legal proceedings are fair, etc. Consequently, freedom can promote stability, as Rodrik suggests, and it may promote greater technical efficiency. In particular, if one's freedom and property is not subject to capricious behavior by government or by other citizens, more resources and attention can be devoted to wealth increasing as opposed to wealth protecting behavior.

The effects of political freedom on efficiency, however, may not be unambiguous; political freedom may promote restrictions on economic freedom. Such may be the case in countries like Israel, Sweden, and India where distributional politics can affect tax rates and administrative regulations. Hence, political freedom and economic freedom can have opposite effects on efficiency. While economic theory is fairly clear on the impact of economic freedom, the effect of political freedom on economic efficiency is less certain. This argument, however, implies that for a given level of economic freedom, political freedom will be associated with greater efficiency.

Human capital is another variable that can influence technical efficiency. Huffman [15], building on the insights of T. W. Shultz [25] regarding the ability to deal with disequilibrium, refers to the ability to perceive and respond to changes in economic conditions as allocative ability. Allocative ability is acquired by investments in human capital; he reports econometric evidence that human capital enhances the allocative efficiency of U.S. Corn Belt farmers. Similarly, countries with more highly educated workers are anticipated to be quicker in adapting to changing economic conditions. To incorporate this idea, a measure of human capital is included as a determinant of inefficiency in the model.

The final variable in the model is a dummy variable designating whether a country is considered developed (D=1) or not (D=0). Developed countries are expected to have other unmeasured externalities that make them more efficient. These externalities might be related to civil infrastructure, greater marketization of the economy, or a wider variety of goods. They are potentially but otherwise excluded from our model.

3 Data

The data on economic freedom come from 2 sources. Gwartney, Lawson, and Block [13] construct an index of economic freedom (IS1) based on the premise that the central elements of economic freedom are personal choice, protection of private property, and freedom of exchange. Their index consists of 17 components grouped into four major areas: Money and inflation, government operations and regulations, takings and discriminatory taxation, and restrictions on international trade and exchange. The component weights were assigned by Gwartney et al. based on the responses of knowledgeable people as to the relative importance of each component to economic freedom. The data used are for the years 1975, 1980, and 1985.

Another measure of economic freedom is the relative size of government in GDP, or indirectly, the relative tax burden of each country. This is measured as tax revenue divided by GDP. The OECD publishes such a measure, defined consistently across the member countries (see [22] Table 3). Although data for only 25 countries are reported, the sample covers a much longer period than the economic freedom index, IS1, or the political freedom indicator. The larger sample is useful in improving the finite sample performance of the MLE.

Political freedom is measured using an index published by Freedom House [12]. This index classifies countries as Free (1), Partially Free (0), and Not Free (-1) Gastil assigns an index number from 1 to 7 for each country for political rights and civil rights. Political rights refer to the choice of government, election, party system and so on. Civil rights refer to individual rights and their enforcement. Freedom House combines these two indices to obtain the Free-Not Free categories.

Human capital is measured is measured as the average years of schooling in the population [21]. Output is measured in 1985 purchasing power parity dollars (PPP$) and was obtained from the Summers-Heston data base. Following the method used in Benhabib and Speigel [5], capital stock is measured in 1985 PPP$ and obtained by adjusting the output variable for the capital output ratio. The capital-output ratio is obtained from Nehru and Dhareshwar [20]. The labor is measured as number of workers and comes from [20].

The developed countries in the OECD, for which D=1, include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom, and the United States.[4] Otherwise D=0. The complete list of countries appears in Table 7.

Summary statistics of the various samples are summarized in tables (1)-(3).

4 Results

In general, the results indicate that developed countries lie closer to their production frontiers, that greater amounts of human capital decrease inefficiency, and that economic freedom decreases technical inefficiency. Greater political freedom also reduces technical inefficiency in the model using all of the countries..

Specifically, Table (4) contains the results from various specifications of the model using the available data on 77 countries. The sample consists of the years 1975, 1980, and 1985. Dummy variables for 1980 and 1985 are included in the first stage of the model (the production function) to permit systematic worldwide variations in overall economic conditions and or technical changes. Columns (7) and (8) contain the coefficient estimates and t-ratios for the unrestricted model. This is the translog production model containing two time dummy variables and includes a development dummy variable, human capital, political and economic freedom as determinants of technical inefficiency. Negative signs on the inefficiency coefficients indicate that increases in the variables reduce inefficiency. Each of the variables has a negative sign and is significantly different from zero at conventional 5% levels. Various other specifications were estimated (Cobb-Douglas in (5) and (6), translog with no time dummies in (3) and (4), and Cobb-Douglas without time dummies in (1) and (2)). In each case, the restrictions were tested against the alternative unrestricted model that appears in the last two columns. In each case, the restrictions were rejected at the 5% level. Capital and labor elasticities were computed at the means for each model and are also reported.

At the relevant means, the elasticity of output with respect to capital range between 0.64 and 0.75 and the elasticities with respect to labor range from 0.24 to 0.36. Although these elasticities may not be consistent with our intuition, Rodrik [24] reports data on labor's share of output in 7 countries in our sample over multiple years; it averages 0.28.

In general, the results for the OECD countries reported in Tables (5) and (6) are

[4] The other OECD countries are Greece, Portugal, and Turkey

similar to those for the larger sample of countries. This is especially pertinent because data for OECD countries may be more reliable than data for many countries outside the OECD.[5] If we were to find vastly different results for the OECD sample, there would be greater concern that data inadequacies were driving the results. In Table (5) the regressions of table (4) are replicated, with minor modification. In the OECD countries the share of taxes of GDP are available as an additional explanatory variable in the inefficiency portion of the model. The other major difference is that the sample size is only 74 (T=3, N=25 with one missing observation) and the estimator is probably less precise.[6] The coefficient estimates and asymptotic t-ratios for the unrestricted model appear in columns (9) and (10). The results are somewhat different in that human capital and political freedom are no longer significant. The share of taxes is also insignificant. Development status and economic freedom, however, continue to be significant. Various restrictions are tested and the estimates and t-ratios for the preferred model appears in columns (3) and (4). In this model, production is modeled using the translog without time dummies and inefficiency is modeled based on development and economic freedom.

Human capital and taxes as a share of GDP along with development and economic freedom are significant in Table 5 in the Cobb-Douglas model with no time dummies. Although the restrictions are rejected in favor of the model in column (9), the small change in the elasticities suggests that perhaps their lack of statistical significance may be due to the small sample. At any rate, the effects of human capital, political freedom, and taxes/GDP on inefficiency are not supported in this sample.

To explore the possibility that small sample may be responsible for our inability to determine whether human capital and taxes matter, we extend the sample to include data from 1965-1987 for the OECD. In this instance, we lose data on political and economic freedom which is only available for 3 of those years. The results appear in Table (6). In column (5) and (6) are the coefficient estimates and t-ratios of the unrestricted model. This model also includes a quadratic time trend (T and T^2). In this case, developed countries are closer to the frontier, human capital reduces inefficiency and a higher ratio of taxes to GDP increases inefficiency. Both restricted models are rejected in favor of the unrestricted model based on the likelihood ratio tests. In fact, the Cobb-Douglas model with no time dummies has a χ^2_5 statistic of 603.889, indicating a strong rejection of that functional form in favor of the translog.

[5] One of the goals of the OECD is to collect data for international comparison and a fairly conscientious effort is made to make data comparable.

[6] It follows from the fact that all of our inferences are based on the asymptotic properties of the MLE and 74 "seems" like a very long way from infinity–though technically no further than 228 or 538

5 Conclusion

Our results are consistent with other findings that democracy has economic benefits, that economic freedom promotes economic growth, that one benefit of investment in human capital is improved allocative ability in the economy, and that market-oriented economies are more efficient than planned economies. Our specific findings are similar in spirit to those of Moroney and Lovell [19] who find that planned economies operate farther from the production frontier. Our results, however, show that gradations of planning or its lack–economic freedom–promote inefficiency. Moreover, our results our consistent with those who, like Dawson [10], find that economic freedom promotes total factor productivity; moreover, we show that one of the mechanisms operates through technical efficiency rather advances in knowledge. In addition, we find stronger evidence for a role for political freedom in the same process. We also find that human capital is associated with greater allocative ability.

Although problems with estimation of the frontier production function suggest that these efficiency results must be treated with care, our results indicate that developed countries having higher stocks of human capital, and higher degrees of economic freedom tend to lie closer to the production frontier. As an examination of Table 7 shows, the results also suggest that developing countries, or countries experiencing low levels of economic freedom could increase output substantially given current technology.

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Variable	N	Mean	Std Dev	Minimum	Maximum
ID	538	41.8066914	24.1377910	4.0000000	78.0000000
YEAR	538	1976.36	6.6168330	1965.00	1987.00
TAX/GDP	538	31.4862458	8.9690773	10.5654620	55.3621430
Y	538	25.6096557	1.3859609	20.9103330	29.0642914
K	538	26.5532517	1.3900566	21.9718866	30.0289644
L	538	15.7433653	1.3408481	11.2938611	18.6005312
KK	538	355.0447311	36.7667830	236.3346858	451.6414465
LL	538	124.8240422	21.0330244	63.7756491	172.9898797
LK	538	420.6628125	56.2884834	245.5393898	559.0327342
T	538	12.3550186	6.6168330	1.0000000	23.0000000
HC	538	2.0507355	0.2992774	0.8149222	2.7547429

Table 1: Means, Standard Deviations, Minimum and Maximum values of each of the variables. The sample consists of observations from 1965-1987 on 77 countries. Y (output), L (workers), K (capital), and HC (human capital) are measured in natural logarithms.

Variable	N	Mean	Std Dev	Minimum	Maximum
YEAR	74	1980.07	4.0958752	1975.00	1985.00
SL1	74	4.5945946	1.1912802	2.2000000	7.3000000
TAX/GDP	74	32.8106175	9.1019753	15.2007190	50.0200210
Y	74	25.6526819	1.4807658	21.3634400	29.0084899
K	74	26.6637968	1.4779012	22.3006877	29.9791404
L	74	15.7183237	1.4542701	11.5462732	18.5807769
KK	74	357.6001836	39.0582376	250.0392460	450.0844036
LL	74	124.5760106	22.4471450	66.6582124	172.6226352
LK	74	421.7273446	60.4298792	258.2027820	557.4755808
T	74	2.0135135	0.8191750	1.0000000	3.0000000
HC	74	2.0678206	0.2709932	1.1584523	2.6646555
PolFree	74	0.8918919	0.3126365	0	1.0000000
Dev	74	0.8108108	0.3943323	0	1.0000000

Table 2: Means, Standard Deviations, Minimum and Maximum values of each of the variables. The sample consists of the OECD countries for the years 1975, 1980, and 1985. Y (output), L (workers), K (capital), and HC (human capital) are measured in natural logarithms.

Variable	N	Mean	Std Dev	Minimum	Maximum
ID	228	42.4473684	23.9169238	1.0000000	83.0000000
YEAR	228	1980.00	4.0914653	1975.00	1985.00
SL1	228	4.3114035	1.2981355	1.2000000	8.0000000
Y	228	24.3569054	1.6795981	21.3634400	29.0084899
K	228	25.2446846	1.7498688	21.3835925	29.9791404
L	228	15.3687355	1.3934938	11.5462732	19.5041045
KK	228	321.4481096	44.5449388	231.0359224	450.0844036
LL	228	119.0656690	21.7095099	66.6582124	190.2050467
LK	228	390.6180725	59.2450763	258.2027820	557.4755808
T	228	2.0000000	0.8182931	1.0000000	3.0000000
HC	228	1.5290915	0.6018132	-0.7721904	2.6646555
F	228	0.2412281	0.7559819	-1.0000000	1.0000000
Dev	228	0.3026316	0.4604079	0	1.0000000

Table 3: Means, Standard Deviations, Minimum and Maximum values of each of the variables. The sample consists of 77 counties for the years 1975, 1980, and 1985. Y (output), L (workers), K (capital), and HC (human capital) are measured in natural logarithms.

	(1) Coef	(2) T-Ratio	(3) Coef	(4) T-Ratio	(5) Coef	(6) T-Ratio	(7) Coef	(8) T-Ratio
Constant	2.1096	8.204	14.3199	13.3161	1.9952	8.252	13.4733	13.0836
$\ln(L)$	0.3267	14.299	1.5213	6.7987	0.3096	13.766	1.4938	6.4399
$\ln(K)$	0.6936	34.917	-1.0124	-6.1882	0.7109	37.218	-0.9311	-5.7882
$\ln^2(L)$	-	-	0.0218	0.6906	-	-	0.0223	0.6902
$\ln^2(K)$	-	-	0.1080	5.6153	-	-	0.1048	5.2803
$\ln(L)\ln(K)$	-	-	-0.0637	-2.6410	-	-	-0.0631	-2.5237
D=1 if 1980	-	-	-	-	-0.0610	-1.634	-0.0602	-1.9542
D=1 if 1985	-	-	-	-	-0.1522	-4.053	-0.1176	-3.3226
σ^2	0.2034	3.170	0.1831	5.5078	0.2036	2.933	0.1876	6.4956
γ	0.8820	18.669	0.8933	29.9653	0.8919	21.650	0.9048	38.7580
Constant	1.2977	5.242	1.2134	5.7010	1.3742	4.813	1.3110	6.0579
D=1 if developed	-2.1624	-2.138	-2.0182	-2.2767	-1.7291	-2.008	-1.8323	-3.0228
Human Capital	-0.3161	-2.477	-0.3593	-3.5050	-0.3588	-2.570	-0.4115	-4.0328
Econ Freedom	-0.2099	-2.841	-0.2242	-3.9379	-0.2356	-2.634	-0.2551	-4.5485
Pol Freedom	0.0167	0.225	-0.1884	-2.3881	0.0068	0.095	-0.2013	-2.8334
Log-likelihood	-7.5924		23.8186		0.9306		30.5136	
L-Elasticity	0.3267		0.2493		0.3096		0.2437	
K-Elasticity	0.6936		0.7351		0.7109		0.7456	
Test of Restrictions	76.2122	0.000	13.3900	0.020	59.1661	0.000		

Table 4: ML estimates of the production frontier and determinants of technical inefficiency for 77 countries–1975, 1980, 1985.

	(1) Coef	(2) T-Ratio	(3) Coef	(4) T-Ratio	(5) Coef	(6) T-Ratio	(7) Coef	(8) T-Ratio	(9) Coef	(10) T-Ratio
Constant	2.6579	7.240	26.1914	25.969	24.9121	25.090	25.9234	24.513	24.4787	18.398
$\ln(L)$	0.3527	11.178	1.5695	4.334	1.4672	3.962	1.5442	3.908	1.4580	4.235
$\ln(K)$	0.6567	21.397	-1.8313	-7.263	-1.6768	-6.618	-1.8037	-6.644	-1.6461	-6.410
$\ln^2(L)$	-	-	-0.1814	-2.460	-0.1682	-2.295	-0.1957	-2.656	-0.1790	-2.918
$\ln^2(K)$	-	-	0.0589	1.386	0.0557	1.300	0.0531	1.220	0.0514	1.398
$\ln(L)\ln(K)$	-	-	0.0598	1.066	0.0557	0.987	0.0687	1.207	0.0619	1.304
D=1 if 1980	-	-	-	-	-0.0020	-0.078	-	-	0.0010	0.035
D=1 if 1985	-	-	-	-	-0.0157	-0.601	-	-	-0.0114	-0.411
σ^2	0.0115	4.507	0.0099	3.634	0.0102	3.187	0.0089	3.200	0.0090	4.815
γ	0.3305	2.578	0.4261	2.110	0.4559	2.358	0.3450	1.682	0.3780	2.572
Constant	0.0774	0.190	0.7416	6.269	0.7531	6.002	0.2449	0.513	0.2527	0.600
D=1 if developed	-0.2789	-2.218	-0.2021	-2.971	-0.1970	-2.400	-0.2422	-3.147	-0.2388	-3.120
Human Capital	-0.4013	-2.121	-	-	-	-	-0.1775	-0.895	-0.1695	-1.094
Econ Freedon	-0.0749	-2.304	-0.1470	-4.262	-0.1524	-4.263	-0.1136	-3.012	-0.1220	-2.731
Taxes/GDP	0.3516	1.770	-	-	-	-	0.2157	1.008	0.2152	1.263
Pol Freedom	0.0118	0.123	-	-	-	-	0.0083	0.080	0.0113	0.138
Log-likelihood	71.0784		79.6077		79.7619		80.6931		80.8826	
L-Elasticity	0.3527		0.3132		0.3094		0.3011		0.2961	
K-Elasticity	0.6567		0.6790		0.6837		0.6932		0.6984	
Test of Restriction	19.6085	0.001	2.5498	0.769	2.2414	0.524	0.3790	0.827		

Table 5: ML estimates of the production frontier and determinants of technical inefficiency for the OECD countries–1975, 1980, 1985

	(1)	(2)	(3)	(4)	(5)	(6)
	Coef	T-Ratio	Coef	T-Ratio	Coef	T-Ratio
Constant	7.0392	28.682	9.6396	14.664	9.3535	13.44
$\ln(L)$	0.8138	38.379	0.6233	8.184	0.6472	8.201
$\ln(K)$	0.2272	11.121	-0.0232	-2.022	-0.0231	-2.015
$\ln^2(L)$	-	-	-0.0753	-3.336	-0.0577	-2.385
$\ln^2(K)$	-	-	0.0038	0.394	0.0115	1.095
$\ln(L)\ln(K)$	-	-	0.0354	2.231	0.0234	1.373
$Time$	-	-	-	-	-0.0095	-2.263
$Time^2$	-	-	-	-	0.0177	1.892
σ^2	0.0621	8.333	0.0128	11.086	0.0129	9.877
γ	0.8333	16.470	0.3169	4.980	0.3358	4.976
Constant	3.1050	12.740	-0.0610	-0.421	-0.0481	-0.385
D=1 if developed	-0.5579	-9.994	-0.4008	-6.977	-0.3862	-5.818
Human Capital	0.1197	1.639	-0.4603	-9.434	-0.4742	-8.911
Taxes/GDP	-0.8357	-8.468	0.3615	5.951	0.3595	6.384
log-likelihood	192.9718		490.9453		494.9164	
Labor Elasticity	0.8138		0.3772		0.3619	
Capital Elasticity	0.2272		0.6350		0.6520	
Test of Restrictions	603.8892	0.000	7.9423	0.019		

Table 6: ML estimates of the production frontier and determinants of technical inefficiency for the OECD countries –1965-1987.

Country	1975	1980	1985	Country	1975	1980	1985
Algeria	0.7126	0.6800	0.7037	Korea	0.9440	0.9233	0.9390
Argentina	0.8840	0.8611	0.8564	Madagascar	0.7104	0.7080	0.6906
Australia	0.9334	0.9384	0.9460	Malawi	0.3895	0.4109	0.4558
Austria	0.9425	0.9458	0.9456	Malaysia	0.9139	0.9133	0.9119
Bangladesh	0.7758	0.8429	0.9015	Mali	0.4526	0.5432	0.5319
Belgium	0.9576	0.9618	0.9645	Mauritius	0.6130	0.6983	0.8740
Bolivia	0.6664	0.6475	0.6698	Mexico	0.9243	0.9189	0.9096
Brazil	0.8643	0.8674	0.8612	Morocco	0.7798	0.8528	0.8450
Cameroon	0.6993	0.8479	0.8843	Netherlands	0.9426	0.9464	0.9492
Canada	0.9677	0.9691	0.9679	New Zealand	0.9543	0.9534	0.9559
Chile	0.7735	0.9228	0.9067	Nigeria	0.5643	0.5520	0.5433
Colombia	0.9047	0.9246	0.9281	Norway	0.8771	0.9104	0.9305
Costa Rica	0.9416	0.9348	0.9226	Pakistan	0.7731	0.8493	0.9073
Ivory Coast	0.7976	0.8081	0.7720	Panama	0.8681	0.9277	0.9334
Cyprus	0.9131	0.9165	0.9461	Paraguay	0.8973	0.8764	0.8909
Denmark	0.9426	0.9476	0.9583	Peru	0.8350	0.8300	0.8302
Ecuador	0.7738	0.8516	0.8661	Philippines	0.8878	0.8966	0.7785
Egypt	0.9135	0.9387	0.9377	Portugal	0.7301	0.8166	0.8106
El Salvador	0.9297	0.8981	0.8795	Rwanda	0.6669	0.8310	0.7728
Finland	0.9140	0.9323	0.9424	Senegal	0.6272	0.6446	0.7523
France	0.9457	0.9468	0.9445	Sierra Leone	0.7271	0.7399	0.6972
Germany	0.9317	0.9441	0.9452	Singapore	0.9383	0.9501	0.9385
Ghana	0.6259	0.6670	0.6964	Spain	0.9484	0.9460	0.9480
Greece	0.8954	0.9111	0.9084	Sri Lanka	0.9020	0.8361	0.8824
Guatemala	0.9244	0.9406	0.9204	Sweden	0.9518	0.9519	0.9591
Haiti	0.7386	0.7913	0.7120	Switzerland	0.9543	0.9560	0.9561
Honduras	0.8222	0.8729	0.8763	Tanzania	0.4036	0.4366	0.3854
Iceland	0.9498	0.9655	0.9673	Thailand	0.8091	0.8578	0.8775
India	0.7549	0.7746	0.8427	Tunisia	0.7048	0.7692	0.7872
Indonesia	0.9137	0.9188	0.9165	Turkey	0.8263	0.7855	0.8491
Iran	0.9664	0.8517	0.9273	Uganda	0.4460	0.2847	0.5261
Ireland	0.9592	0.9617	0.9616	United Kingdom	0.9520	0.9533	0.9612
Israel	0.9390	0.9509	0.9572	United States	0.9411	0.9499	0.9569
Italy	0.9213	0.9386	0.9420	Uruguay	0.8899	0.9016	0.8835
Jamaica	0.5467	0.4964	0.5329	Venezuela	0.9237	0.8806	0.8190
Japan	0.9383	0.9365	0.9400	Zaire	0.8044	0.6888	0.6556
Jordan	0.8583	0.9582	0.9446	Zambia	0.3091	0.3525	0.3905
Kenya	0.4087	0.4990	0.5623	Zimbabwe		0.5915	0.6464
Iraq	0.9742						

Table 7: Estimated efficiencies based on results in Table 4