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Introduction

Vast changes in the world economy over the past three decades suggest that a new modeling approach may be appropriate for estimating productivity levels. First, the contest between the market economy and the planned economy to determine the superior engine of growth has been over for more than a decade. Most experts agree that market forces are pre-eminent. The only question is: What is the proper level of government activity in the economy? All indications are that the optimal level of government activity to foster maximum growth may be quite limited. Continuing research over several decades has developed institutional measures that allow researchers to assess the impact of different levels of government activity on growth and productivity over substantial periods of time.

The second key change in the world over the same period is the shift from goods based to services based economies. Services productivity is closely related to the explosion in computing power and voice and data communication technologies.

Employing the latest advances in the stochastic-frontier production function approach, we are able to derive a model that allows us to simultaneously regress inefficiency estimates with variables measuring the institutional environment and the information and telecommunications network environment to explain inefficiency in the production function. Our model estimates for a panel of countries from 1975 to 1990 allows for a calculation of technical efficiency results by country.

The remainder of the paper is divided as follows. After a brief review of the literature, we discuss the model and the data, then the technical basis for the estimation of the model is developed, next the results are reported and, finally, policy conclusions are

suggested. Additional data for the decade of the 1990s will be available in future months providing additional significant information to the model.

Brief Review of the Literature

Adam Smith (1776) explains how the invisible hand of the market leads to the wealth of nations. Of course, there have to be reasonable and enforceable rules of the market game - protection of property is assumed, government is limited, growth flows from an expansion of the market through investments, trade, economies of scale and effective economic policy. And the industrial revolution follows with the cyclical processes of business. As a result of the Great Depression and Marxist experiments in Russia, China and elsewhere the stage is set for the battle between the market and the planned economy.

Economic development policy after WWII assumed the rich/poor country gap could only be bridged by massive transfer of resources from rich to poor to jump start poor economies through more or less central government planning. Foreign aid was supposed to be the key component. This approach was repudiated by assessments of the actual outcome (Bauer, 1972).

Modern growth theory is based on the work of Solow (1956) in which he argues that the inputs of capital, labor and technology provide the source of growth. More recent work incorporates human capital (Lucas 1988; Romer 1990) into the production process so that growth flows from both additional inputs and the enhancement of the inputs through education, training and the rapid dissemination of new information and technology.

North (1990) rediscovered the importance of the institutional environment in fostering markets that lead to economic growth. Friedman (1962) hypothesized that democracy and economic growth are strongly related. Scully (1988) finds that economic and political freedom are both strongly correlated with economic growth. Przeworski and Limongi (1997) rule out political freedom as a cause of economic growth. Barro's (1997) empirical growth model finds that low inflation policy, property rights, free trade and limited government all are found to have a favorable impact on growth.

In 1986, Michael Walker and Milton Friedman initiated a number of conferences on the essence of economic freedom. Gary Becker and Douglass North were also involved. Six meetings were held between 1986 and 1994 with many papers and ideas discussed. The economic freedom index (EFI) was developed as a result – now available for 123 countries. The overall index sums a number of subcomponents over the years 1970, 1975, 1980, 1985, 1990, 1995 and 2000. The five major subcomponents include government share of the economy, legal structure and protection of property rights, sound money, free international trade, and government regulation. In 2000 there are more than thirty-six total measures for some countries. In earlier periods fewer measures are available.

Gwartney et al. (2002) finds that EFI is a powerful factor in an economic growth model based on 82 countries covering various periods from 1975-1995. Dawson (1998) finds similar results using panel data.

Moroney and Lovell (1997) are the first to employ the stochastic-frontier approach to measure the difference in technical efficiency between planned and market economies. They find that East Europe approached only about 76 percent of the

efficiency of West Europe over the period 1978-80. Adkins et al. (2002) and Klein (2002) execute stochastic-frontier estimates that find EFI reduces production inefficiency. Klein also finds that a policy stability variable is an indicator of productivity. East Asia countries are shown by Klein to have high levels of enhanced productivity contrary to the arguments of Young (1994) and Krugman (1994) that larger inputs led to faster growth on the part of the Asian Tigers.

Röller and Waverman (2001) find for OECD countries that telecommunications infrastructure growth has a positive effect on economic growth especially when a threshold of universal service is achieved sometime during the 1970-1990 period. The vast majority of OECD countries, for the period studied, had state owned telecommunications enterprises and universal service was a subsidized government policy. Garbacz and Thompson (2003), supported by other work, find for the United States that both untargeted and targeted universal service policies for households from 1970-2000 were ineffective, inefficient and generally counter-productive. Nevertheless, some threshold level of telecommunications penetration as a measure of the extent of the information and communications network may provide additional possibilities for efficient interaction in the market.

Model and Data

Our model is a stochastic-frontier production function approach, with capital and labor as inputs. We simultaneously regress the inefficiency estimates from this model with an EFI variable, telephone penetration and a universal service threshold measure to help explain inefficiency in the production function. The results produce efficiency

indicators by country for a panel of 34 countries for the period covering 1975, 1980, 1985 and 1990. Countries for which all the data are available for the variables below are listed in table 1. The dependent variable in the production function format is real GDP per worker (RGDPW) and the independent variable is real capital per worker (RKW). Model 1 also includes the summary index for economic freedom (EFI). Model 2 includes telephone penetration in mainlines per thousand population (TL) and a universal service threshold variable (TD) in dummy variable form (1 is equal to or greater than 300 mainlines per thousand population and 0 is less than 300). Model 3 includes the combination of variables from models 1 and 2. We hypothesize that inputs to the production function should have positively signed parameters, and the variables explaining technical inefficiency should have negative signs if they act to reduce production inefficiency. Model 3 can be directly compared statistically with models 1 and 2 to determine the best model.

Estimation of the Model

We use a variant of the basic stochastic-frontier production function estimation technique developed by Aigner, Lovell and Schmidt (1977). The version we employ was proposed by Battese and Coelli (1995), which imposes reasonable restrictions on the model, allows the use of panel data and permits the simultaneous estimation of the frontier production function with the variables which may influence the efficiency of a country's production function. This method is an improvement over previous two-stage estimations which calculate a production frontier in stage one, and regresses the inefficiency error terms against possible explanatory variables in the second stage, by

avoiding an untested assumption of independence of the inefficiency terms in the two stages. Further support for the single-stage, simultaneous estimation relative to the 2-stage approach is given in Wang and Schmidt (2002). Estimation is performed using Frontier 4.1, Model 2, developed and referenced by Coelli (1996).

Specifically, Model 2 estimates a production function of the following form:

$$Y_{it} = x_{it}\beta + (V_{it} - U_{it}),$$

with $i = 1, \dots, N$ countries, and $t = 1, \dots, T$ time periods. Y is the output per worker variable for each country and time period (in the Cobb-Douglas production function form we are utilizing), and x is a vector of production inputs (capital per worker). The β is the unknown input parameters to be estimated (this formulation would be adjusted to reflect the multiplicative form of the production function we use). We also include time dummies in the production function for the 4 5-years time periods to control for unaccounted-for technical change. We have opted not to use country effects variables in our specification.¹

The V are randomly distributed error terms, and assumed to be independent of U , which are the non-negative error terms that are to account for technical inefficiency in production – and have a half-normal distribution as discussed in Aigner, Lovell and

¹ We elected not to use country effects variables for several reasons. First, the statistical properties of country effects estimators are poor for panels of this type (short and wide). Second, these variables imply that important changes in unmeasured effects occur between countries but not over time within a country (See Barro, 1997 for a complete discussion). Therefore, in this type of panel, controlling for unexplained changes over time is more important, in our opinion. Finally, Coelli (in correspondence) warns that problems could occur with his computer program when using country effects variables and estimating technical efficiency parameters simultaneously.

Schmidt (1977), and subsequent work. The U can then be explained in the following formula;

$$U_{it} = z_{it}\delta + w_{it},$$

where z is a vector of explanatory variables for technical inefficiency (ETI, telephone penetration, and universal service threshold variables), and δ is a vector of parameters to be estimated. The w are assumed to be randomly distributed error terms.

The ability of the model to estimate and explain a stochastic production frontier are indicated by the variation parameters $\sigma^2 \equiv \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2/\sigma^2$. The value of γ may be interpreted as an inefficiency indicator. As γ approaches zero, overall variation in the errors of the production function can be attributed to random elements. Alternatively, as γ approaches one, more of the estimation errors can be attributed to technical inefficiency. An efficiency measure, with ability to identify and rank the efficiency of production for different countries and time periods is developed by the program and is the ratio of the actual production level to the estimated production frontier level.

Results

Parameter estimates are reported in Table 3. Results of Models 1 and 3 are somewhat at odds with results reported by Adkins et al. (2002) and Klein (2002). In Model 1, our economic freedom summary variable has a smaller impact on technical efficiency relative to earlier findings, but the variable still explains virtually all of the technical inefficiency in the production function (a γ above 0.999). We believe the smaller estimated parameter may be partly the result of using different countries in the

sample but the main reason appears to be, at least for the Klein paper, that Klein has altered the economic freedom index numbers in a way that is not adequately explained in his write-up. In Model 3, which includes EFI and the telephone variables, the EFI parameter estimate is statistically insignificant.

In Model 1, we find that EFI parameter estimate has the correct signs and is statistically significant at high levels. Model 2, which includes the telephone penetration and universal service threshold variables, shows these estimated parameters to be highly significant and of the correct sign for reducing inefficiency in production. Model 3, which includes all three variables, is statistically superior to Model 1 but not to Model 2, based on a likelihood ratio test. There is no way to directly compare Models 1 and 2. Models 2 and 3 suggest that telephone access as a measure of the size of the information network, significantly reduces production inefficiency and therefore is conducive to greater productivity. Importantly, EFI is not statistically significant in Model 3 probably because of the strong correlation between the measures of economic freedom and the development of a telecommunications network. We use Model 3 to calculate specific technical efficiency scores by country as reported in table 4.

The changes in technical efficiency in East Asia shown in table 4 are quite large such as in Hong Kong, Taiwan and Thailand. In Japan the change is a bit smaller though still large by world standards of our thirty-four country group. The South Korean result is quite small over the whole period but is substantial from 1985 to 1990. This provides additional evidence that the Asian Tiger phenomenon is real. In each of these countries telephone penetration had reached a relatively high level by 1990, with the exception of Thailand.

In the rest of the world category, Italy makes a very good showing especially for a developed country. The United States, as with many of the highly developed western economies, has little margin for improvement in production efficiency, relative to non-western countries. The Philippines suffered a disastrous decline.

An additional decade of data will be available soon. The decade of the 1990s with its enormous advances in voice and data communications, especially with the growth in cell phones and Internet services, should have an important impact on our model.

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Table 1: Countries

Argentina
Australia
Belgium
Canada
Chile
Denmark
Finland
France
Germany
Greece
Guatemala
Hong Kong
India
Israel
Italy
Japan
Kenya
Mexico
Netherlands
New Zealand
Nigeria
Norway
Philippines
Portugal
South Korea
Spain
Sweden
Switzerland
Taiwan
Thailand
Turkey
United Kingdom
United States
Venezuela

Table 2: Summary Statistics

Variable	Mean	Std.	Min	Max	Number
RPGDPW	17946.640	9556.810	1863.000	36771.000	136
RKW	19479.272	14043.400	553.000	73459.000	136
EFI	5.964	1.160	3.060	8.660	136
TL	238.463	184.329	1.000	680.800	136
TD	0.427	0.496	0	1	136

Table 3: Model Results

Parameter	Variable	Model 1	Model 2	Model 3
β_0	Constant	1.632*** (0.1508)	1.9803*** (0.0882)	1.903*** (0.0824)
β_1	RKW	0.676*** (0.0199)	0.584*** (0.0214)	0.584*** (0.0199)
δ_0	Constant	0.308*** (0.1112)	0.273*** (0.0548)	0.238*** (0.1006)
δ_1	EFI	-0.011*** (0.0043)	-----	0.008 (0.0092)
δ_2	TL	-----	-0.098*** (0.0194)	-0.102*** (0.0184)
δ_3	TD	-----	-0.076** (0.0360)	-0.083*** (0.0322)
σ^2		0.010*** (0.0026)	0.020*** (0.0069)	0.020*** (0.0062)
γ		0.999*** (0.0845)	0.931*** (0.0440)	0.931*** (0.0432)
Log – Likelihood		123.946	133.169	133.240
Mean Efficiency		0.785	0.881	0.881

Table 4: Country Production Performance

Country	Year	Output Per Worker	Capital Per Worker	Production Efficiency	Average Country Efficiency	Percentage Change: 1975-90	Telephone Mainlines per 1,000	Percentage Change: 1975-90
Arg	1975	16043	9445	0.9627			63.3	
Arg	1980	17828	11663	0.9664			66.8	
Arg	1985	14955	12084	0.9253			89.8	
Arg	1990	13406	11244	0.8837	0.9346	-8.56%	93.0	38.00%
Aus	1975	25988	28530	0.9177			254.7	
Aus	1980	27276	31080	0.9351			322.7	
Aus	1985	28960	33875	0.9500			391.8	
Aus	1990	30312	37854	0.9297	0.9331	1.30%	456.3	56.71%
Belg	1975	24859	26999	0.9122			188.8	
Belg	1980	27739	31324	0.9337			247.9	
Belg	1985	27325	33160	0.9360			307.6	
Belg	1990	31730	36646	0.9490	0.9327	3.95%	392.5	70.08%
Can	1975	27350	25813	0.9559			356.6	
Can	1980	28725	28910	0.9608			405.7	
Can	1985	31147	34535	0.9644			481.1	
Can	1990	34380	42745	0.9471	0.9571	-0.93%	564.9	45.21%
Chile	1975	9173	6907	0.8380			28.7	
Chile	1980	11498	6997	0.9276			32.5	
Chile	1985	9768	7060	0.8827			44.4	
Chile	1990	11854	9543	0.8723	0.8801	4.01%	65.9	78.65%
Den	1975	20250	24650	0.8653			337.2	
Den	1980	21481	28223	0.8723			434.2	
Den	1985	23861	29286	0.9165			497.3	
Den	1990	24971	33125	0.8897	0.8860	2.78%	566.8	50.80%
Finland	1975	19698	28920	0.8190			287.1	
Finland	1980	21788	33564	0.8416			364.0	
Finland	1985	23700	38591	0.8565			446.6	
Finland	1990	27350	45767	0.8552	0.8431	4.33%	534.1	60.16%
France	1975	23818	24242	0.9190			134.7	
France	1980	26810	29104	0.9375			295.0	
France	1985	27064	31796	0.9419			416.5	
France	1990	30357	35600	0.9419	0.9351	2.46%	495.2	114.46%
Germany	1975	23342	27757	0.8842			207.5	
Germany	1980	27273	32672	0.9254			331.8	
Germany	1985	27252	35693	0.9216			416.0	
Germany	1990	30099	39884	0.9167	0.9120	3.61%	440.8	71.97%
Greece	1975	13532	16380	0.8036			186.4	
Greece	1980	15511	19891	0.8245			235.4	
Greece	1985	16270	22151	0.8384			313.7	
Greece	1990	17717	23476	0.8395	0.8265	4.37%	388.6	70.33%
Guat	1975	7639	3040	0.9361			7.9	
Guat	1980	9044	4118	0.9463			11.9	
Guat	1985	7358	3985	0.8981			16.0	
Guat	1990	7435	3647	0.9034	0.9210	-3.55%	21.2	91.41%
HK	1975	9730	9758	0.7936			190.4	

Country	Year	Output Per Worker	Capital Per Worker	Production Efficiency	Average Country Efficiency	Percentage Change: 1975-90	Telephone Mainlines per 1,000	Percentage Change: 1975-90
HK	1980	14030	12189	0.8873			253.7	
HK	1985	16447	11220	0.9669			323.3	
HK	1990	22827	12762	0.9867	0.9086	21.69%	450.1	81.09%
India	1975	2069	1259	0.6804			2.3	
India	1980	2292	1514	0.6898			3.1	
India	1985	2719	1712	0.7304			4.1	
India	1990	3235	1946	0.7462	0.7117	9.22%	5.9	87.80%
Israel	1975	20237	19967	0.9027			172.7	
Israel	1980	21192	21578	0.9175			221.5	
Israel	1985	21953	22307	0.9365			278.7	
Israel	1990	23780	21453	0.9560	0.9282	5.73%	343.2	66.10%
Italy	1975	21359	21527	0.9058			174.2	
Italy	1980	26847	25391	0.9591			230.7	
Italy	1985	27189	28117	0.9610			304.5	
Italy	1990	30797	31640	0.9625	0.9471	6.07%	387.6	75.97%
Japan	1975	13381	16400	0.8005			289.2	
Japan	1980	16284	22085	0.8254			341.1	
Japan	1985	18820	28106	0.8402			374.2	
Japan	1990	22624	36480	0.8348	0.8252	4.19%	441.1	41.60%
Kenya	1975	1945	1205	0.6713			3.8	
Kenya	1980	2157	1224	0.7085			4.4	
Kenya	1985	2014	1187	0.7058			5.9	
Kenya	1990	1863	907	0.7151	0.7002	6.33%	7.6	66.67%
Mexico	1975	16328	11786	0.9690			27.9	
Mexico	1980	18890	14047	0.9624			40.2	
Mexico	1985	17036	14016	0.9788			49.5	
Mexico	1990	17012	12900	0.9773	0.9719	0.85%	64.8	79.61%
Nether	1975	27421	25511	0.9347			244.0	
Nether	1980	29233	28922	0.9611			345.7	
Nether	1985	28563	29325	0.9458			401.8	
Nether	1990	31242	32380	0.9455	0.9468	1.15%	464.1	62.17%
Nigeria	1975	3067	553	0.9241			1.0	
Nigeria	1980	3606	991	0.9004			1.0	
Nigeria	1985	2874	1103	0.9202			2.4	
Nigeria	1990	2082	702	0.8782	0.9057	-5.09%	3.0	100.00%
Norway	1975	21850	38930	0.9645			228.0	
Norway	1980	25265	41244	0.9268			292.9	
Norway	1985	28749	44866	0.8447			423.2	
Norway	1990	29248	48135	0.8090	0.8862	-17.53%	501.8	75.03%
NZ	1975	25970	25788	0.9583			319.7	
NZ	1980	24614	28190	0.9644			361.4	
NZ	1985	26039	30511	0.9661			395.7	
NZ	1990	25413	33080	0.9627	0.9629	0.46%	433.6	30.24%
Phil	1975	4458	3314	0.8330			6.6	
Phil	1980	5176	3698	0.7996			8.6	
Phil	1985	4229	4087	0.7615			9.3	
Phil	1990	4784	3698	0.7086	0.7757	-16.13%	10.0	40.96%

Country	Year	Output Per Worker	Capital Per Worker	Production Efficiency	Average Country Efficiency	Percentage Change: 1975-90	Telephone Mainlines per 1,000	Percentage Change: 1975-90
Portugal	1975	10354	7461	0.7470			89.5	
Portugal	1980	11321	8111	0.7849			106.7	
Portugal	1985	11343	9503	0.7187			145.2	
Portugal	1990	16637	11819	0.7593	0.7525	1.63%	242.5	92.17%
SK	1975	6245	6533	0.9550			29.9	
SK	1980	8004	9759	0.8935			70.9	
SK	1985	10361	12036	0.8776			159.7	
SK	1990	16022	17995	0.9529	0.9198	-0.22%	309.6	164.77%
Spain	1975	20722	15309	0.8674		8.58%	132.2	
Spain	1980	21449	19428	0.9405			193.3	
Spain	1985	21169	21831	0.9276			242.5	
Spain	1990	26364	27300	0.9452	0.9202	8.59%	315.9	81.99%
Sweden	1975	24795	25611	0.9302			513.7	
Sweden	1980	24864	28773	0.9212			579.9	
Sweden	1985	26504	31326	0.9389			627.8	
Sweden	1990	28389	39409	0.8999	0.9226	-3.31%	680.8	27.98%
Switz	1975	27074	51159	0.8188			385.6	
Switz	1980	29548	57061	0.8397			444.6	
Switz	1985	29848	62769	0.8380			501.6	
Switz	1990	32812	73459	0.8229	0.8299	0.50%	573.5	39.18%
Taiwan	1975	7657	8451	0.7432			47.9	
Taiwan	1980	10837	13664	0.7775			130.5	
Taiwan	1985	12701	19194	0.7786			219.5	
Taiwan	1990	18409	25722	0.8333	0.7832	11.44%	309.6	146.41%
Thailand	1975	3371	2385	0.7142			5.5	
Thailand	1980	4296	3359	0.7387			8.1	
Thailand	1985	4751	4051	0.7490			12.6	
Thailand	1990	6754	4912	0.8103	0.7530	12.60%	24.2	125.93%
Turkey	1975	6416	4717	0.7922			16.8	
Turkey	1980	6692	6513	0.7594			25.6	
Turkey	1985	7091	6989	0.7778			44.3	
Turkey	1990	8632	7589	0.8123	0.7854	2.50%	121.4	151.37%
UK	1975	19843	14618	0.9547			235.3	
UK	1980	21246	16563	0.9654			322.4	
UK	1985	22981	17636	0.9771			373.9	
UK	1990	26755	21179	0.9768	0.9685	2.29%	440.7	60.77%
USA	1975	30134	26109	0.9727			372.8	
USA	1980	31698	27551	0.9793			414.0	
USA	1985	33783	29925	0.9837			486.3	
USA	1990	36771	34705	0.9799	0.9789	0.74%	544.5	37.44%
Ven	1975	23889	17017	0.9709			39.3	
Ven	1980	22461	21827	0.9300			53.0	
Ven	1985	18362	20419	0.8877			70.8	
Ven	1990	17426	18271	0.8754	0.9160	-10.35%	76.2	63.90%