Measuring and Explaining the Impact of Productive Efficiency on Economic Development

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A limitation of most empirical cross-country studies that focus on determinants of GDP or GDP growth is that they fail to distinguish explicitly between inputs used in production and conditions that facilitate production. For example, physical capital, human capital, and labor are production inputs, whereas the quality of institutions, macroeconomic stability, and market quality are conditions that facilitate production. This article takes this distinction seriously and uses a stochastic frontier approach to study factors affecting economic performance. A panel data set of 71 countries for the 1980–98 period is used to estimate a production frontier with physical capital, human capital, and labor as inputs. The article also analyzes what drives productive efficiency, using the institutional framework, macroeconomic stability, market quality, and urbanization as possible explanatory factors. Urbanization turns out to be an important determinant, with the rule of law, inflation rate, and market quality also affecting productive efficiency.

Measuring economic performance is an issue not only of academic interest but also of practical concern. Numerous cross-country studies that use gross domestic product (GDP) levels or growth rate as a yardstick for economic performance have found that conventional factors used to determine output, such as physical and human capital and labor force size, do not fully explain production. Although the results are somewhat sensitive to the model specification, measures of market distortion, macroeconomic environment, political stability, research and development, and the depth of financial markets have all been found to affect economic development (for reviews, see among others Barro and Sala-i-Martin 1995; Sala-i-Martin 1997; Solow 2000; Aron 2000; Easterly 2001).

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I. The Literature on Productive Efficiency

The focus in the literature has recently shifted to the quality of public and private institutions and of markets in explaining economic performance in cross-country analyses (Brunetti and others 1998; Hall and Jones 1999; Knack and Keefer 1995; Keefer and Knack 1997).[1] Although the institutional framework and market structure of a country measure different aspects, they overlap to a considerable degree. Both can be measured by such factors as the quality of bureaucracy, pervasiveness of corruption, rule of law, risk of appropriation, contract repudiation, political environment, and civil liberties, and both would be expected to have an impact on production and allocation decisions. Market and institutional deficiencies may distort public and private decisionmaking and lead entrepreneurs to undertake wasteful rent-seeking activities that divert time and resources from productive activities, thereby preventing firms from adjusting effectively to technological change. Weak institutions and market structures may result in suboptimal selection and use of inputs. In developing economies, where the potential for industrialization and the potential gains from industrialization are higher, the inability of firms to fully benefit from low-cost access to advanced technology from overseas and better returns to scale (relative to developed economies) may be especially damaging to development.

The macroeconomic environment has also received much attention in studies of economic performance. The inflation rate, and to a lesser extent the black market premium, are widely used as proxies for macroeconomic conditions. Numerous theoretical studies have also focused on the costs of inflation (for surveys, see Briault 1995; Temple 2000). These analyses have shown that businesses and households perform poorly when inflation is high and unpredictable. Although empirical studies have found some support for the harmful effects of inflation, the evidence is not overwhelming. Inflation rates of 100 percent a year or higher have been found to inhibit economic development, but the impact of moderate inflation is less clear.

Urbanization has largely been omitted in models of economic performance, yet the results reported here show it to have a key positive impact on productive efficiency. Urbanization likely influences productive efficiency through a variety of channels (for a review of the role of cities in development, see World Bank 2002, chap. 6). With the presence of universities, research centers, and many firms, cities thrive on learning and innovation, thereby facilitating spillover

1. Brunetti and others (1998), using firm-level data from a private sector survey in 73 countries to gauge the environment faced by local businesses, find that the institutional framework is crucial in explaining differences in economic performance. Hall and Jones (1999) also find that good institutions and sound policies help for economic development by supporting entrepreneurial activities, capital accumulation, invention, skill acquisition, and technology transfers. Aiming to explain why poor countries are falling behind rather than catching up with wealthy nations, Keefer and Knack (1997) also conclude that deficient institutions and government policies lead to poor performance.

effects (Glaeser and others 1992; Adams 2001). Personal contacts remain important in the digital age, and they are easier to maintain in cities (Wheeler and others 2000; Glaeser 1998; Lall and Ghosh 2002). Cities lead to economies of scale, encourage the division of labor, and provide a better environment for matching skills with needs (Quigley 1998; Mills 2000; Ciccone and Hall 1996). Cities also make access to education, health services, and infrastructure easier because costs tend to be lower and competition is greater.

One limitation of most cross-country studies is that they lump together all the independent variables in regressions that focus on the determinants of GDP levels or growth rates. Yet not all independent variables are the same. Variables such as physical capital, human capital, and labor are production inputs, but others such as the quality of institutions, market structures, or macroeconomic management are conditions that facilitate production, not inputs. This article takes this distinction seriously. It estimates a production function that depicts optimal output levels given input use and measures economic performance using the productive efficiency of reaching optimal output. This framework is used to analyze the determinants of efficiency that facilitate the production process. A range of institutional, macroeconomic, and market quality variables as well as the level of urbanization are explored.

The work on analyzing productive efficiency dates back to empirical work by Farrell (1957). Over time two broad approaches have been used in production frontier estimation: deterministic methods and stochastic techniques.[2] The deterministic methods, data envelopment analysis and the free disposal hull, apply linear programming techniques to construct a frontier by using a piecewise linear envelope that connects best performers.[3] The main advantage of the deterministic methods is that none or few restrictions are imposed on the production technology, but the disadvantage is the inability to disentangle white noise from the inefficiency measures. In the stochastic techniques random shocks are incorporated that account for some of the deviations from the production frontier. Following Aigner and others (1977) and Meeusen and van den Broeck (1977), the first technique (the error components model) assumes that the error term has two components: one for white noise and one a nonnegative component for inefficiency (Battese and Coelli 1992, 1995). The second technique applies fixed-effects and random-effects methods to measure efficiency, with the effects being nonnegative (Cornwell and others 1990; Kumbhakar 1990).

2. As noted by an anonymous referee, in the 1960s there was much activity estimating production functions and using the results to assess relative levels of efficiency (see, for example, Arrow and others 1961). Economists were reluctant to introduce noninput variables directly into the production function but would compute the residual and try to explain it through various factors (see, for example, Denison 1964). Covariance analysis, or panel estimation, was used to allow for unobserved country-specific effects, and some researchers regarded the dummy variables as measures of efficiency to be explained.

3. On data envelopment analysis, see Charnes and others (1978), Färe and others (1994), Coelli (1995), Tulkens and Vanden Eeckhaut (1995), and Kumar and Russell (2002). On free disposal hull analysis, see Deprins and others (1984) and Tulkens (1993).

II. Methodology

This article estimates a production frontier using an extension to panel data of the error components model of Aigner and others (1977) proposed by Battese and Coelli (1992, 1995). Similar to the augmented neoclassical model, the model uses physical capital, human capital, and labor force size as production inputs. The production frontier, given input use, depicts the optimal output level, whereas country-level productive efficiency is measured by comparing actual outcome and optimal outcome. The model estimates the impact on productive efficiency of the institutional framework, macroeconomic stability, market quality index (reliance on market mechanisms in the production process and allocation of resources), and level of urbanization.

Other efforts have been made recently to analyze the role of various factors in determining productive efficiency. For example, Kumar and Russell (2002) use the data envelopment analysis estimation approach and focus on labor productivity growth for 57 countries over 1965–90. They construct a world production frontier and decompose labor productivity growth into technological change, improvements in efficiency, and capital accumulation. This article uses the stochastic frontier approach instead and focuses on a different outcome, namely, GDP. It calculates productive efficiency by estimating a world production frontier and attempts to explain what drives productive efficiency. Rather than explicitly discussing the impact of technological change, improvements in efficiency, and capital accumulation on country-level production, it focuses primarily on factors driving improvements in efficiency.

The stochastic frontier approach proposed in Battese and Coelli (1992, 1995) and panel data are used to estimate a production possibilities frontier to determine optimal GDP outcomes given input use. The model estimated in this study is discussed in Kumbhakar and Lovell (2000), and a generalized production frontier approach to estimating inefficiency can be found in Kumbhakar and others (1991). Comparing a country's actual GDP outcome with the optimal GDP outcome derived from the production frontier yields a measure of economic performance—productive efficiency. This estimation framework can be used to quantify the impact of the institutional structure, macroeconomic environment, market quality, and urbanization on a country's economic performance in reaching optimal GDP outcomes.

Let Y_{it} represent real GDP for country i at time period t, and let X_{it} depict the inputs used in production: physical capital, human capital (years of schooling), and number of workers. The log-log specification is used in the estimation. Incorporating the period variable (t) captures the impact of technology improvements. Over time, technology is expected to improve and cause an outward shift in the production frontier. As a result, the parameter corresponding to the period variable is expected to be positive (and is also used as a robustness test for the stability of the impact of other variables). To enable the production frontier to vary by region, regional dummy variables (D_{Region}) are used for Asia, Latin America and the Caribbean, Middle East and North Africa, and North America and Europe, with Africa as the omitted region (see appendix table A.1 for the list of countries by region).[4] These regional dummy variables enable testing for the robustness of the findings with and without their inclusion in the specification. The regional dummy variables are also important because, even after controlling for inputs and efficiency, other regional (or country-level) factors may affect GDP.[5] For example, as noted by Nelson and Pack (1999), rapid growth in some Asian economies was accompanied by "productive assimilation" or shifts in the size of firms and sectors of specialization, which led to changes in economic structure and higher growth.

The production frontier is estimated as follows:

$$(1) \qquad \ln Y_{it} = \alpha + \ln X_{it}\beta + t\beta_{Period} + \sum \gamma_{\text{Region}} D_{\text{Region}} + (v_{it} - u_{it})$$
$$i = Country\ 1, \ldots, Country\ N\ and\ t = 1, \ldots, T.$$

The technical inefficiency effects are estimated as:

$$(2) \qquad u_{it} = \delta_0 + \sum \delta_j^{Institutinal} Z_{it}^{Institutional} + \delta_{INF} Inflation_{it} + \delta_{MKT} Market_{it} + \delta_{URB} Urban_{it} + w_{it}$$

$$u_{it} = {}^{*}Z_{it}\delta + w_{it}$$

Estimating equations 1 and 2 separately leads to biased results (Wang and Schmidt 2002), and thus a one-step procedure is used in the estimation. The error term in the production frontier presented in equation 1 consists of two components: the random noise term (v_{it}) that accounts for random shocks and measurement errors, and the nonnegative term (u_{it}) used to measure inefficiency. The v_{it} and the u_{it} terms are assumed to be independent. The v_{it} term is assumed to be *iid* $N(0,\sigma_v^2)$. The nonnegative u_{it} term that depicts deviation from the optimal (best practice) outcome is assumed to be independently distributed of the factor inputs (X), and as modeled in equation 2 is a function of country-specific variables that vary over time. The u_{it} term is obtained from a truncated (at zero) normal distribution with a variance of σ_u^2, but with means that are a linear function of the observable country-specific variables.[6]

The production frontier presented in equation 1 is in terms of known input and output variables, whereas the inefficiency terms are assumed to be a function of

4. Any geographic grouping is somewhat arbitrary, but the regional groups probably capture some relevant commonalities across countries.

5. The authors are grateful to an anonymous referee for pointing this out.

6. The u_{it} term is assumed to be independently distributed and is obtained from a truncated normal distribution with a mean of ${}^{*}Z_{it}\delta$ and a variance of σ_u^2 (Battese and Coelli 1995). The derivation of the log-likelihood function using the distributional assumptions on the u_{it} and v_{it} terms and the maximum likelihood estimation approach used in the estimation are discussed in Battese and Coelli (1995).

an unknown vector of coefficients, δ, and a known set of the institutional, macroeconomic, and market quality variables along with urbanization. Indices of bureaucratic quality, prevalence of corruption, and rule of law are used as institutional variables. The inflation rate is used as a proxy for macroeconomic stability. The reliance of a country on market mechanisms in the production process and allocation of resources is proxied using a market quality index.

The productive efficiency measure of country i at time period t is defined as:[7]

$$(3) \qquad Efficiency_{it} = \frac{E(Y_{it}|X_{it}, D_{Region}, u_{it})}{E(Y_{it}|X_{it}, D_{Region}, u_{it} = 0)}$$

$$i = Country\ 1, \ldots, Country\ N \text{ and } t = 1, \ldots, T$$

The numerator depicts the observed country i outcome in period t at a given level of input use, X_{it}. The denominator represents the corresponding optimal (or best practice) outcome for country i in period t, which implies no inefficiency ($u_{it} = 0$).

The maximum likelihood estimation method is used to simultaneously estimate parameters of the stochastic frontier (equation 1) and the model for technical inefficiency effects (equation 2).[8]

III. Data

The study uses data for 71 countries for 1980–98. All variables are averaged over five-year intervals (1980–84, 1985–89, 1990–94, and 1995–98) to reduce the impact of short-run fluctuations on the estimated parameters (to capture long-term effects). There are two groups of variables: one for estimating the production frontiers and one for explaining country efficiency in producing output.

The first group of variables consists of real GDP, real domestic capital stock, average years of schooling (a proxy for a country's stock of human capital), and total number of workers. Data on real GDP and total number of workers (a country's employment base) are from Penn World Table 6.0, compiled by Heston and Summers (1996). Real GDP is in constant U.S. dollars at purchasing power parity (PPP) terms (chain index; expressed in international prices, base 1996). The Heston and Summers real GDP measures account for and assign suitable weights for cross-country price differences of various components of GDP, which enables meaningful cross-country comparisons. Real domestic capital stock data are from Kraay and others (2001) in constant U.S. dollars

7. The conditional expectation of the u_{it} term, conditional on the observed value of $v_{it} - u_{it}$, is used in calculating the efficiency measures (Battese and Coelli 1992, 1995).

8. FRONTIER version 4.1 is used in the estimation (Coelli 1996).

in PPP terms.[9] The human capital data are from the educational attainment database compiled by Barro and Lee (2000).

The second group of variables consists of country-level data on the institutional framework, macroeconomic stability, market quality, and urbanization. Indices of bureaucratic quality, prevalence of corruption, and rule of law are used to proxy a country's institutional framework. Data on these indices are from the *International Country Risk Guide* (ICRG) published regularly by Political Risk Services (2004; see www.prsgroup.com/icrg/icrg.html). Data on the structure of the economy and use of markets variable used to measure a country's market quality are from the *Economic Freedom of the World: 2001 Annual Report* (Gwartney and Lawson 2001). Data on the inflation rate, used as a proxy for a country's macroeconomic stability, and urbanization are from the World Development Indicators database (World Bank 2001).

The ICRG indices are subjective assessments by a worldwide network of experts. To ensure coherence and cross-country comparability, the indices are subject to peer review. The bureaucratic quality index measures the strength and expertise of bureaucrats and their ability to manage political alterations without drastic interruptions in government services or policy changes. Higher values of this index indicate greater bureaucratic quality. The rule of law index assesses the strength and impartiality of the legal system and popular observance of the law. Higher values of this index indicate more effective enforcement and greater adherence to the law. The corruption index measures actual or potential corruption within the political system, which distorts the economic and financial environment, reduces government and business efficiency by enabling individuals to assume positions of power through patronage rather than ability, and introduces inherent instability in the political system. Higher values indicate a decreased prevalence of corruption. The three indices, which use different rating systems, have been normalized to take values between 0 and 100, with higher values indicating better outcomes.

Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a fixed basket of goods and services. A country's market power is proxied by the structure of the economy and use of markets variable. The share of the public sector in industry and investment, use of price controls, and top marginal tax rates are incorporated in this index. This index has been normalized to take values between 0 and 100, with higher values indicating the existence of more effective market structures. Urbanization data refer to the urban population as a share of the total population.

9. As described in Kraay and others (2001), initial estimates of domestic capital stock are obtained from the Penn World Table data set. Flow data on gross domestic investments are then used to construct time series of capital stock measures valued in constant U.S. dollars at PPP (base year 1990). Although it could be interesting to test for the sensitivity of the results here to alternative choices for the measurement of capital (say, not using PPP-based data), such alternative measures are not available.

Summary statistics indicate that in general, input use increased over the 1980–98 period, although with differences across regions (table 1). The Africa region is the least endowed in physical capital (the stock of physical capital even declined), human capital, and number of workers and thus has the lowest optimal output among all regions. In contrast, the North America and Europe region has high and increasing endowment levels and is thus able to reach the highest optimal output levels. The Asia, Latin America and Caribbean, and Middle East and North Africa regions in general have also experienced a steady increase in input endowments over time.

Summary statistics indicate that the variables used for the determinants of efficiency improved over the 1980–98 period, although again with differences across regions (table 2). As was the case for input endowments, the Africa region has the smallest magnitudes for the efficiency determinant variables, implying greater potential for efficiency enhancements in the region from improvements in the institutional framework, macroeconomic stability, and market quality and from greater urbanization. The North America and Europe region has high magnitudes for the efficiency-determinant variables and has had steady improvements over time. The Asia, Latin America and Caribbean, and Middle East and North Africa regions generally also experienced steady improvements in the determinants of efficiency variables during this period.

IV. Results

The estimation results can be divided into two broad categories: production frontier estimates and determinants of efficiency. Results are presented for four different specifications to provide tests for robustness. The specifications vary by whether a time trend is used in the production frontier or in the determinants of inefficiency and whether regional dummy variables are included in the production frontier. Regional differences as captured by regional dummy variables could themselves reflect differences in conditions that facilitate production, such as the bureaucratic quality index or the market quality index.[10] For example, if African countries have a lower efficiency level, this may not be because of "Africanness" but possibly because of factors influencing efficiency (for example, lower rule of law index or a higher black market premium). At the same time there may still be real differences in efficiency related to geographic location. To deal with this issue, the model is estimated with and without regional dummy variables.

The parameter estimates for the production frontiers show that a country's physical capital stock and number of workers have a positive and statistically significant affect on GDP levels (table 3). Given the log-log specification for key inputs, the associated parameters represent elasticities. A 1 percentage point increase in the level of capital stock leads to a 0.38–0.43 percentage point increase in GDP. A 1 percentage point increase in the number of workers leads

10. The authors are grateful to an anonymous referee for pointing this out.

Table 1. Summary Statistics for Production Function Variables, 1980–98

		1980–84	1985–89	1990–94	1995–98
Africa region					
Number of observations		5	10	13	7
GDP (constant 1996 US$ at PPP; billions)	Mean	16.71	16.10	14.57	19.50
Capital stock (constant 1990 US$ at PPP; billions)	Mean	18.21	12.47	10.52	13.32
Years of schooling	Mean	2.29	2.47	2.87	3.75
Workers (thousands)	Mean	5,859	5,340	5,869	6,129
Asia region					
Number of observations		11	13	12	14
GDP (constant 1996 US$ at PPP; billions)	Mean	392.33	568.48	786.71	876.24
Capital stock (constant 1990 US$ at PPP; billions)	Mean	745.60	1,044.20	1,518.83	1,755.54
Years of schooling	Mean	5.46	5.70	6.46	6.69
Workers (thousands)	Mean	48,481	95,543	110,871	103,011
Latin America and Caribbean region					
Number of observations		15	19	18	19
GDP (constant 1996 US$ at PPP; billions)	Mean	136.15	126.15	149.14	166.30
Capital stock (constant 1990 US$ at PPP; billions)	Mean	200.38	184.84	242.77	278.42
Years of schooling	Mean	4.39	4.80	5.17	5.39
Workers (thousands)	Mean	7,392	7,026	8,439	9,088
Middle East and North Africa region					
Number of observations		3	3	5	5
GDP (constant 1996 US$ at PPP; billions)	Mean	72.17	86.11	119.44	144.66
Capital stock (constant 1990 US$ at PPP; billions)	Mean	55.11	77.99	313.12	115.60
Years of schooling	Mean	4.42	4.81	4.87	5.46
Workers (thousands)	Mean	5,100	5,856	7,612	8,325
North America and Europe region					
Number of observations		14	17	17	18
GDP (constant 1996 US$ at PPP; billions)	Mean	645.23	678.10	760.07	819.12
Capital stock (constant 1990 US$ at PPP; billions)	Mean	1,453.91	1,467.97	1,657.27	1,674.34
Years of schooling	Mean	7.56	8.06	8.63	9.01
Workers (thousands)	Mean	16,392	15,316	16,104	15,937

Source: Heston and Summers (1996); Barro and Lee (2000); Kraay and others (2001); World Bank (2001).

TABLE 2. Summary Statistics for Determinants of Inefficiency, 1980–98

	1980–84	1985–89	1990–94	1995–98
Africa region				
Bureaucratic quality index				
Number of observations	5	10	13	7
Mean	33.33	47.00	46.67	47.62
Minimum	16.67	20.00	26.67	16.67
Maximum	50.00	66.67	66.67	62.50
Corruption index				
Number of observations	5	10	13	7
Mean	36.67	43.00	48.46	45.24
Minimum	0.00	0.00	0.00	33.33
Maximum	66.67	66.67	63.33	50.00
Rule of law index				
Number of observations	5	10	13	7
Mean	23.33	40.00	43.07	61.31
Minimum	16.67	16.67	13.33	37.50
Maximum	33.33	83.33	83.33	75.00
Inflation				
Number of observations	5	10	13	7
Mean	32.32	37.37	29.05	20.33
Minimum	13.56	2.73	4.35	5.68
Maximum	70.28	155.25	122.19	37.13
Market quality index				
Number of observations	5	10	13	7
Mean	23.80	22.60	19.77	46.64
Minimum	17.00	13.00	0.00	34.50
Maximum	30.00	31.00	43.00	60.50
Urbanization				
Number of observations	5	10	13	7
Mean	22.14	27.82	31.86	34.04
Minimum	9.62	10.42	11.72	13.35
Maximum	31.64	39.58	55.40	49.00
Asia region				
Bureaucratic quality index				
Number of observations	11	13	12	14
Mean	59.09	59.74	63.33	69.35
Minimum	16.67	16.67	30.00	37.50
Maximum	100.00	100.00	100.00	100.00
Corruption index				
Number of observations	11	13	12	14
Mean	48.48	50.00	59.44	58.63
Minimum	0.00	0.00	33.33	33.33
Maximum	100.00	100.00	96.67	91.67
Rule of law index				
Number of observations	11	13	12	14
Mean	56.06	50.26	61.39	78.57
Minimum	16.67	13.33	16.67	50.00
Maximum	100.00	100.00	100.00	100.00
Inflation				
Number of observations	11	13	12	14
Mean	10.41	7.18	7.25	6.60

Minimum	3.91	1.15	2.00	0.60
Maximum	18.44	14.76	13.05	20.44
Market quality index				
Number of observations	11	13	12	14
Mean	34.09	35.23	46.58	51.18
Minimum	17.00	13.00	19.00	20.00
Maximum	53.00	56.00	79.00	92.00
Urbanization				
Number of observations	11	13	12	14
Mean	45.26	44.08	48.83	52.84
Minimum	15.44	17.92	19.22	20.80
Maximum	85.68	85.34	84.94	100.00
Latin America and Caribbean region				
Bureaucratic quality index				
Number of observations	15	19	18	19
Mean	40.00	38.95	43.15	48.68
Minimum	16.67	16.67	16.67	12.50
Maximum	66.67	66.67	66.67	70.83
Corruption index				
Number of observations	15	19	18	19
Mean	46.67	46.49	50.93	50.66
Minimum	16.67	3.33	26.67	33.33
Maximum	83.33	83.33	80.00	79.17
Rule of law index				
Number of observations	15	19	18	19
Mean	41.11	42.28	49.07	57.90
Minimum	16.67	16.67	23.33	33.33
Maximum	66.67	66.67	70.00	83.33
Inflation				
Number of observations	15	19	18	19
Mean	52.82	62.23	56.99	17.20
Minimum	5.81	0.49	8.19	1.25
Maximum	178.46	219.47	432.78	61.41
Market quality index				
Number of observations	15	19	18	19
Mean	41.47	38.47	46.00	61.08
Minimum	17.00	19.00	0.00	27.50
Maximum	83.00	80.00	74.00	89.50
Urbanization				
Number of observations	15	19	18	19
Mean	58.73	60.92	63.76	64.58
Minimum	36.02	37.92	38.30	34.15
Maximum	86.00	87.80	89.22	90.65
Middle East and North Africa region				
Bureaucratic quality index				
Number of observations	3	3	5	5
Mean	44.44	55.56	55.33	63.33
Minimum	33.33	50.00	43.33	50.00
Maximum	50.00	66.67	80.00	95.83
Corruption index				
Number of observations	3	3	5	5
Mean	55.55	55.55	56.67	59.17
Minimum	33.33	33.33	46.67	41.67
Maximum	83.33	83.33	80.00	70.83

(*Continued*)

TABLE 2. Continued

	1980–84	1985–89	1990–94	1995–98
Rule of law index				
Number of observations	3	3	5	5
Mean	38.89	38.89	52.00	78.33
Minimum	33.33	33.33	43.33	66.67
Maximum	50.00	43.33	60.00	83.33
Inflation				
Number of observations	3	3	5	5
Mean	67.40	36.02	12.38	10.79
Minimum	8.90	7.32	5.85	4.08
Maximum	177.53	81.82	20.63	28.78
Market quality index				
Number of observations	3	3	5	5
Mean	11.67	16.33	20.00	27.80
Minimum	10.00	11.00	12.00	21.00
Maximum	14.00	21.00	30.00	39.00
Urbanization				
Number of observations	3	3	5	5
Mean	61.78	63.14	64.18	66.51
Minimum	43.84	43.98	44.22	44.80
Maximum	89.08	90.00	90.46	90.95
North America and Europe region				
Bureaucratic quality index				
Number of observations	14	17	17	18
Mean	86.91	86.47	89.41	93.29
Minimum	50.00	50.00	56.67	70.83
Maximum	100.00	100.00	100.00	100.00
Corruption index				
Number of observations	14	17	17	18
Mean	86.90	87.26	85.88	83.33
Minimum	50.00	66.67	56.67	62.50
Maximum	100.00	100.00	100.00	100.00
Rule of law index				
Number of observations	14	17	17	18
Mean	88.10	87.25	91.18	96.53
Minimum	50.00	46.67	70.00	87.50
Maximum	100.00	100.00	100.00	100.00
Inflation				
Number of observations	14	17	17	18
Mean	12.12	5.42	4.66	2.26
Minimum	5.05	0.69	2.08	0.79
Maximum	22.76	17.19	16.21	6.86
Market quality index				
Number of observations	14	17	17	18
Mean	31.29	36.24	48.00	58.00
Minimum	10.00	14.00	17.00	40.00
Maximum	53.00	72.00	79.00	83.00
Urbanization				
Number of observations	14	17	17	18
Mean	71.74	71.73	73.01	75.55
Minimum	32.52	41.00	50.58	58.45
Maximum	95.64	96.20	96.70	97.15

Source: PRS (2004); Gwartney and Lawson (2001); World Bank (2001).

Table 3. Joint Estimation for the Production Frontier and the Determinants of Inefficiency

	Model I	Model II	Model III	Model IV
Production frontier				
Constant	2.8794 (7.70)	3.3083 (8.05)	2.6540 (6.90)	3.0903 (7.65)
Log(capital stock)	0.4173 (16.12)	0.3813 (14.46)	0.4283 (15.69)	0.3929 (15.24)
Log(years of schooling)	0.0223 (0.36)	0.0538 (0.97)	0.0009 (0.01)	0.0358 (0.66)
Log(workers)	0.5949 (19.71)	0.6137 (21.61)	0.5860 (17.97)	0.6015 (21.40)
Period			0.0209 (1.55)	0.0148 (1.20)
Dummy variables (Sub-Saharan Africa omitted)				
Asia		0.1723 (2.38)		0.1885 (2.59)
Latin America and Caribbean		0.1316 (2.14)		0.1485 (2.49)
Middle East and North Africa		0.4583 (5.51)		0.4543 (5.67)
North America and Europe		0.3606 (4.62)		0.3736 (4.81)
Determinants of inefficiency				
Constant	1.5358 (9.96)	1.3380 (8.98)	1.6090 (10.10)	1.3689 (8.78)
Bureaucratic quality index	0.0828 (0.32)	0.0230 (0.09)	0.0362 (0.14)	−0.0328 (−0.14)
Corruption index	0.0172 (0.08)	0.2045 (0.94)	−0.0438 (−0.18)	0.1777 (0.88)
Rule of law index	−0.6373 (−2.51)	−0.4953 (−2.10)	−0.4226 (−1.75)	−0.3338 (−1.48)
Inflation	0.2016 (3.04)	0.1150 (1.87)	0.2060 (3.09)	0.1176 (1.82)
Market quality index	−0.3851 (−2.01)	−0.5895 (−3.11)	−0.2437 (−1.25)	−0.4613 (−2.45)
Urbanization	−1.8223 (−7.62)	−1.5690 (−5.48)	−1.8814 (−7.28)	−1.6037 (−5.28)
Period	0.0650 (1.77)	0.0489 (1.52)		
Log likelihood function	107.48	108.51	100.80	101.68
Number of observations	238	238	238	238

Note: Numbers in parentheses are *t*-statistics.
Source: Authors' estimation based on data described in text.

to a 0.59–0.61 percentage point increase in GDP. Human capital (measured by the number of years of schooling) has a positive, but insignificant impact on GDP, which is somewhat surprising.[11] The regional dummy variables are statistically significant, with each region having a higher production frontier than Africa, the excluded region.[12] These results indicate that increasing input use (or factor endowments) is one of the means of reaching higher optimal output levels.

The time period variable, when included in the production possibilities frontier, is positive with a significance level (*p*-value) of 0.1229 in model III and 0.2325 in model IV. These results (especially for model III) depict improvements in technology during the 1980–98 period and indicate that with each additional period (and controlling for other factors) the production possibilities frontier shifts outward by 1.5–2.1 percentage points over the level reached in the previous period.

The analysis of the impact of the institutional framework, macroeconomic stability, market quality, and urbanization on a countries' productive efficiency does not incorporate differences in industry mix across countries because of a lack of reliable data.[13] Improvements in the rule of law index and the market quality index and a decrease in inflation lead to decreases in inefficiency (see table 3). Inefficiency declines by 1.57–1.88 percentage points for a 1 percentage point increase in urbanization, by 0.42–0.64 percentage point for a 1 percentage point increase in the rule of law index, by 0.38–0.59 percentage point for a 1 percentage point increase in the market quality index, and by 0.12–0.21 percentage points for a 1 percentage point decrease in the inflation rate. These results suggest that improvements in urbanization, institutional framework, market quality, and macroeconomic stability that lead to better productive efficiency outcomes are another way to boost output levels.[14]

In recent years indices of bureaucratic quality, corruption, rule of law, and market quality have improved in many countries. The level of urbanization has also increased, and inflation rates have declined. This implies that many countries

11. An anonymous referee suggested including the education variable instead as a determinant of efficiency, but this study follows the literature in keeping education as an input to the production function.

12. Note that the Middle East and North Africa dummy variable is higher than the North America and Europe dummy variable, which would imply that more can be produced in the Middle East and North Africa than in North America and Europe with the same level of inputs. One potential explanation for this apparently counterintuitive finding could be the impact on GDP of oil and tourism in the countries included in the Middle East and North Africa region (although one could argue that these industries also require high levels of inputs).

13. As indicated by an anonymous referee, industry mix may have an impact on productive efficiency because of differences in productivity across sectors. For example, countries with a higher share of GDP in the primary sector may be less efficient, and this will not be captured in the estimation of the frontier. However, the use of urbanization in the analysis of the determinants of efficiency may be considered a proxy for sectoral shares of GDP, because a higher level of urbanization is typically a sign of an economy with a lower emphasis on agriculture (but as mentioned earlier, there may also be other reasons for more efficient production in countries that are more urbanized).

14. As pointed out by an anonymous referee, productivity (and hence efficiency) and per capita output may themselves have an impact on urbanization. Unfortunately, the authors are unaware of any mechanism to incorporate appropriate instruments to correct for such potential endogeneity using the stochastic frontier approach. This must bet left for future work.

have achieved greater productive efficiency. Indeed, summary statistics at the region level on the estimated efficiency measures for models I and II show an increase in efficiency during the period under review (table 4).[15] Yet levels of productive efficiency, like input use, vary by region, with the lowest levels in the Africa region and the highest in North America and Europe over the period under review.

These results suggests that both high input endowments and greater productive efficiency have played a key role in North America and Europe's success in achieving high output levels, whereas lack of input endowments and comparatively low productive efficiency have contributed to the Africa region's poorer performance. It is heartening to note, however, that the Africa region has experienced strong improvements in productive efficiency over the period under review, with this result being robust to the choice of specification. Although the Africa region has the smallest magnitudes for the efficiency-determinant variables (see table 2), it experienced relatively greater improvements in these variables, with greater impacts on efficiency (see table 3). As a result, the Africa region experienced strong improvements in productive efficiency during the 1980–98 period.

While the sample of countries used in the estimation is unbalanced, that does not seem to affect the efficiency trend results. A general increase in the levels of efficiency is observed for a majority of the countries in the sample, including those in Africa, for all four periods. For countries that are not in the sample for all four periods, there is no evidence of more omissions because of lack of data for countries with high levels of efficiency in the early periods or for countries with low levels of efficiency in the later periods. If there had been such bias, the improvements in efficiency could have been due to the unbalanced nature of the panel. Also, although the use of regional dummy variables in some of the specifications means that the standard for comparing efficiency levels is region-specific, this standard is increasing over time because the regional dummy variable is invariant over time and the time trend in the production function is positive. Therefore, the improvement in productive efficiency in Africa is not just a reflection of a scenario in which even the best-performing countries in the region would be doing poorly.

It is worth emphasizing again that the stochastic frontier approach used here requires that the inefficiency terms (u_{it}) be nonnegative, as the terms measure the deviation from the optimal (best practice) outcome. An alternative estimation method would be to substitute equation 2 into equation 1 and then estimate a single regression using traditional estimation techniques (ordinary least squares). This method would not permit imposing efficiency measures, so any comparison of the results with those presented here would need to be done with care. A traditional approach would provide less information because it could not measure efficiency as well. Still, it is worth noting that in the traditional approach, the capital stock and labor force variables remain statistically significant, whereas

15. The estimated efficiency measures for models III and IV are available on request.

TABLE 4. Summary Statistics on the Estimated Efficiency Measures (models I and II)

	Number of Observations	Mean	Minimum	Maximum	Standard Deviation
Model I					
Africa region					
1980–84	5	32.24	21.62	41.48	8.64
1985–89	10	39.90	21.62	71.51	15.41
1990–94	13	36.88	21.30	81.61	15.52
1995–98	7	46.65	23.01	83.79	19.54
Asia region					
1980–84	11	55.81	29.43	91.45	20.46
1985–89	13	55.13	27.96	90.63	19.87
1990–94	12	59.36	30.75	91.20	20.23
1995–98	14	64.70	35.20	94.40	19.36
Latin America and Caribbean region					
1980–84	15	65.64	36.06	88.90	15.35
1985–89	19	66.63	37.45	89.62	15.40
1990–94	18	68.66	41.38	87.22	15.17
1995–98	19	68.52	40.78	91.22	15.90
Middle East and North Africa region					
1980–84	3	86.19	79.69	94.35	7.47
1985–89	3	83.04	79.48	89.49	5.60
1990–94	5	81.36	40.88	94.43	22.85
1995–98	5	91.52	83.77	95.69	4.78
North America and Europe region					
1980–84	14	85.23	74.28	93.81	6.54
1985–89	17	87.86	74.55	95.34	5.86
1990–94	17	89.07	74.50	96.12	4.93
1995–98	18	92.10	81.49	96.72	4.05
Model II					
Africa region					
1980–84	5	39.92	25.90	51.12	10.89
1985–89	10	48.89	25.83	86.76	18.99
1990–94	13	44.34	25.58	93.95	17.71
1995–98	7	55.30	27.75	95.03	21.61
Asia region					
1980–84	11	61.12	33.06	94.76	21.31
1985–89	13	60.43	31.23	95.38	20.79
1990–94	12	65.51	34.34	95.74	21.35
1995–98	14	70.96	40.08	97.24	19.48
Latin America and Caribbean region					
1980–84	15	73.60	40.20	94.02	16.64
1985–89	19	74.36	41.71	95.16	16.37
1990–94	18	76.37	46.02	93.12	16.25
1995–98	19	75.67	45.30	96.31	16.62

Middle East and North Africa region					
1980–84	3	75.80	67.82	87.42	10.29
1985–89	3	71.10	67.56	78.07	6.04
1990–94	5	72.63	36.98	87.58	20.75
1995–98	5	82.83	72.40	91.45	8.38
North America and Europe region					
1980–84	14	81.82	69.25	93.28	8.05
1985–89	17	85.32	70.33	96.19	7.36
1990–94	17	87.05	70.02	96.96	6.22
1995–98	18	91.09	78.40	97.55	5.21

Source: Authors' estimation based on data described in text.

education (years of schooling) remains statistically insignificant.[16] The ranking of the regional dummy variables also remains the same. The rule of law index, the market quality index, and the urbanization rate are again statistically significant, and inflation is statistically significant only in some of the specifications. The results are thus broadly similar, but the advantage of the approach taken here is the ability to explicitly separate the impact of production inputs and that of efficiency in using the inputs.

V. Conclusion

There is an extensive literature on identifying and measuring factors that improve economic performance, as measured by GDP levels and growth rates, using cross-country analyses. In contrast to previous studies, the approach used here estimates a production possibilities frontier that depicts optimal output for different levels of input use and calculates efficiency by comparing actual output levels with optimal outputs. This framework permits studying not only how greater input use increases the optimal output levels that can be reached (according to the production frontier) but also how better conditions that facilitate production can help in reaching these optimal output levels.

Similar to previous growth studies, the results indicate statistically significant positive relationships between production and levels of physical capital and number of workers employed. The impact of years of schooling is positive in all cases but lacks statistical significance. The production frontier estimation framework shows an impact of the institutional framework, macroeconomic stability, quality of markets, and level of urbanization on productive efficiency.

Finally, the results also indicate that average world productive efficiency levels have improved during 1980–98. High input endowments and greater productive efficiency played a key role in North America and Europe's success,

16. The results of the ordinary least squares estimation are available on request.

TABLE A.1. Countries by Region

Sub-Saharan Africa	Asia	Latin America	Middle East and North Africa	North America and Europe
Botswana	Australia	Argentina	Egypt, Arab Rep.	Austria
Cameroon	Bangladesh	Bolivia	Iran, Islamic Rep.	Belgium
Congo, Rep.	China	Brazil	Israel	Canada
Ghana	Indonesia	Chile	Jordan	Switzerland
Kenya	India	Colombia	Tunisia	Denmark
Malawi	Japan	Costa Rica		Spain
Niger	Korea, Rep.	Ecuador		Finland
Senegal	Sri Lanka	Guatemala		France
Sierra Leone	Malaysia	Honduras		United Kingdom
Togo	New Zealand	Haiti		Greece
Uganda	Pakistan	Jamaica		Ireland
Congo, Dem. Rep.	Philippines	Mexico		Iceland
Zambia	Singapore	Nicaragua		Italy
Zimbabwe	Thailand	Panama		Netherlands
		Peru		Norway
		Paraguay		Portugal
		El Salvador		Sweden
		Trinidad and Tobago		United States
		Uruguay		
		Venezuela		

whereas the Africa region performed poorly due to a lack of input endowments and low productive efficiency. The highest improvement in productive efficiency over time was observed in the Africa region, however, which is promising for the future.

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