EFFICIENCY IN IMPROVING HEALTH AND EDUCATION OUTCOMES: PROVINCIAL AND STATE-LEVEL ESTIMATES FOR ARGENTINA AND MEXICO*

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Resumen: Con datos de panel para Argentina y México se hace un análisis a nivel de estados y provincias a fin de medir su eficiencia para mejorar indicadores de salud y educación. Los métodos estocásticos de la estimación de frontera se utilizan para determinar los indicadores óptimos que podrían ser alcanzados con los recursos disponibles y para medir la eficiencia para lograrlos. El método es potencialmente útil al permitir determinar si las regiones con retraso se deben a una ausencia de recursos, o a una falta de eficiencia en el uso de los recursos disponibles.

Abstract: Provincial and state-level analyses are conducted using panel data sets for Argentina and Mexico to assess the efficiency of provinces and states in improving health and education outcomes. Stochastic frontier estimation methods are used to determine optimal outcomes that could be reached with current resources, and to measure efficiency in reaching these benchmarks. The method is potentially useful since it enables the analyst to assess whether lagging regions have a lower performance due to a lack of resources, or a lack of efficiency in using their available resources.

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Palabras clave: eficiencia productiva, educación, salud, productive efficiency, education, health, Argentina, Mexico.

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1. Introduction

Decentralization has now been implemented in many Latin American countries (Burki, Perry, and Dillinger, 1999; Finot, 2002). Argentina and Brazil decentralized first, but other large countries have followed suit, including Mexico (Giugale and Webb, 2000). Smaller countries such as Bolivia and Paraguay have also adopted decentralization laws (Ajwad and Wodon, 2002). As a result, a wide range of decisions is currently made at the sub-national level, especially in the social sectors (e.g., education, health, and access to basic infrastructure services). Given that decentralized sub-national governments are more likely to lack the necessary expertise (including qualified personnel) to allocate their limited resources optimally, it is important to find ways to monitor and evaluate their performance in improving social outcomes for their population.

In this paper, following previous work at the cross-country level (Jayasuriya and Wodon, 2003), we show how stochastic frontier estimation techniques can help in providing an assessment of the efficiency with which sub-national entities use their available resources in order to improve social outcomes.[1] For this analysis, we rely on an extension to panel data of the error component approach of Aigner, Lowell and Schmidt (1977) proposed by Battese and Coelli (1992, 1995).[2] We focus on health and education outcomes because these are

[1] Although the stochastic frontier approach has been widely used in agricultural and industrial economics, applications to health and education indicators remain few, but they include Grosskopf and Valdmanis (1987), Mirmirani, and Li (1995), Kirjavainen and Loikkanen (1998), Chirikos and Sear (2000), Evans et al. (2000), and Zere (2000). For a brief review of the role of public spending and governance in achieving outcomes, see among others Rajkumar and Swaroop (2003). For a broader discussion of the role of efficiency in reaching development outcomes, see Christiaensen and Wodon (2002).

[2] Parametric methods (stochastic frontier method and thick frontier approach) and non-parametric approaches (*Data Envelope Analysis*, DEA, and *Free Disposal Hull*, FDH) are widely used in the estimation of production frontiers. Each approach has its strengths and weaknesses. DEA and FDH approaches impose few or no restrictions on the production technology but are also unable to disentangle random noise (white noise) from the inefficiency measure. By contrast, the stochastic frontier approach enables the incorporation of a random noise term (that can capture measurement error) in addition to the inefficiency term. In this study, in order to account for the fact that some of the deviations from the observed maximum output may be due to random shocks, we used the stochastic frontier approach. On the Free Disposal Hull, see for example Deprins, Simar and Tulkens (1984) and Fakin and de Crombrugghe (1997). On Data Envelope

closely related to the *Millennium Development Goals* (MDG) adopted by the international community.[3] The basic idea is that gains in social indicators can be achieved not only through an increase in the use of resources, but also through a more efficient use of existing resources (or a combination of both). Since resources are often limited, improvements in efficiency become crucial. The techniques used here enable us to assess the level of efficiency of sub-national entities, and thereby the potential gains from improvements in efficiency.[4]

The maximum likelihood estimation technique for the production frontiers is presented in section 2. Section 3 presents basic statistics on our data and key results. Section 4 concludes.

2. Methodology

We conduct a provincial-level analysis in Argentina and a state-level analysis in Mexico, and focus on basic health and education outcomes. For health, we consider the infant mortality and child mortality rates.[5] For education, we consider school enrollment rates as well as test scores. The estimation of the stochastic production frontiers relies on the maximum likelihood program provided by Coelli (1996). Let Y_{it} represent the health or education indicator for province or state i at time t. X_{it} depicts the factors or inputs influencing the health/education outcome. The functional form of the production frontiers can be presented as in (1):

$$Y_{it} = \alpha + X_{it}\beta + (v_{it} - u_i) \tag{1}$$
$$i = 1, \ldots, N \textit{ and } t = 1, \ldots, T$$

Analysis, see Charnes, Cooper and Rhodes (1978), Tulkens and Vanden Eeckhaut (1995), and Gupta, Honjo and Verhoeven (1997).

[3] More detailed information on the *Millennium Development Goals* can be found at the following URL: http://www.developmentgoals.org/.

[4] From a policy point of view, at least two options can be used to improve efficiency, namely changing the allocation mix of public expenditures (see for example, Murray, Kreuser and Whang, 1994), or implementing institutional reforms, for example, to improve bureaucratic quality and reduce corruption. While we do not discuss this here, we do provide measures of efficiency.

[5] The infant mortality rate is the share of children who die before the age of one. The child mortality rate is the share of children who die before the age of five. For the production frontier framework, better outcomes depict larger values, and thus non-mortality rates are used.

The error term in (1), $(v_{it}-u_i)$, consists of two components. The random noise term, $v_{it} \sim N(0,\sigma_v^2)$, accounts for random shocks and measurement errors. This term is independent of the non-negative term, $u_i \sim |N(\mu,\sigma_u^2)|$, which measures the deviation from the optimal (best practice) outcome, and is used to derive the measures of efficiency.[6] Denoting by N the number of provinces (states), T_i the number of available observations for each province (state) i and $\Phi(\bullet)$ the cumulative standard normal distribution function, the log likelihood function incorporating all the information derived from the distributional assumptions on the inefficiency term (u_i) and the random noise (v_{it}) is:

$$\begin{aligned}\ln(L) = &-\tfrac{1}{2}\sum_{i=1}^{N} T_i[\ln(2\pi)+\ln(\sigma_u^2+\sigma_v^2)] - \tfrac{1}{2}\sum_{i=1}^{N}(T_i-1)\ln\left(\tfrac{\sigma_v^2}{\sigma_u^2+\sigma_v^2}\right)\\ &-\tfrac{1}{2}\sum_{i=1}^{N}\ln\left(\tfrac{\sigma_v^2+T_i\sigma_u^2}{\sigma_u^2+\sigma_v^2}\right) - N\ln\left(1-\Phi\left(\tfrac{-\mu}{\sigma_u}\right)\right) - \tfrac{N}{2}\left(\tfrac{\mu}{\sigma_u}\right)^2\\ &+\sum_{i=1}^{N}\ln\left(1-\Phi\left(\frac{-\mu\sigma_v^2+\sigma_u^2\sum_{t=1}^{T_i}(y_{it}-\alpha-x_{it}\beta)}{\sigma_u\sigma_v\sqrt{\sigma_v^2+T_i\sigma_u^2}}\right)\right) \qquad (2)\\ &+\tfrac{1}{2}\sum_{i=1}^{N}\left(\frac{\mu\sigma_v^2-\sigma_u^2\sum_{t=1}^{T_i}(y_{it}-\alpha-x_{it}\beta)}{\sigma_u\sigma_v\sqrt{\sigma_v^2+T_i\sigma_u^2}}\right)^2 - \tfrac{1}{2\sigma_v^2}\sum_{i=1}^{N}\sum_{t=1}^{T_i}(y_{it}-\alpha-x_{it}\beta)^2\end{aligned}$$

The distributional assumptions on the inefficiency term (u_i) and the random noise term (v_{it}) are used along with the maximum likelihood estimation technique to obtain consistent estimates for the parameters of interest, α and β. The measures of technical efficiency for each province or state are then calculated as follows:[7]

$$Efficiency_i = \frac{E\,(Y_{it}|X_{it},u_i)}{E\,(Y_{it}|X_{it},u_i=0)} \qquad i,\ldots,N \qquad (3)$$

[6] Kumbhakar and Lovell (2000) show that efficiency rankings appear to be robust to the choice of the distribution.

[7] The conditional mean of u_i given the observed error term $(v_{it}-u_i)$ is used to calculate the efficiency measures (Battese and Coelli, 1995).

The expected outcome for a level of input use X_{it} is the numerator, $E(Y_{it}|X_{it}, u_i)$. The denominator, $E(Y_{it}|X_{it}, u_i = 0)$, represents the optimal outcome that can be attained with input use X_{it} under zero inefficiency. As noted by an anonymous referee, given the decentralization process in each of the two countries, each state or province could very well have its own production function, but due to data limitations, we cannot estimate state-specific or province-specific production functions. A description of the variables is presented in the next section.

3. Data and Production Frontiers

The Argentine and Mexican health data consist of outcome measures (infant mortality and child mortality) and various inputs or resources used in producing these outcomes (per capita GDP, per capita health expenditure, adult literacy, access to vaccinations, access to public hospitals, access to potable water and time).[8] In order to have larger numbers indicating better outcomes, non-mortality rates are used in the estimations. The education data consist of outcome measures (enrollment rates in primary or elementary school, as well as in secondary school,[9] and test scores) and resources used in producing these outcomes (mainly per capita GDP, per capita education expenditure, adult literacy, and time). Per capita GDP and per capita expenditures

[8] For example, the number of births at public hospitals is used as a proxy for access to public hospitals, because one would use medical facilities for childbirth when available. Since a vast majority of the states and provinces considered in this analysis do not have hospitals owned by the private sector that can substitute for state provided health care services, we believe this is a reasonable proxy.

[9] We use net primary and secondary enrollment rates defined as the number of children of primary or secondary school age enrolled in primary or secondary school divided by the total number of children of primary or secondary school age in the population. By contrast, gross primary and secondary enrollment rates (not used here) would be defined as the number of children of any age enrolled in primary or secondary school divided by the total number of children of primary or secondary school age in the population. In a few rare instances, we observe net primary enrollment rates higher than 100 percent. This can happen when enrollment rates are high and the parameters are estimated, because the denominator of the ratio at the state or provincial level which represents the number of children of a given school age range is not available on a yearly basis and may thus be computed with an error (the nominator, which is the number of children in school, is normally available on a yearly basis from Ministries of Education.)

are used as proxies to capture the state- or provincial-level supply of services (such as education, health and infrastructure facilities) as well as, in the case of per capita GDP, the level of income of the population in the different states or provinces. Adult literacy is used as a proxy to capture the parents' willingness, knowledge and ability to provide their children with adequate educational, nutritional and health care attention.

We are well aware that the input variables used here are only general proxies in the "production functions" for health and education outcomes.[10] We are also aware that some of the inputs may be endogenous (for example, some countries may decide to allocate more resource to health in poor areas in order to fight higher rates of mortality there). These limitations in the data on inputs mean that we have to be careful in the interpretation of the production frontier coefficients. Unfortunately, we do not have access to better data, and using a production frontier framework is certainly more appropriate than relying, as is often done, on simple scatter plots of outcomes *versus* one measure of inputs such as per capita GDP or social sector public expenditure. On a more positive note, given that our focus here is on the measures of efficiency obtained, we hope to alleviate concerns regarding the data used for inputs by testing the robustness of our efficiency measures to different specifications of the production frontiers. If we find that under different specifications, we get similar efficiency measures (as we actually do), then we can have some confidence in the validity of our comparisons of actual *versus* optimal outcomes and the associated gains that could be obtained from improvements in efficiency. At the very least, our estimations provide a first rough idea as to whether the fact that some outcome measures are worse in some areas within a country as compared to other areas is due to a lack of resources in these areas, or a lack of efficiency in using existing resources.[11]

[10] There are at least two issues here. One is the fact that some of the variables included as inputs (such as per capita GDP or public spending) may be used for other outcomes than those identified here, in which case we do not have a one-to-one correspondence between inputs and outcomes, as we would hope to have in a more traditional production framework. Another issue is that some of the more detailed inputs that could be included, such as the availability of prenatal care, are simply not available. Such issues can have an impact on the efficiency measures obtained from the production frontier, which calls for using different specifications in order to test for robustness.

[11] We also studied the presence of heteroscedasticity in our estimation by plotting the residuals and also by conducting likelihood ratio tests for groupwise

Summary statistics for the outcome measures as well as input measures in the panel data sets from Argentina and Mexico are presented in table 1. The primary sources for this data, which are indicated in table 1, are various Ministries in the two countries. Although the samples differ somewhat, the panel data sets from Argentina typically consist of indicators for all 24 provinces observed during the 1995 to 1999 period. The Mexican panel data sets typically consist of indicators for all 32 states observed during the 1990 to 1996 period for health outcomes, and for 1994 and 2000 for education outcomes.

The health and education production frontier results are in tables 2 to 4. For all outcomes, we use three separate models in order to test for the robustness of the results to the choice of specification. The models differ in terms of the inclusion of per capita GDP, per capita public health or education expenditure, or both as inputs (apart from the other inputs used in the estimation).

The results for health outcomes presented in table 2 suggest that in both Argentina and Mexico, per capita GDP has a statistically significant impact on infant and child mortality. In Mexico for example, an increase in per capita GDP of 1,000 pesos (approximately US$ 100) reduces infant and child mortality by 0.3 and 0.4 per 1,000 births respectively. Given that the average state-level infant and child mortality rates are 26.5 and 32.3 per 1,000 respectively, these impacts are not negligible. Time also has a statistically significant impact in both countries, with each additional year reducing infant or child mortality by close to one point per 1,000 births. This impact of time is probably due to progress in medicines and care practices. The impact of per capita public health expenditures is, by contrast, rather weak: it is never statistically significant when controlling for GDP. In Mexico, the adult literacy rate has a negative and statistically significant impact on infant and child mortality, but this is not the case in Argentina, perhaps because the adult literacy rate is already very high in that country - above 97 percent. Still in Mexico, the vaccination rate also has a statistically significant impact on infant and child mortality.[12] Finally, access rates to public hospitals and potable water lack statistical significance in both countries.

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heteroscedasticity. In the residual plots we did not observe patterns that would be indicative of the presence of heteroscedasticity. In addition, the likelihood ratio tests conducted to test for groupwise heteroscedasticity did not reject the null hypothesis of homoscedasticity.

[12] As expected, the impact of the vaccination rate on child mortality is larger than on infant mortality. The corresponding data on the vaccination rates for Argentina was not available.

The education school enrollment frontier estimations for both Argentina and Mexico are presented in table 3. We find that in both countries, per capita GDP and per capita public spending on education do not seem to have a statistically significant impact on net primary and net secondary enrolment rates. In Argentina, net primary enrollment is decreasing over time, but is due to an unexplained drop in 1999, which may be due to data problems (in appendix 1, we provide alternative production function estimates for primary enrollment as well as efficiency measures for the Argentina sample without the year 1999; net primary enrollment is increasing over time when the 1999 data is excluded). Enrollment in secondary school improves with each additional year, by almost half a percentage point.

Time has a statistically significant and positive impact on both primary and secondary enrollment in Mexico, with one additional year leading to a 0.7 percent (the increase during the 1994 to 2000 period is approximately 4.2 percent; with a range from 4.0 percent to 4.4 percent) increase in both the net primary and net secondary enrollment rates. In Mexico, a one percent increase in the adult literacy rate leads to net primary enrollment increasing by 0.61 percent to 0.65 percent, and net secondary enrollment increasing by 1.03 percent to 1.21 percent. In Argentina, a one percent increase in the adult literacy rate leads to net primary enrollment increasing by 0.26 percent to 0.37 percent, and net secondary enrollment increasing by 1.18 percent to 1.96 percent.

The results for test scores are presented in table 4 in the case of Argentina. An increase in per capita GDP of 1,000 pesos increases language and mathematics test scores by one half to one full point. Adult literacy has a strong positive impact on primary and secondary enrollment, but not on test scores, once we control for per capita GDP in the regressions. For test scores, when significant, a one percent increase in the adult literacy rate leads to scores increasing by 2.07 to 2.71 points. For secondary school test scores, the grade variable (i.e., the year of study of the student) has a positive and statistically significant impact, indicating that as a student advances a grade, test scores increase by 1.78 points to 2.07 points.

4. Efficiency Measures and Interpretation: The Case of Mexico's Southern States

As with any empirical work, we have to be careful in the estimation of the production functions, especially when there are data limitations regarding the inputs identified in the specifications. This is why we have provided robustness tests in the efficiency measures by estimating various specifications. Given that the results appear to be robust, we can use these efficiency measures to have at least a rough idea of how much progress could be achieved though better efficiency. This is what we do in this section for the Mexico case (a similar analysis could be done for lagging provinces in Argentina, and would yield very similar findings; for information, we have included in appendix 2 the actual and optimal outcomes for the various indicators for all provinces in Argentina for the baseline model). That is, the error term structure in (1) enables us to assess whether some areas lag behind others due to a lack of resources, or a lack of efficiency in using their existing resources.

Summary statistics of our efficiency measures are provided in table 5, and it can be seen that they are fairly robust to the choice of the three specifications.[13] To illustrate more concretely how these measures can be used to compare actual *versus* optimal outcomes, we discuss in this section estimates for three states located in the southern part of Mexico, namely Chiapas, Guerrero, and Oaxaca.

These three states are known to be among the poorest in the country, with a high proportion of indigenous peoples. This can readily be seen through basic statistics for our health and education outcomes measures in table 6. For example, the "infant non-mortality rate" for the average Mexican state is one percent better than the corresponding southern state outcomes (97.35 per 100 in the average Mexican state *versus* 96.51, 95.47 and 96.60 per 100 in the southern states: Chiapas, Guerrero and Oaxaca).[14] The "child non-mortality rate" also indicates disparities between states. The Mexico state average is one and half percent better than the corresponding southern state outcomes (96.77 per 100 in Mexico *versus* 94.95, 94.81 and 95.10 in the southern states).

Not surprisingly, the input measures for the average Mexican state are also better than those observed in the southern states. The state average GDP per capita is twice as large in the country as a whole than in the southern states (11,622 pesos in Mexico *versus* 5,346, 7,148 and 5,440 pesos in the southern states). The same is observed for per

[13] The efficiency measures indicated by the three models for the southern Mexican states presented in table 7 are similar, and in most cases the differences in efficiency are very small.

[14] This means that the infant mortality rates vary from 34.0 per 1,000 in Oaxaca to 45.3 per 1,000 in Guerrero, so that infant mortality is about one third higher in Guerrero than in Oaxaca.

capita health expenditure (327 pesos in Mexico *versus* 168, 185 and 168 pesos in the southern states). The average Mexican state adult literacy rate is approximately 13 percentage points higher than in the southern states (88.7 percent in Mexico *versus* 72.8, 75.2 and 75.4 in the southern states). The vaccination data indicates that the Mexican average is much better than in Chiapas (90.8 in Mexico *versus* 76.7 in Chiapas), but only slightly better or on par with Guerrero and Oaxaca (90.8 in Mexico *versus* 90.8 and 89.0 in Guerrero and Oaxaca respectively). The Mexico state average for access to public hospitals and access to potable water are roughly 20 points better than in the southern states (access to public hospitals: 77.4 in Mexico *versus* 56.2, 55.8 and 59.3 in the southern states; access to potable water: 85.5 in Mexico *versus* 66.0, 65.0 and 66.0 in the southern states).

For each state and each indicator, we have three different estimates of efficiency, one each for the three different specifications of the production frontier (as shown in table 7). It turns out that the efficiency in reaching the best possible health outcomes for infant and child mortality in Chiapas and Oaxaca are on par (and even sometimes better) with the Mexican state averages. The Guerrero efficiency measures, however, are below the Mexican average for all models.

Importantly, the fact that the efficiency measures appear to be very high does not mean that no progress can be achieved with better efficiency. Indeed, the measures must be interpreted with care given the way the indicators have been defined. For example, in the preferred specification of model I, an infant mortality efficiency measure of 98.62 for Guerrero (99.80 for Oaxaca; 99.91 for Chiapas) means that under perfect efficiency and at the current level of input use, infant mortality could be improved by 13.3 per 1,000 births (for Oaxaca: 1.9 per 1,000 births; for Chiapas: 0.9 per 1,000 births). The improvement of 13.3 per 1,000 in Guerrero is obtained by noting that the infant mortality rate under perfect efficiency is equal to one minus the ratio of the observed infant mortality rate to the efficiency measure.[15] Similarly, for the child mortality rates, an efficiency measure of 99.13 for Guerrero (99.49 for Oaxaca; 99.80 for Chiapas) means that under perfect efficiency and at the current level of input use, child mortality could be improved by 8.3 per 1,000 births (for Oaxaca: 4.9 per 1,000 births; for Chiapas: 2.0 per 1,000 births).

[15] That is, under perfect efficiency, we have an infant mortality rate of 0.0319 = 1-(0.9547/0.9862). Since the actual infant mortality rate is 0.0453, the reduction in infant mortality is 0.0133, or 13.3 per 1,000.

The conclusion of these calculations is that in Guerrero, apart from low levels of inputs, inefficiencies in using existing inputs explain part of the lags in mortality indicators (and especially infant mortality). In Chiapas and Oaxaca, efficiency is higher. Yet this does not mean that there is no scope for efficiency gains in these two states, since the benchmark for the comparison of the efficiency of the three southern states is the other Mexican states, and there may be scope for efficiency gains throughout Mexico that are not captured in our analysis.

A similar analysis can be conducted for education outcomes. As one would expect, the net primary and secondary enrolment rates in the three southern states are worse than the Mexican average. The net primary enrolment rate for the Mexico state average is 8 percent better than the southern state average outcome (93.2 in Mexico *versus* 77.9, 86.9 and 88.2 in the three southern states). The net secondary enrollment rate differences are larger, with the Mexico state average being 14 percentage points higher than the southern state average (60.4 in Mexico *versus* 39.4, 50.5 and 51.2 in the southern states). As expected, the input levels used to reach outcomes in the south are below the Mexican state average. We already mentioned differences in state average GDP per capita and adult literacy rates. Per capita net primary education expenditure is also higher in the average Mexican state than in the southern states (565 constant pesos in Mexico *versus* 351, 554 and 552 constant pesos in the southern states), and the same is true for net secondary education expenditure per capita (236 constant pesos in Mexico *versus* 128, 192 and 184 constant pesos in the southern states). Yet the question analyzed here is whether efficiency is lower in the south than elsewhere in Mexico. It turns out that for efficiency in net primary enrollment, Chiapas is below the Mexican average, but Guerrero and Oaxaca are on par or slightly above the average. A similar result holds for secondary enrollment efficiency measures.

Figure 1 provides a visualization of key efficiency results regarding the Mexican southern states. The figure gives the actual and optimal outcomes for the three states and the averages for Mexico and the three southern states as a whole. In some cases, such as infant and child mortality in Guerrero and net enrollment rates in Chiapas, low levels of efficiency in using existing resources seem to explain part of the low performance of the states for these indicators. But in most cases, levels of inputs rather than high inefficiencies in using existing inputs tend to explain most of the lags observed in the south. Again, this does not mean that there is no scope for efficiency gains (the benchmark for the comparison of the efficiency of the southern states is the other states, and there may be scope for efficiency gains throughout Mexico which are not captured in our analysis), but it does suggest that the three southern states are not necessarily less efficient than richer states in using their resources in order to improve outcomes.

5. Conclusion

A stochastic production frontier approach was used to determine provincial- and state-level optimal health and education outcomes that could be reached in Argentina and Mexico given available resources. The comparison of optimal and actual outcomes then provides measures of efficiency in using available resources in order to improve social indicators related to the Millennium Development Goals.

In the context of the widespread movement towards decentralization in many countries, the methodology is potentially useful for policy because it enables us to benchmark the performance of various sub-national entities and also assess whether lagging regions are behind in their social indicators due to a lack of inputs or resources, or a lack of efficiency in using these resources, with both potential explanations for poor performance clearly requiring different policy interventions. For example, the analysis, as applied for example to Mexico's southern states of Chiapas, Guerrero, and Oaxaca, suggests that in most cases, a lack of appropriate inputs, rather than a lack of efficiency, is most often the reason for comparatively weaker performance. However, in some cases, such as infant mortality in Guerrero and schooling in Chiapas, the southern states also suffer from low efficiency in using their existing resources.

Possible extensions to this work include attempting to explain what factors are driving state- or provincial-level inefficiencies. Corruption, lack of a sound bureaucracy, and urbanization are some of the variables that could play a role in explaining inefficiencies at the sub-national level. Another potential extension would be the measurement of cost efficiency in public expenditure on health and education by using a cost rather than a production frontier estimation. This approach would enable the incorporation of multiple outputs simultaneously in the estimation, but the data requirements would typically be high. A third potential extension would be to use semi-parametric approaches in the production and/or cost frontier estimation (however, again, these semi-parametric methods would require larger number of observations and places greater data requirements).

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Table 1

Summary Statistics for Health Indicators and Efficiency Measures

	*N*T*	*Mean*	*Min*	*Max*	*Std Dev*
Argentine Provincial-Level Data: Outcomes					
Infant non-mortality, per 100	120	98.01	96.88	98.98	0.49
Child non-mortality (age under 5), per 100	120	97.65	96.17	98.66	0.60
Net primary enrollment rate	120	96.09	91.49	97.84	1.39
Net secondary enrollment rate	120	72.10	61.50	82.80	5.62
Primary school language test score	328	59.61	52.20	72.31	4.76
Primary school mathematics test score	328	56.80	48.78	68.59	5.10
Secondary school language test score	236	57.16	49.44	68.02	5.17
Secondary school mathematics test score	236	53.55	44.53	66.99	6.56
Argentine Provincial-Level Data: Inputs					
GDP, per capita (constant 1999 pesos)	120	7205	2017	23571	4908
Health expenditure, per capita (constant 1999 pesos)	120	146.68	62.39	432.09	88.48
Adult literacy (% of population)	120	97.74	96.42	99.24	0.75
Access to public hospitals (# of births)	120	17985	1656	145615	28450
Access to potable water (% of population)	120	89.77	58.66	99.92	11.84
Education expenditure, per capita (constant 1999 pesos)	120	349	205	805	163

Table 1
(continued)

	*N*T*	*Mean*	*Min*	*Max*	*Std Dev*
Mexico State-Level Data: Outcomes					
Infant non-mortality, per 100	224	97.35	95.47	98.39	0.71
Child non-mortality (age under 5), per 100	224	96.77	94.81	98.04	0.91
Net primary enrollment rate	64	93.21	77.85	102.65	4.91
Net secondary enrollment rate	64	60.43	39.35	83.50	9.16
Test score (grade 1 to 6)	318	44.80	43.19	47.30	1.14
Mexico State-Level Data: Inputs					
GDP, per capita (constant 1993 pesos)	64	13579	6086	35900	6497
Adult literacy (% of population)	64	89.90	75.60	96.95	5.72
GDP, per capita (constant 1993 pesos)	224	11622	5346	29358	5952
Health expenditure, per capita (constant 1993 pesos)	224	326.85	168.35	974.81	163.69
Adult literacy (% of population)	224	88.69	72.79	96.64	6.30
Vaccination (% of population)	224	90.81	76.70	97.96	4.25
Access to public hospitals (# of births)	224	77.42	43.30	112.30	16.76
Access to potable water (% of population)	224	85.53	62.00	97.00	10.54
Education expenditure: primary, pc (constant 1993 pesos)	64	564.75	88.89	2562	465.11

Table 1
(*continued*)

	*N*T*	*Mean*	*Min*	*Max*	*Std Dev*
Education expenditure: secondary, pc (constant 1993 pesos)	64	235.74	50.61	824.67	162.42

Sources: In Argentina, the data are from ENOHSA, Ministerio de Salud y Acción Social, Ministerio de Economía, Ministerio de Educación and UNICEF. In México, the data are from INEGI, DGIED, INEA, CONAPO, CIFRA, Consejo Nacional de Vacunación, and Comisión del Agua.

Table 2
Production Frontier Coefficients for Health Indicators in Argentina and Mexico

	Infant non-mortality			*Child non-mortality*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Argentina (1995-1999)						
Constant	93.01 (21.04)	92.23 (19.76)	92.36 (21.08)	90.22 (16.81)	88.96 (16.14)	90.30 (16.89)
GDP, per capita (constant 1999 pesos)	.00005 (2.72)	-	.00006 (4.52)	.00007 (3.00)	-	.00007 (4.18)
Expenditure, per capita	.00037^{ns}	.00149	-	-.00005^{ns}	.00145	-

Table 2
(*continued*)

	Infant non-mortality			*Child non-mortality*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Argentina (1995-1999)						
(constant 1999 pesos)	(0.54)	(2.70)		(-0.06)	(2.28)	
Adult literacy (% of population)	$.0528^{ns}$ (1.17)	$.0594^{ns}$ (1.24)	$.0599^{ns}$ (1.33)	$.0798^{ns}$ (1.45)	$.0906^{ns}$ (1.62)	$.0790^{ns}$ (1.45)
Access to public hospitals (# of births)	$-.000001^{ns}$ (-0.40)	$.000001^{ns}$ (0.16)	$-.000002^{ns}$ (-0.53)	$-.000004^{ns}$ (-1.06)	$.000001^{ns}$ (0.21)	$-.000004^{ns}$ (-1.01)
Access to potable water (% of population)	$-.0031^{ns}$ (-0.55)	$.0002^{ns}$ (0.05)	$-.0032^{ns}$ (-0.52)	$-.0052^{ns}$ (-0.82)	$-.0005^{ns}$ (-0.09)	$-.0053^{ns}$ (-0.84)
Year	.0879 (7.63)	.0873 (7.15)	.0877 (7.53)	.0940 (6.50)	.0930 (6.53)	.0940 (6.70)
Log likelihood	4.2	0.6	4.0	-17	-21	-17
No. of Observations	120	120	120	120	120	120
Mexico (1990-1996)						
Constant	90.71 (133.26)	90.06 (130.82)	90.49 (138.21)	85.59 (89.31)	84.86 (89.52)	85.48 (80.20)
GDP, per capita	.00003	-	.00003	.00004	-	.00004

Table 2
(*continued*)

	Infant non-mortality			*Child non-mortality*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Mexico (1990-1996)						
(constant 1993 pesos)	(2.76)		(2.57)	(2.71)		(2.34)
Expenditure, per capita	.00033^{ns}	.00024^{ns}	-	.00031^{ns}	.00035^{ns}	-
(constant 1993 pesos)	(1.01)	(0.71)		(0.80)	(0.89)	
Adult literacy	.0689	.0789	.0709	.1038	.1196	.10480
(% of population)	(4.56)	(4.77)	(4.71)	(6.50)	(7.08)	(5.89)
Vaccinations	.0084	.0104	.0076	.0192)	.0218	.0182
(% of population)	(2.27)	(2.71)	(2.09)	(4.08)	(4.58)	(3.96)
Access to public hospitals	.0009^{ns})	.0065^{ns}	.0019^{ns}	.0004^{ns}	.0084^{ns}	.0014^{ns}
(# of births)	(0.16)	(1.26)	(0.34)	(0.08)	(1.47)	(0.26)
Access to potable water	-.0066^{ns}	-.0107^{ns}	-.0056^{ns}	-.0021^{ns}	-.0131^{ns}	-.0015^{ns}
(% of population)	(-0.48)	(-0.74)	(-0.41)	(-0.20)	(-1.03)	(-0.13)
Year	.0737	.0524^{ns}	.0948	.0906	.0542^{ns}	.1133
	(2.64)	(1.88)	(5.14)	(2.56)	(1.64)	(4.64)
Log likelihood	-88	-93	-89	-137	-143	-137

Table 2

(*continued*)

	Infant non-mortality			*Child non-mortality*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Mexico (1990-1996)						
No. of Observations	224	224	224	224	224	224

Source: Authors' estimation. ns = not statistically significant at 5% level. Other coefficients significant at the 5% level or better. Model I includes per capita GDP and per capita expenditure as resources used in reaching the health outcome, while Model II excludes per capita GDP and Model III excludes per capita expenditure respectively. Different model specifications are estimated to measure the robustness of results.

Table 3

Production Frontier Coefficients for Enrollment Rates in Argentina and Mexico

	Net primary enrollment			*Net secondary enrollment*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Argentina (1995-1999)						
Constant	72.11	61.71	62.21	-51.47	-34.97	-110.16
	(70.71)	(60.71)	(53.85)	(-17.90)	(-15.69)	(-21.92)

Table 3
(*continued*)

	Net primary enrollment			*Net secondary enrollment*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Argentina (1995-1999)						
GDP, per capita (constant 1999 pesos)	$.00004^{ns}$ (0.75)	-	$.00004^{ns}$ (0.89)	$.00012^{ns}$ (0.41)	-	$.00036^{ns}$ (1.73)
Expenditure, per capita (constant 1999 pesos)	$.00061^{ns}$ (0.52)	$.00081^{ns}$ (0.65)	-	$-.00172^{ns}$ (-0.26)	$.00352^{ns}$ (0.61)	-
Adult literacy (% of population)	0.2619 (22.04)	0.3709 (31.08)	0.3658 (27.66)	1.3743 (40.33)	1.1838 (33.95)	1.9569 (31.86)
Year	-0.3718 (-3.66)	-0.3789 (-3.71)	-0.3806 (-3.82)	0.4769 (2.07)	0.4653 (2.10)	0.4657 (2.07)
Log likelihood	-235	-236	-236	-355	-354	-356
No. of Observations	120	120	120	120	120	120
Mexico (1994-2000)						
Constant	33.64 (33.48)	35.35 (34.11)	33.64 (33.51)	-26.88^{ns} (-1.34)	-38.59 (-2.02)	-25.98^{ns} (-1.27)

Table 3
(*continued*)

	Net primary enrollment			*Net secondary enrollment*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Mexico (1994-2000)						
GDP, per capita (constant 1993 pesos)	-.00007^{ns} (-0.57)	-	-.00006^{ns} (-0.55)	.00014^{ns} (0.75)	-	.00015^{ns} (0.82)
Expenditure, per capita (constant 1993 pesos)	.00017^{ns} (0.17)	-.00010^{ns} (-0.11)	-	-.00083^{ns} (-0.31)	-.00118^{ns} (-0.45)	-
Adult literacy (% of population)	0.6546 (10.32)	0.6145 (18.31)	0.6452 (15.43)	1.0394 (4.15)	1.2073 (5.95)	1.0287 (4.06)
Year	4.0167 (2.99)	4.1772 (3.47)	4.4125) (5.25)	4.3167 (4.09)	4.3619 (4.16)	4.1144 (4.80)
Log likelihood	-189	-189	-189	-200	-200	-200
No. of Observations	64	64	64	64	64	64

Source: Authors' estimation. ns = not statistically significant at 5% level. Other coefficients significant at the 5% level or better. Model I includes per capita GDP and per capita expenditure as resources used in reaching the education outcome, while Model II excludes per capita GDP and Model III excludes per capita expenditure respectively. Different model specifications are estimated to measure the robustness of results.

Table 4

Production Frontier Coefficients for Test Scores in Argentina

	Language test scores			*Mathematics test scores*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Primary School						
Constant	74.61^{ns} (1.29)	-185.00 (-41.68)	81.19^{ns} (1.38)	71.49^{ns} (0.89)	-151.80 (-9.35)	73.80^{ns} (0.93)
GDP, per capita (constant 1999 pesos)	.00069 (3.65)	-	.00063 (3.32)	.00050 (2.67)	-	.00049 (2.65)
Expenditure, per capita (constant 1999 pesos)	$-.00605^{ns}$ (-1.32)	$-.0027^{ns}$ (-0.50)	-	$-.00097^{ns}$ (-0.15)	$.00068^{ns}$ (0.12)	-
Adult literacy (% of population)	$-.0539^{ns}$ (-0.09)	2.7073 (75.70)	$-.1325^{ns}$ (-0.22)	$-.0402^{ns}$ (-0.05)	2.3049 (14.96)	$-.0657^{ns}$ (-0.08)
Grade	-1.1762 (-10.56)	-1.1709 (-9.78)	-1.1736 (-10.42)	-1.8288 (-11.66)	-1.7856 (-11.92)	-1.8284 (-11.71)
Year	$-.2463^{ns}$ (-1.59)	-.4180 (-2.59)	$-.2873^{ns}$ (-1.88)	.6766 (3.17)	.4117 (3.84)	.6708 (3.20)
Log likelihood	-915	-934	-916	-1017	-1026	-1017
No. of Observations	328	328	328	328	328	328

Table 4
(*continued*)

	Language test scores			*Mathematics test scores*		
	Model I	*Model II*	*Model III*	*Model I*	*Model II*	*Model III*
Secondary School						
Constant	14.49^{ns} (0.23)	-145.39 (-3.19)	46.33^{ns} (0.74)	41.45^{ns} (0.76)	-26.35^{ns} (-0.47)	74.30^{ns} (1.21)
GDP, per capita (constant 1999 pesos)	.00063 (3.51)	-	.00059 (3.08)	.00090 (4.28)	-	.00073 (3.25)
Expenditure, per capita (constant 1999 pesos)	$.00258^{ns}$ (-0.49)	$.00138^{ns}$ (0.24)	-	-.0170 (-3.41)	-.00913 (-2.08)	-
Adult literacy (% of population)	$.4012^{ns}$ (0.63)	2.0718 (3.73)	$.0669^{ns}$ (0.11)	$.0499^{ns}$ (0.09)	$.8086^{ns}$ (1.41)	$-.3050^{ns}$ (-0.49)
Grade	2.0723 (16.06)	1.9998 (11.34)	2.0556 (16.04)	1.7789 (13.67)	1.9018 (17.84)	1.7795 (14.25)
Year	.3009 (2.10)	$.1576^{ns}$ (0.94)	$.2587^{ns}$ (1.81)	3.0776 (21.96)	3.0177 (19.69)	3.0019 (21.41)
Log likelihood	-626	-635	-625	-626	-637	-631
No. of Observations	236	236	236	236	236	236

Source and observations are the same as in tables 2 and 3.

Table 5
Basic Statistics on Efficiency Measures for All Provinces and States

	N	*Mean*	*Min*	*Max*	*Std Dev*
Argentine Provincial-Level Efficiency Measures					
Infant non-mortality					
Model I	24	99.44	98.60	99.91	0.35
Model II	24	99.45	98.47	99.93	0.40
Model III	24	99.41	98.60	99.91	0.35
Child non-mortality					
Model I	24	99.40	98.26	99.91	0.44
Model II	24	99.37	98.05	99.92	0.50
Model III	24	99.40	98.26	99.91	0.44
Net primary enrollment					
Model I	24	98.96	94.91	99.62	1.02
Model II	24	98.93	94.87	99.60	1.04
Model III	24	98.94	94.79	99.63	1.04
Net secondary enrollment					
Model I	24	85.26	73.97	97.17	5.99
Model II	24	86.49	75.41	97.60	5.69
Model III	24	84.79	74.46	97.96	5.87
Language scores, primary					
Model I	24	91.35	80.94	98.44	5.11
Model II	24	83.76	73.62	97.10	5.77
Model III	24	90.80	79.47	98.62	5.47
Mathematics score, primary					
Model I	24	89.76	79.47	98.23	6.28
Model II	24	86.62	75.36	98.34	6.42
Model III	24	89.64	79.21	98.24	6.35
Language score, secondary					
Model I	24	87.24	75.84	97.49	6.01
Model II	24	87.83	75.37	99.15	6.89

Table 5

(*continued*)

	N	*Mean*	*Min*	*Max*	*Std Dev*
Argentine Provincial-Level Efficiency Measures					
Language score, secondary					
Model III	24	87.76	75.86	98.60	6.33
Mathematics score					
Model I	24	85.84	74.76	98.24	7.91
Model II	24	82.12	68.57	99.08	9.22
Model III	24	82.43	69.36	98.12	8.50
Mexico State-Level Efficiency Measures					
Infant non-mortality					
Model I	32	99.50	98.56	99.93	0.38
Model II	32	99.46	98.25	99.93	0.43
Model III	32	99.48	98.49	99.93	0.39
Child non-mortality					
Model I	32	99.49	98.65	99.93	0.33
Model II	32	99.43	98.31	99.90	0.41
Model III	32	99.45	98.61	99.92	0.33
Net primary enrollment					
Model I	32	95.39	92.65	98.32	1.11
Model II	32	96.28	94.28	98.39	0.78
Model III	32	95.66	93.10	98.35	1.01
Net secondary enrollment					
Model I	32	80.84	67.46	96.33	8.43
Model II	32	79.26	65.66	96.82	8.57
Model III	32	80.89	67.48	96.32	8.42

Source: Authors' estimation. Model I includes per capita GDP and per capita expenditure as resources used in reaching the health outcome, while model II excludes per capita GDP and model III excludes per capita expenditure respectively. Different model specifications are estimated to measure the robustness of results.

Table 6

Mexico State-Level Outcome and Input Measures: Chiapas, Guerrero and Oaxaca

	Mexico average	*Southern states*	*Chiapas*	*Guerrero*	*Oaxaca*
Infant and Child Mortality (1990-1996)					
Infant non-mortality, per 100†	97.35	96.19	96.51	95.47	96.60
Child non-mortality, per 100†	96.77	94.95	94.95	94.81	95.10
GDP, per capita (constant 1999 pesos)	11,622	5,978	5,346	7,148	5,440
Expenditure, per capita (constant 1999 pesos)	326.85	173.98	168.49	185.10	168.35
Adult literacy (% of population)	88.69	74.48	72.79	75.23	75.41
Vaccination (% of population)	90.81	85.49	76.70	90.80	88.96
Access to public hospitals (# of births)	77.42	57.10	56.20	55.80	59.30
Access to potable water (% of population)	85.53	65.67	66.00	65.00	66.00
Net Primary/Secondary Enrollment (1994 and 2000)					
Net primary enrollment (% of students)	93.21	84.32	77.85	86.95	88.15
Net secondary enrollment (% of students)	60.43	46.98	39.35	50.45	51.15
GDP, per capita (constant 1993 pesos)	13,579	6,617	6,086	7,649	6,116
Expenditure primary, per capita	564.75	485.77	351.24	554.23	551.84

Table 6

(*continued*)

	Mexico average	*Southern states*	*Chiapas*	*Guerrero*	*Oaxaca*
Net Primary/Secondary Enrollment (1994 and 2000)					
Expenditure secondary, per capita	235.74	168.19	127.84	192.35	184.37
Adult literacy (% of population)	89.90	76.87	75.60	77.35	77.65

Sources: CIFRA, INEGI, DGIED, INEA, Consejo Nacional de Vacunación (Mexico) and Comisión Nacional del Agua (México); † = non-mortality rates are used in the estimation.

Table 7

Mexico State-Level Efficiency Measures: Chiapas, Guerrero and Oaxaca

	Mexico average	*Southern states*	*Chiapas*	*Guerrero*	*Oaxaca*
Infant and Child Mortality (1990-1996)					
Infant non-mortality, Model I	99.48	99.44	99.91	98.62	99.80
Infant non-mortality, Model II	99.46	99.42	99.91	98.60	99.74
Infant non-mortality, Model III	99.48	99.45	99.91	98.63	99.80
Child non-mortality, Model I	99.49	99.47	99.80	99.13	99.49

Table 7

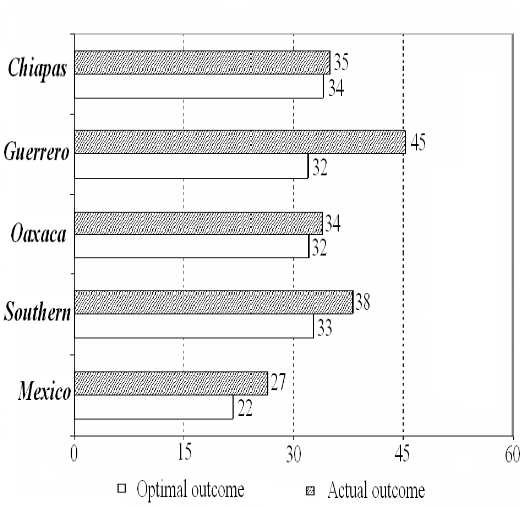
(*continued*)

	Mexico average	*Southern states*	*Chiapas*	*Guerrero*	*Oaxaca*
Infant and Child Mortality (1990-1996)					
Child non-mortality, Model II	99.43	99.41	99.79	99.07	99.37
Child non-mortality, Model III	99.45	99.44	99.76	99.11	99.45
Net Primary/Secondary Enrollment (1994 and 2000)					
Net primary enrollment, Model I	95.39	94.71	92.65	95.59	95.90
Net primary enrollment, Model II	96.28	95.74	94.28	96.35	96.59
Net primary enrollment, Model III	95.66	95.00	93.10	95.81	96.09
Net secondary enrollment, Model I	80.84	77.78	67.69	82.37	83.28
Net secondary enrollment, Model II	79.26	77.28	67.10	82.06	82.67
Net secondary enrollment, Model III	80.89	77.82	67.76	82.38	83.32

Source: Authors' estimation. Note: non-mortality rates are used in the estimation. Model I includes per capita GDP and per capita expenditure as resources used in reaching the health outcome, while model II excludes per capita GDP and model III excludes per capita expenditure respectively. Different model specifications are estimated to measure the robustness of results.

Figure 1
Actual and Optimal Outcomes in Selected Mexican States

Infant Mortality (per 1000 live births)



Child Mortality (per 1000 live births)

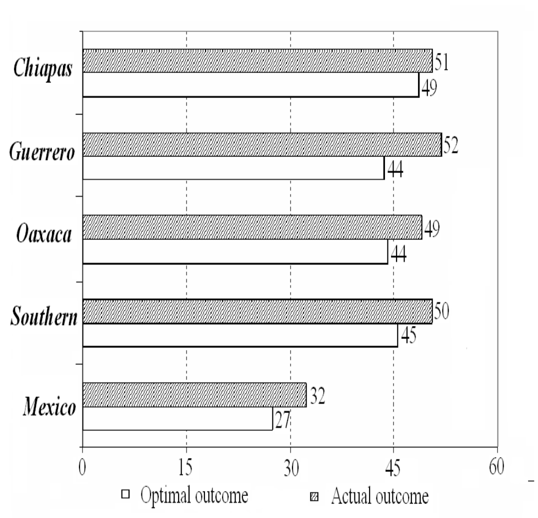
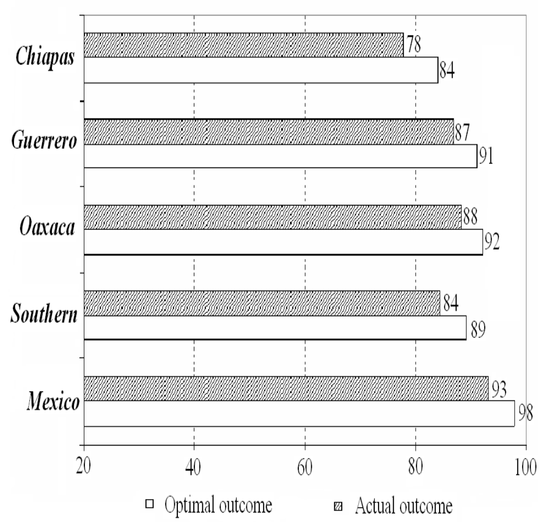
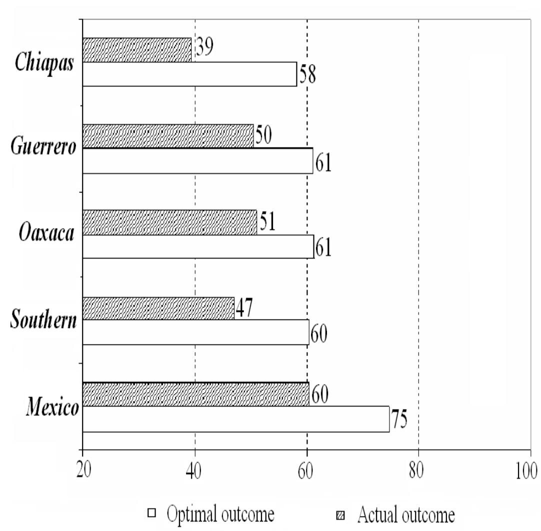


Figure 1
(*continued*)

Net Primary Enrollment Rate (% of Population)



Net Secondary Enrollment Rate (% of Population)



Source: Authors'estimation

Appendix 1

Estimations for Argentina Without Outlier Data for 1999

Table A1.1

Production Frontier Coefficients
for Enrollment Rates in Argentina

	Net primary enrollment		
	Model I	*Model II*	*Model III*
Constant	62.73 (56.96)	60.46 (58.39)	49.34 (48.23)
GDP, per capita (constant 1999 pesos)	$.000003^{ns}$ (0.06)	-	$.000007^{ns}$ (0.23)
Expenditure, per capita (constant 1999 pesos)	$.0010^{ns}$ (0.91)	$.00099^{ns}$ (0.94)	-
Adult literacy (% of population)	0.3492 (26.59)	0.3726 (30.73)	0.4904 (44.64)
Year	0.2247 (2.27)	0.2246 (2.17)	0.2086 (2.07)
Log likelihood	-165	-165	-165
Number of Observations	96	96	96

Source: Authors' estimation. ns = not statistically significant at 5% level. Other coefficients significant at the 5% level or better. Model I includes per capita GDP and per capita expenditure as resources used in reaching the education outcome, while model II excludes per capita GDP and model III excludes per capita expenditure respectively. Different model specifications are estimated to measure the robustness of results.

Table A1.2

Basic Statistics on Efficiency Measures for All Argentina Provinces

		N	*Mean*	*Min*	*Max*	*Std. Dev.*
Argentine Provincial-Level Efficiency Measures						
Net primary enrollment	Model I	24	98.75	92.85	99.70	1.45
	Model II	24	98.76	92.86	99.70	1.45
	Model III	24	98.71	92.66	99.71	1.49

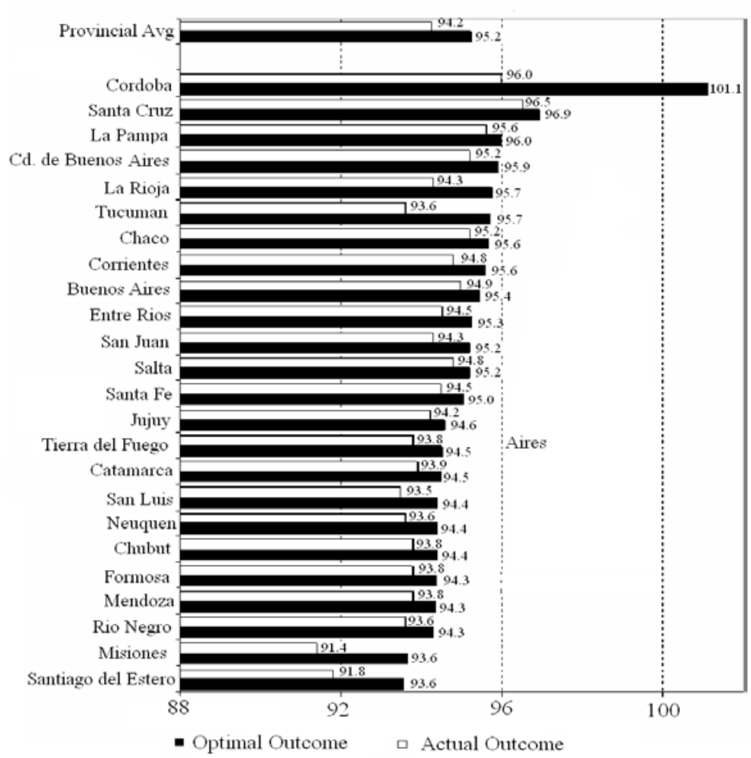
Source: Authors' estimation. Model I includes per capita GDP and per capita expenditure as resources used in reaching the health outcome, while model II excludes per capita GDP and model III excludes per capita expenditure respectively. Different model specifications are estimated to measure the robustness of results.

Appendix 2

Optimal and Actual Outcome Measures by Province in Argentina Using the Baseline Model

Figure A2.1
Optimal and Actual Enrollment Outcome Measures by Province in Argentina, 1999

Optimal and Actual Net Primary Enrollment

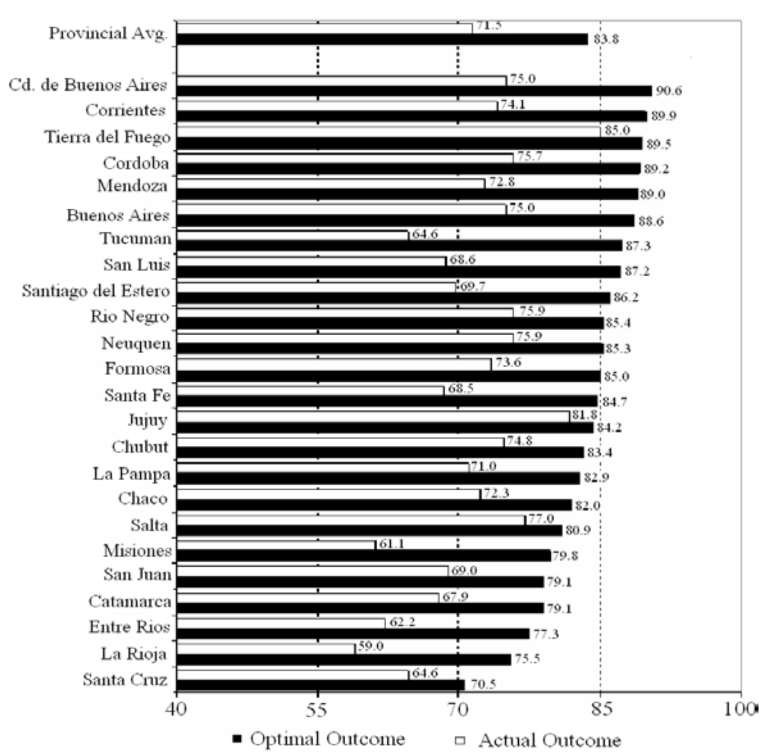


Source: Authors.

Figure A2.1

(*continued*)

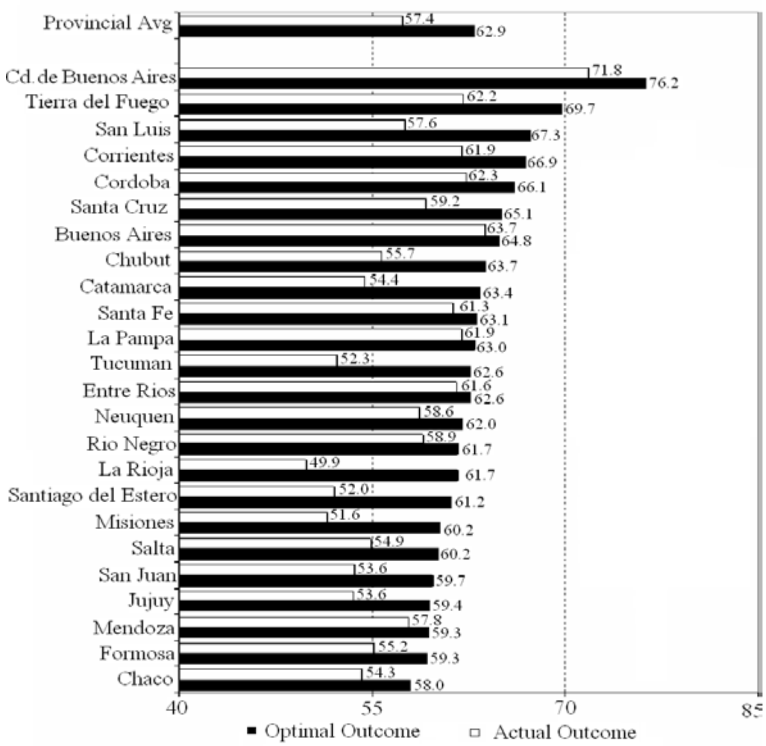
Optimal and Actual Net Secondary Enrollment



Source: Authors.

Figure A2.2
Optimal and Actual Test Score Measures,
Primary, by Province in Argentina, 1999

Optimal and Actual Language Test Scores

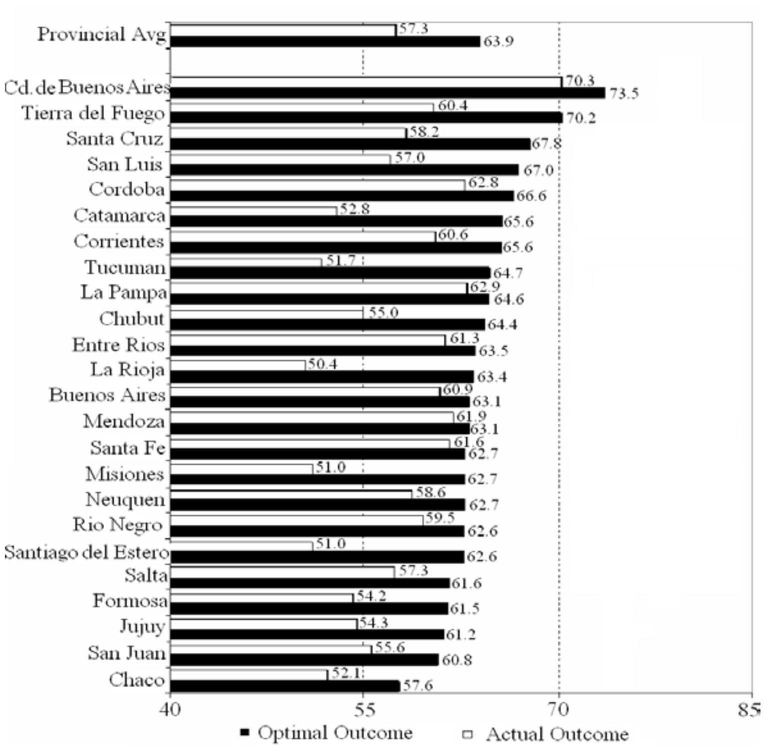


Source: Authors.

Figure A2.2

(*continued*)

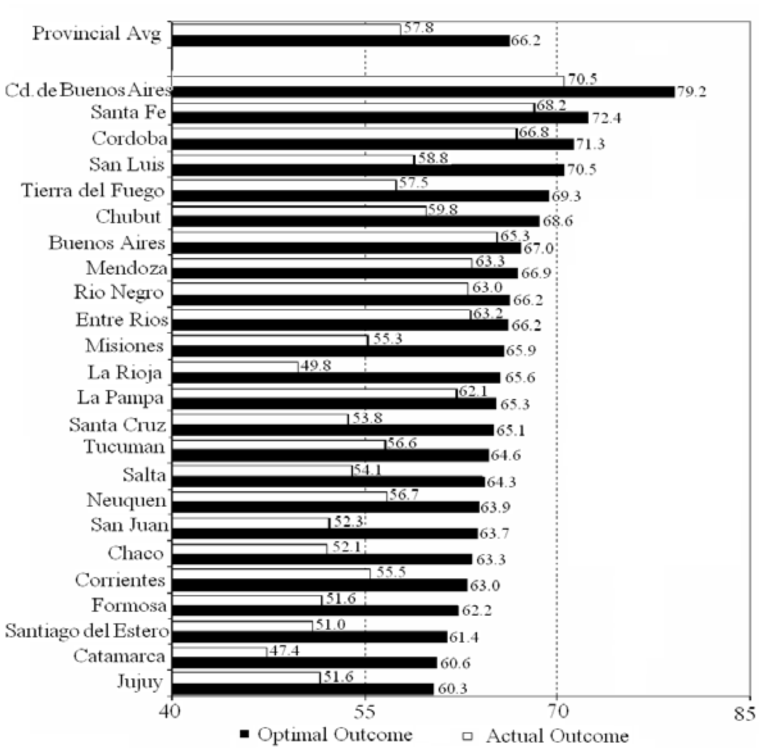
Optimal and Actual Mathematics Test Scores



Source: Authors.

Figure A2.3
Optimal and Actual Test Score Measures, Secondary, by Province in Argentina, 1999

Optimal and Actual Language Test Scores

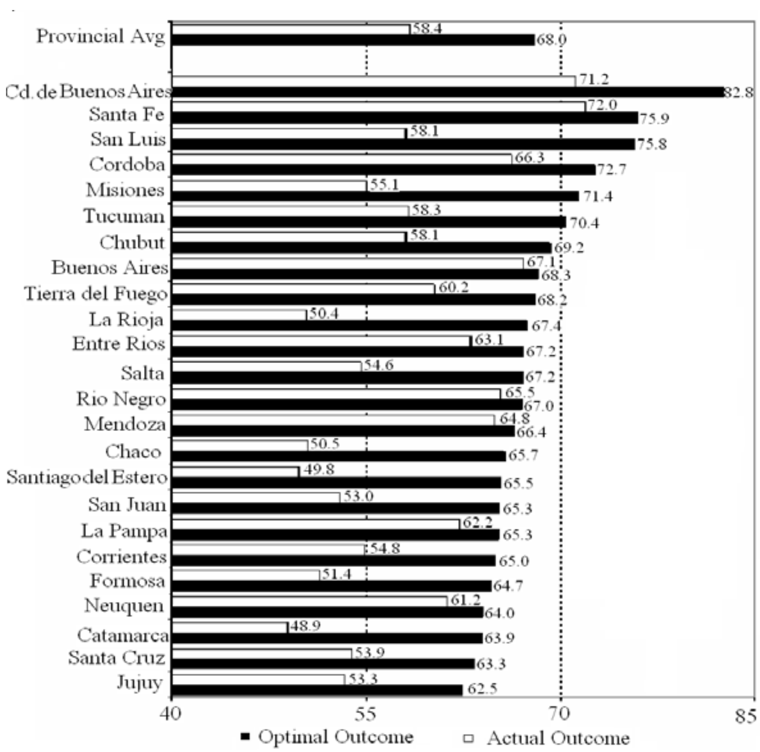


Source: Authors.

Figure A2.3

(*continued*)

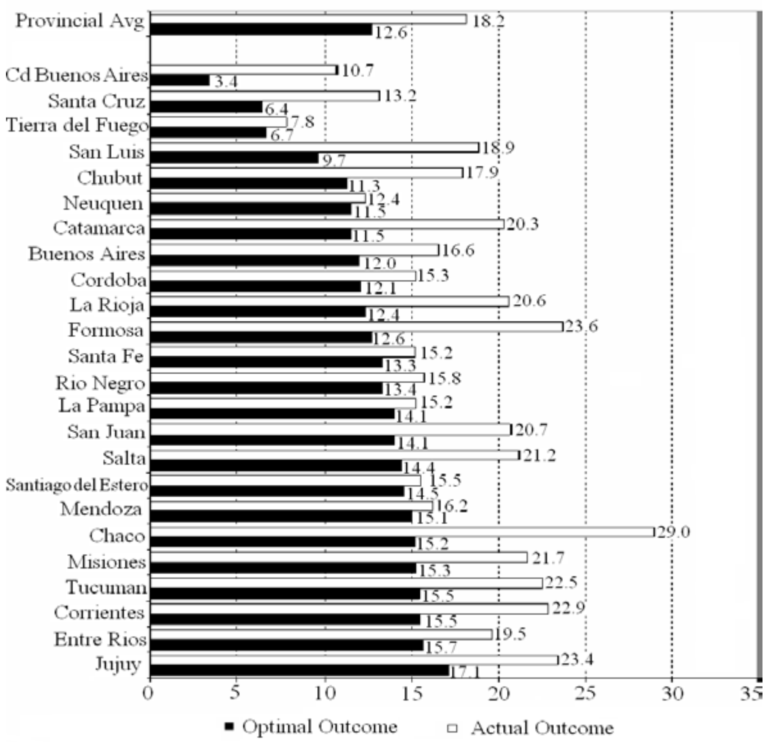
Optimal and Actual Mathematics Test Scores



Source: Authors.

Figure A2.4
Optimal and Actual Health Outcomes
Measures by Province in Argentina, 1999

Optimal and Actual Infant Mortality Outcomes (per 1000)

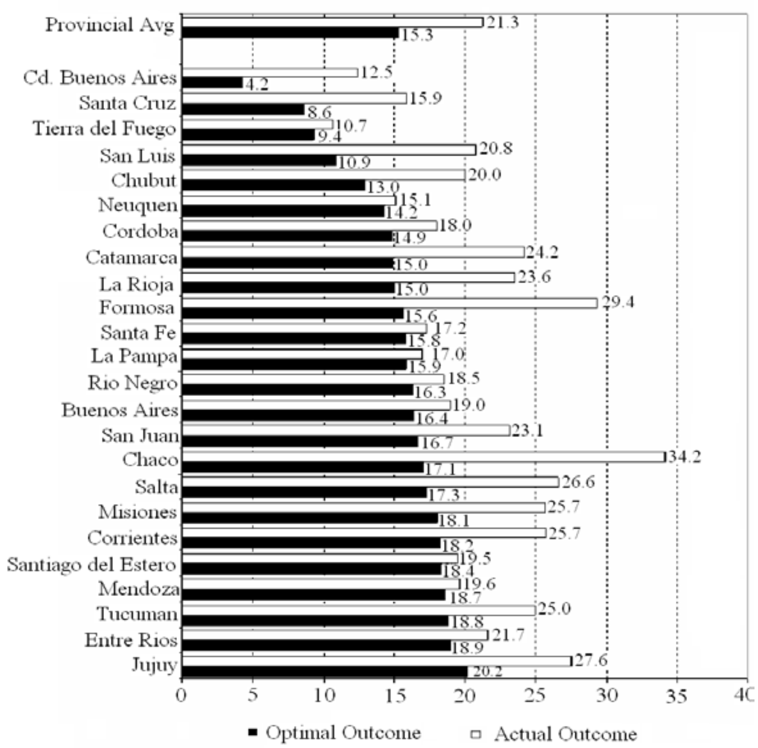


Source: Authors.

Figure A2.4

(*continued*)

Optimal and Actual Child Mortality Measures (per 1000)



Source: Authors.