NÚMERO 588

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Estimating the Technical Efficiency of Mexican States

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FEBRERO 2015

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Agradecimientos

Seniority of authorship is shared equally. The authors gratefully acknowledge the assistance of Alejandro Becerra, Alberto Gude and Krystyna Pechena.

Abstract

In this paper we estimate the technical efficiency of Mexican states using several stochastic production frontier models. The empirical section uses panel data over the period 1988-2008. A distinctive feature of the paper is to use socioeconomic and location data in order to control for the heterogeneity of the states. We find that inefficiency explains part of the difference in production across regions, which is not accounted by other explanatory variables. Our results show that infrastructure, education, productive specialization and the presence of oil production shift the production frontier upwards. Additionally, northern states are more efficient than the rest of the country.

Keywords: Regional efficiency, stochastic frontier, state characteristics, panel data.

Resumen

Este trabajo estima la eficiencia técnica de los Estados de México utilizando diferentes modelos de fronteras estocásticas de producción. El apartado empírico se sirve de datos de panel para el periodo 1988-2008. La característica distintiva de este trabajo es el uso de variables socioeconómicas y de localización para controlar por la heterogeneidad de los Estados. Encontramos que la ineficiencia explica parte de la diferencia en producción entre regiones que no es esclarecida por otras variables explicativas. Los resultados muestran que la infraestructura, educación, especialización productiva y la presencia de producción petrolera desplazan la frontera de producción hacia arriba. Asimismo, los Estados del Norte son más eficientes que el resto del país.

Palabras clave: **eficiencia regional, frontera estocástica, características estatales, datos de panel.**

Introduction

The study of regional efficiency provides valuable information about which factors explain the observed differences in productivity across regions in a country. This is important in Mexico, where regional differences in economic growth are important. In fact, empirical evidence shows that most of the economic growth has been concentrated in regions near the U.S. Mexican border (Garduño-Rivera, 2014).
One of the main drivers of economic growth is the improvement in technical efficiency. Nowadays it is common to use production frontiers in order to measure (in) efficiency as distance from the technological frontier[1]. In particular, some recent papers have estimated the technical efficiency of Mexican states using both parametric (e.g., Chávez and Fonseca, 2012) and non-parametric approaches (e.g., Chavez and López, 2013) to determine the frontier.
In this paper we follow a parametric approach and estimate two stochastic frontier models that allow not only to estimate the level of technical efficiency of each state but also to study the variables that explain best the differences in technical efficiency across states. We use a panel dataset of the 32 Mexican states. The data come from the economic censuses undertaken by the Mexican Statistical Institute (INEGI) every five years. A distinctive feature of our paper is to use a good number of state characteristics that are expected to pick up most of the observed differences between the states. These variables reflect differences in human capital, infrastructures, productive specialization, location and business environment.
The structure of the paper is as follows. In section 2, we present the stochastic frontier models. In section 3, we review the literature that uses stochastic frontiers to estimate regional efficiency. Section 4 describes the data and the empirical models. In section 5, we present the estimation results. Section 6 discusses the estimated efficiency of the states. Section 7 contains some conclusions.

Modeling Technical Efficiency

Technical efficiency is defined as the ratio between observed production and potential production, i.e. production on the frontier, given a set of inputs. We follow the stochastic frontier approach (Aigner *et al*., 1977) in order to estimate the technical efficiency of Mexican states. Our basic model is a production frontier, which can be written as:

$$y_{it} = \beta' x_{it} + v_{it} - u_{it} \qquad (1)$$

[1] See Alvarez and Arias (2014) for a recent survey.

where *y* is the output, *x* are the inputs, *v* is random noise and *u* is a non-negative stochastic term that is assumed to be independent from *v* and to capture distance from the frontier, i.e. inefficiency. When $u=0$, the observation lies on the technological frontier and is, therefore, efficient. When $u>0$, the observation is below the frontier, indicating that it is technically inefficient.

Since we are interested in finding which variables explain the efficiency of states, we estimate several models that modify equation (1) by allowing the inefficiency term *u* to be a function of some exogenous variables z. The general form of this type of models is:

$$y_{it} = \beta' x_{it} + v_{it} - u_{it}(z_{it}) \tag{2}$$

There are two possible alternative specifications of $u_{it}(z_{it})$, depending on the way that the variables *z* affect the distribution of *u*: they can affect the mean or the variance. In this paper we use two models in order to explore these possibilities.

a) Modelling the mean of the inefficiency term

Kumbhakar *et al.* (1991), and Huang and Liu (1994) were the first papers that attempted to model the inefficiency term in a stochastic frontier framework. Their approach consists of making the mean of the distribution of the inefficiency term depend on a set of exogenous variables. While these models were originally developed for cross-sectional data, Battese and Coelli (1995) (from now on referred as BC95) extended this approach to accommodate panel data. In the BC95 model the inefficiency term is assumed to follow a truncated normal distribution where the mean of the pre-truncated distribution of u_{it} depends on a set of exogenous variables, z. That is,

$$u_{it} \sim N^{+}(\mu_{it}, \sigma_u^2), \quad \mu_{it} = \delta \cdot z_{it} \tag{3}$$

where superscript "+" indicates truncation of a distribution from the left at zero. In this way, we make sure that $u \geq 0$.

Modeling the variance of the inefficiency term

Reifschneider and Stevenson (1991) was the first paper to incorporate heteroskedasticity in the stochastic frontier model, assuming that u_{it} is distributed as $N^{+}(0, \sigma_{it}^2)$. Caudill *et al.* (1995) (from now on referred as CFG95) assumed that *u* exhibits multiplicative heteroskedasticity, a choice that we will use in this paper. In particular, the CFG95 model suggests an exponential function:

$$u_{it} \sim N^{+}(\mu, \sigma_{it}^2), \quad \sigma_{it} = g(z_{it}, \delta) = \sigma_u \cdot \exp(\delta z_{it}) \tag{4}$$

Modeling the variance of the one-sided error term is very important since the presence of heteroskedasticity in *u* will yield biased estimates of both the frontier parameters and the efficiency scores. This result differs markedly from the typical effect of heteroskedasticity in the two-sided error term *v*, which causes the variances of the parameter estimates to be biased.

Regional Efficiency in Mexico

In the case of Mexico, just a few papers explicitly study regional efficiency. We will refer only to those that follow a parametric approach. The reader interested in non-parametric approaches may also check Bannister and Stolp (1995) and Chavez and López (2013).

Becerril *et al.* (2009) estimate a stochastic frontier using data from the federal entities. They use the BC95 model in order to analyze the effect of the infrastructures on state efficiency and find that Nuevo León, Mexico City (*Distrito Federal*, D.F.) and the State of Mexico are on the efficient frontier. A sigma convergence analysis shows that the disparities among the states have been declining over time. They divide their period of analysis according to the two main economic policies of each period: Import Substitution Industrialization (ISI,1970-1985) and Export-oriented Industrialization (1988-2003). They conclude that convergence in technical efficiency, as well as the infrastructure variable, reported better results during the ISI period.

Becerril *et al*. (2010) build a stochastic frontier model for the total production of the Mexican states using a data set that covers from 1980 to 2003 (using quinquennial censuses). They also use the BC95 model, specifying the production function as a translogarithmic function and integrating the analysis of beta and sigma convergence. Their main finding is that productivity can be increased by 20% using the same inputs. According to the authors, in 1980, the State of Mexico, D.F. and Jalisco were the most efficient entities; whereas, in 2003, Nuevo León, D.F., Veracruz and the State of Mexico were the entities on the stochastic frontier.

Aguilar (2011) estimates the BC95 model to a sample of 21 municipalities with data for five economic sectors during the years 2006-2008. Interestingly, the author includes a trend in the inefficiency term obtaining for all sectors a positive sign, which implies that the technical inefficiency of Mexican municipalities increased over the sample period, although it is significant for only two of them.

Braun and Cullmann (2011) use a panel dataset of regional production data from the manufacturing sector at the municipality level. They estimate both the BC95 and the True Random Effects (Greene, 2004) models. They report significant disparities in the efficiency scores across municipalities, finding in particular that northern states operate more efficiently than the southern ones.

Chávez and Fonseca (2012) estimate a stochastic frontier model for the manufacturing sector using data at the state level in order to analyze the regional disparities that exist in Mexico. Covering the periods of 1988, 1993, 1998, 2003 and

2008, they estimate a translogarithmic production frontier using the model proposed by Battese and Coelli (1992) and integrate the analysis of beta and sigma convergence. They find a steady increase in the levels of technical efficiency from 53.7% to 76.4%, as well as the existence of beta and sigma convergence, i.e. efficiency gaps are being closed as more inefficient states are getting more productive. However, there are still marked differences between Central and Northern states and those in the South.

Data and Empirical Models

We use a balanced panel dataset of the 32 Mexican states, including D.F., during the period 1988-2008. The basic data (output, labor and capital) come from the economic censuses carried out by INEGI (National Institute of Statistics and Geography) every five years. We have information for five censuses, where the first one reports information of year 1988 from all Mexican formal economic units, excluding those in the agricultural sector, followed by censuses in years 1993, 1998, 2003 and 2008. As a result, the panel dataset consists of 160 observations (32 states times 5 years).

Output (*Y*) is gross value added and private capital (*K*) is measured as the total stock of fixed assets. Both variables are deflated using the producer price index reported by INEGI with December 2010 equal to 100. Labor (*L*) is the total number of workers.

In order to account for across-state heterogeneity, we include several control variables. Some summary statistics of the main variables are displayed in Table 1. Human Capital is typically included in regional production functions in order to account for labor heterogeneity. As a proxy we use the average years of education of labor in each state (*EDUC*). The information was gathered from population censuses of 1989, 1994, 1999, 2004 and 2009 by INEGI.

Following Aschauer (1989) many papers also include a measure of the stock of public capital. Since in Mexico there are no official figures for this variable for all the years included in the dataset, we use as a proxy the number of airports in each state (*INFR*), reported by INEGI.

Since Mexico is one of the largest oil producing countries in the world, it is relevant to differentiate where the production occurs. To do so, we include the oil production (millions of barrels per day) of each state (*OIL*), according to the yearbooks by PEMEX (2009).

To account for the economic environment to carry out business, we include two variables: One is the total number of people convicted in each state per thousand inhabitants (*CONVIC*), at both federal and state levels, gathered also from INEGI (2013). The second is the crime rate of each state (*CRIME*), measured as total number of homicides per thousand inhabitants (INEGI, 2013).

Additionally, we include a set of regional dummy variables to account for unobserved regional heterogeneity. Following the Mexican Central Bank (Chiquiar, 2008), we divide the Mexican territory into 7 groups: U.S. **Border** (Baja California, Coahuila, Chihuahua, Nuevo León, Sonora and Tamaulipas), **Capital** (D.F.), **Center** (Aguascalientes, Colima, Guanajuato, Hidalgo, Jalisco, México, Michoacán, Morelos, Puebla, Querétaro, and Tlaxcala), **North** (Baja California Sur, Durango, Nayarit, San Luis Potosí, Sinaloa and Zacatecas), **Oil** (Campeche and Tabasco), **Peninsula** (Quintana Roo and Yucatán) and **South** (Chiapas, Guerrero, Oaxaca, and Veracruz). Chávez and Fonseca (2012) used 4 regional areas (north, north-central, south and central) but, in order to better capture the heterogeneity of the states, we consider D.F. as a separate region and divide the south region in three parts (Oil, Peninsula, and South) to isolate the fast growing oil-producing area from the poor and slow growing area of the south.

Finally, we account for the different productive specialization of the regions by means of a Specialization Index (SI) following Alvarez (2007), which is computed as follows:

$$SI_i = \sum_{j=1}^{4} \left(\frac{VA_{ji}}{VA_i} - \frac{VA_{jN}}{VA_N} \right)^2 \tag{5}$$

where *VA* is the Value Added, subscript *j* denotes sector (Commerce, Manufacturing, Mining and Services), *i* represents state and *N* indicates that the value refers to the national average. This index is zero when the regional productive structure is equal to the national average and increases with the level of specialization.

Besides a constant term, we have included two exogenous variables in the inefficiency term. First, a time trend, which is expected to check if there are unobserved factors that make inefficiency vary over time. We also expect the location of each region to affect inefficiency. In particular for the case of Mexico, it is notorious the difference between North and South, where the regions located in the southern part of the country are less developed than those located in the North. To account for this fact, we include the distance to the US border, which we reflect with a variable (*DIST_US*) that is measured as the road distance in kilometers between the state capital and the US border.

The final model to be estimated is a Cobb-Douglas production frontier of the following form:

$$\ln y_{it} = \beta_0 + \gamma_t YR_t + \theta_r REG_r + \sum_{j=1} \beta_j \ln x_{jit} + v_{it} - u_{it}(z_{it}) \tag{6}$$

where subscript *i* indexes states, *t* indexes time, *r* indexes region, *YR* are time dummies, *REG* are regional dummies, x_{it} is a vector of explanatory variables, which includes the standard inputs (labor and capital) as well as a set of control variables (*EDUC, INFR*, *OIL*, *SI*, *CONVIC, CRIME*). The noise component *v* is assumed to be normally distributed with mean zero, while the inefficiency component *u* will follow a truncated normal distribution for the model BC95 and half normal for the model CFG95 explained in section 2.

Estimation and Results

Table 2 presents the maximum likelihood estimates of the stochastic production frontier models described in section 2. First of all it is important to highlight that the results are very similar across the two models. In the frontier part, all explanatory variables are significant and carry the expected signs. Since the functional form is Cobb-Douglas, the estimated parameters are interpreted as elasticities. The hypothesis of constant returns to scale in capital and labor cannot be rejected, as shown in the last row of table 2.

The regional dummies are significant and negative, which means that the (time invariant) unobserved characteristics of the regions make them different from the capital (D.F.), which is the excluded category. The border region effect is the closest one to the capital.

The time effects can be assumed to pick up neutral technical change as well as the effect of some year specific events. In both models, the time dummies carry a positive sign indicating that some unmeasured variables are contributing to increase production. Given that the omitted category is the initial year (1988), the estimated time effects are expected to be increasing over time due to the effect of technical change. However, the dummies for 1998 and 2008 are smaller than the previous year estimates. This is due to the important economic crises in the country that took place in 1995, known as the "tequila crisis", in 2002-2003 due to the global 2000s economic recession that affected the U.S., and in 2007-2008 due to the global financial crisis.

The estimated coefficients of all the control variables are significant and carry the expected sign. Education (EDUC), infrastructure (INFR), oil production (OIL) and the specialization index (SI) are positive, indicating that additionally to the input variables they contribute to increase output. On the other hand, both institutional variables, conviction and crime rates, have a negative effect on the production of the states. The latter signs reflect that those states where conviction and crime rates are high do not provide a good economic environment to carry out business, contributing to a decrease in output.

Inefficiency

The value obtained for λ (2.0 in BC95 and 1.2 in CFG95), which is equal to the ratio between the standard deviations of inefficiency and statistical noise (i.e. σ_u/σ_v), indicates that inefficiency in both models explains part of the difference in production across regions which is not accounted for by the explanatory variables.

We have included a trend as an explanatory variable in the inefficiency term in order to test if the inefficiency of the states changed over time due to factors different from those included in the model. The trend is positive in both models, while only significant in the BC95 model, indicating that some unobserved factors (common to all states) are causing state inefficiency to increase.

As expected, the effect of the distance to the U.S. border (*DIST_US*) is positive and significant. This implies that states near the U.S. border (such as, Baja California, Sonora, Chihuahua, Nuevo León and Tamaulipas) are more efficient than those states further away.

Evaluating the Technical Efficiency of Mexican States

We now proceed to compare the estimated efficiency of each state. Maximum likelihood only provides an estimate of the composed error term. However, using the conditional expectation of u_{it} on v_{it} - u_{it} , we can recover an estimate of u_{it}.

Since the output variable is in logs, the output-based Farrell technical efficiency index can be calculated as:

$$TE_{it} = \exp(-\hat{u}_{it}) \quad (7)$$

Since the inefficiency term u_{it} varies across states and over time, there is an estimation of u_{it} for each state in each year. To better summarize this information, in tables 3 and 4 we show the estimated initial (i.e. 1988) and final (i.e. 2008) efficiency indexes for models as well as the percent change and the ranking according to the later rate. A positive change implies a movement towards the technological frontier and can therefore be interpreted as evidence that the state is "catching-up".

In both models for the initial and final year the most efficient state is Baja California. This indicates that this state is using in the most efficient way the inputs in the production process. On the other hand, the least efficient state in 1988 was Tabasco, but it has the highest efficient growth rate between this year and 2008 under CFG95 (it occupies the fifth position in the ranking under BC95). Not surprisingly, Guerrero became the least efficient state in 2008 under CFG95 (last fourth position under BC95) and in the ranking is also in the last positions. This state depends mainly on commercial and tourist activities. Acapulco, which is the main tourist destination in Guerrero, has reported a record economic decline due to a large decrease in tourist activities, mainly caused by predominance of illegal activities in the region. One last result that is important to highlight is the case of Chiapas, which is located in the second and third position in the ranking under BC95 and CFG95, respectively. While this state is one of the poorest states of the country, the high change in the technical efficiency from 1988 to 2008 could be explained by the increasing government investment in projects for this particular state (Sour, 2008).

To better illustrate the results, we show a quantile map with four categories for the estimated technical efficiency index for 2008 of each state in figures 1 and 2 for BC95 and CFG95, respectively. The maps show that the US border effect is a key driver of efficiency since those states in the border report the highest technical efficiency index, while three out of the four poorest states, namely Michoacán, Oaxaca and Guerrero, located in the south of the country, report the lowest technical efficient indexes.

Conclusions

This paper studies the regional efficiency of the 32 Mexican states by estimating two production frontier models in order to measure it as distance from the technological frontier. The unique feature of the paper is that, besides labor and capital, we explicitly incorporate a number of state characteristics that are expected to pick up most of the observed differences between the states across time. Likewise, we model the possible heteroskedasticity in the inefficiency term that reduces the bias of the estimators.

In this paper we follow the parametric approaches proposed by Battese and Coelli (1995) and Caudill, Ford and Gropper (1995) to estimate the level of technical efficiency and the variables that explain best the differences in technical efficiency across states. We use a panel dataset of the 32 Mexican states.

We present several important findings. First, we confirm that the Mexican economy (excluding the agricultural sector) reports constant return to scale in labor and capital. Second, additionally to the input variables, we find that other characteristics such as education, public infrastructures, productive specialization, and the presence of the oil sector contribute to increase output. Third, we find that inefficiency in both models explains part of the difference in production across regions, which is not accounted by the explanatory variables. Last, our study determines the efficiency of each state with respect to the frontier. Comparing the initial and final year in our sample, we find that Chiapas is one of the states that has reduced more the inefficiency, while the other three poorest states in the country (i.e. Oaxaca, Michoacán and Guerrero) are far from the rest of the states. Similarly, we confirm the important role of the proximity to the US border because results show that Border States reported the most efficient use of the inputs in 2008.

From a policy point of view, one of the most interesting findings of our paper is that state inefficiency has a positive trend, i.e., there are some factors not included in the model that cause the inefficiency of the states to increase.

Appendix

TABLE 1 - PART 1 SUMMARY STATISTICS VARIABLES IN EQUATION (6)

Variable	Year	Border	Capital	Center	North	Oil	Peninsula	South
Gross Value Added*	1988	0.22	0.21	0.33	0.06	0.14	0.01	0.03
	1993	0.20	0.23	0.35	0.06	0.10	0.02	0.04
	1998	0.23	0.27	0.32	0.06	0.07	0.02	0.03
	2003	0.22	0.26	0.28	0.05	0.12	0.02	0.04
	2008	0.21	0.21	0.29	0.06	0.18	0.02	0.04
Total Employment*	1988	0.23	0.23	0.37	0.09	0.02	0.02	0.05
	1993	0.23	0.19	0.40	0.09	0.02	0.03	0.05
	1998	0.25	0.19	0.38	0.09	0.02	0.03	0.05
	2003	0.24	0.18	0.39	0.09	0.02	0.03	0.06
	2008	0.23	0.16	0.40	0.09	0.02	0.04	0.06
Stock of Capital*	1988	0.23	0.12	0.44	0.06	0.12	0.01	0.02
	1993	0.24	0.13	0.39	0.09	0.07	0.03	0.05
	1998	0.23	0.19	0.38	0.07	0.05	0.02	0.06
	2003	0.26	0.18	0.36	0.08	0.04	0.02	0.06
	2008	0.25	0.17	0.34	0.11	0.05	0.03	0.04
Average years of Education of Labor	1988	7.7	9.2	6.5	6.7	6.2	6.5	5.1
	1993	7.8	9.5	6.8	7.0	6.7	6.5	5.6
	1998	8.4	10.3	7.3	7.6	7.5	7.3	5.6
	2003	9.3	10.6	8.6	8.8	8.7	8.8	7.4
	2008	9.2	11.2	8.2	8.7	8.8	8.3	6.1
Infrastructure	1988	23	1	19	15	3	5	11
	1993	23	1	19	15	3	5	11
	1998	26	1	19	12	3	5	13
	2003	26	1	21	12	3	5	13
	2008	23	1	20	12	3	5	13
Crude Oil Production per day in Millions of Barrels	1988	19	0	64	0.9	2479	0	46
	1993	20	0	69	1	264	0	49
	1998	22	0	74	1	286	0	53
	2003	19	0	69	1	326	0	32
	2008	15	0	78	0	266	0	34
People Convicted per 1,000 Inhabitants	1988	1.31	1.66	1.12	1.17	2.43	0.74	0.88
	1993	2.59	1.68	1.31	2.01	2.31	1.67	1.13
	1998	2.38	1.89	1.07	1.74	1.76	1.41	1.10
	2003	2.43	2.54	1.23	1.91	1.40	1.37	1.03
	2008	2.15	2.27	1.04	1.59	0.91	1.41	0.82

Crime Rate per 1,000 Inhabitants	1988	0.09	0.14	0.21	0.06	0.11	0.06	0.26
	1993	0.12	0.13	0.17	0.02	0.13	0.09	0.31
	1998	0.12	0.10	0.11	0.01	0.09	0.05	0.22
	2003	0.09	0.10	0.08	0.00	0.05	0.05	0.13
	2008	0.33	0.10	0.11	4.49	0.08	0.05	0.24
Distance of the region to the U.S. border in kilometers	NA	219	1,054	987	908	1,629	1,998	1,382

*Regional Shares

TABLE 2 - STOCHASTIC PRODUCTION FRONTIER ESTIMATION

		BC95 EQ. (3)		CFG95 EQ. (4)	
Variable	Par.	Estimate	t-ratio	Estimate	t-ratio
INTERCEPT	β_0	3.814	[4.94]	3.295	[4.32]
LABOR	β_1	0.818	[15.10]	0.842	[15.56]
CAPITAL	β_2	0.167	[3.48]	0.179	[3.66]
EDUC	β_3	0.822	[3.71]	0.724	[3.20]
INFR	β_4	0.06	[3.58]	0.055	[3.13]
OIL	β_5	0.045	[2.49]	0.034	[1.90]
CONVIC_RATE	β_6	-0.143	[-3.44]	-0.123	[-2.69]
CRIME_RATE	β_7	-0.07	[-2.68]	-0.062	[-2.28]
SPECIALIZATION INDEX	β_8	1.084	[4.61]	1.118	[4.62]
YR1993	γ_{1993}	0.32	[5.51]	0.303	[5.12]
YR1998	γ_{1998}	0.21	[2.86]	0.159	[2.36]
YR2003	γ_{2003}	0.23	[2.35]	0.163	[1.75]
YR2008	γ_{2008}	0.221	[2.17]	0.159	[1.60]
REG_ BORDER	θ_2	-0.719	[-2.94]	-0.832	[-2.97]
REG_OIL	θ_6	-1.117	[-5.42]	-1.314	[-5.40]
REG_CENTER	θ_4	-1.287	[-6.17]	-1.266	[-5.21]
REG_NORTH	θ_1	-1.334	[-5.65]	-1.15	[-4.44]
REG_PENINSULA	θ_7	-1.042	[-5.42]	-1.085	[-5.10]
REG_SOUTH	θ_3	-1.025	[-5.19]	-1.06	[-4.52]
Inefficiency Model					
TREND	δ_1	0.057	[2.11]	0.344	[1.57]
DISTANCE_US	δ_2	0.436	[3.96]	2.368	[2.83]
CONSTANT	δ_0	-2.746	[-3.70]	-20.6	[-3.45]
sigma_u2	σ_u^2	0.0446		0.042	
sigma_v2	σ_v^2	0.0109		0.027	
lambda	λ	2.019		1.243	
Observations	*NxT*	160		160	
Log-likelihood		26.097		24.874	
H_0: Constant Returns to Scale	$\beta_1+\beta_2=1$	1.19	0.2750[a]	0.05	0.8276[a]

[a] p-value reported

TABLE 3 - INITIAL AND FNAL TECHNICAL EFFICIENCY (TE) INDEX USING BC95

STATE	INITIAL TE	FINAL TE	TE CHANGE	RANK TE CHANGE
Veracruz	0.56	0.75	0.34	1
Chiapas	0.71	0.88	0.24	2
Durango	0.64	0.77	0.21	3
Campeche	0.76	0.89	0.17	4
Tabasco	0.43	0.50	0.16	5
Tamaulipas	0.79	0.90	0.14	6
Sonora	0.92	0.94	0.01	7
Baja California	0.98	0.98	0.00	8
Nuevo Leon	0.95	0.93	-0.02	9
Chihuahua	0.94	0.89	-0.05	10
Distrito Federal	0.58	0.54	-0.06	11
Coahuila	0.91	0.84	-0.08	12
Aguascalientes	0.68	0.63	-0.08	13
Nayarit	0.63	0.57	-0.10	14
Queretaro	0.75	0.66	-0.13	15
San Luis Potosi	0.90	0.74	-0.17	16
Zacatecas	0.75	0.62	-0.17	17
Sinaloa	0.69	0.57	-0.18	18
Tlaxcala	0.58	0.46	-0.20	19
Yucatan	0.53	0.42	-0.20	20
Baja California Sur	0.62	0.49	-0.21	21
Puebla	0.58	0.45	-0.22	22
Quintana Roo	0.47	0.36	-0.24	23
Michoacán	0.58	0.43	-0.26	24
Jalisco	0.76	0.56	-0.27	25
Colima	0.77	0.56	-0.27	26
Hidalgo	0.95	0.64	-0.32	27
Guanajuato	0.86	0.55	-0.36	28
Guerrero	0.60	0.38	-0.38	29
México	0.88	0.53	-0.39	30
Oaxaca	0.75	0.37	-0.50	31
Morelos	0.95	0.43	-0.54	32

TABLE 4 - INITIAL AND FINAL TECHNICAL EFFICIENCY INDEX USING CFG95

STATE	INITIAL TE	FINAL TE	TE CHANGE	RANK TE CHANGE
Tabasco	0.65	0.74	0.15	1
Veracruz	0.84	0.91	0.08	2
Chiapas	0.90	0.95	0.05	3
Campeche	0.91	0.95	0.04	4
Durango	0.90	0.91	0.01	5
Baja California	1.00	1.00	0.00	6
Nuevo Leon	0.99	0.97	-0.01	7
Tamaulipas	0.97	0.95	-0.02	8
Sonora	0.97	0.96	-0.02	9
Chihuahua	0.98	0.96	-0.02	10
Coahuila	0.97	0.95	-0.03	11
San Luis Potosi	0.95	0.90	-0.05	12
Queretaro	0.92	0.87	-0.05	13
Aguascalientes	0.91	0.86	-0.06	14
Distrito Federal	0.85	0.78	-0.08	15
Zacatecas	0.94	0.86	-0.08	16
Nayarit	0.85	0.77	-0.08	17
Hidalgo	0.96	0.86	-0.10	18
Colima	0.92	0.81	-0.12	19
Sinaloa	0.89	0.77	-0.13	20
Jalisco	0.91	0.77	-0.15	21
Guanajuato	0.94	0.79	-0.16	22
Yucatan	0.83	0.69	-0.16	23
Baja California Sur	0.84	0.69	-0.18	24
Tlaxcala	0.86	0.69	-0.20	25
México	0.93	0.75	-0.20	26
Puebla	0.85	0.66	-0.22	27
Quintana Roo	0.76	0.57	-0.25	28
Michoacán	0.85	0.63	-0.25	29
Morelos	0.96	0.64	-0.33	30
Guerrero	0.83	0.52	-0.38	31
Oaxaca	0.90	0.53	-0.41	32

FIGURE 1 - MAP USING BC95 COEFFICIENTS

FIGURE 2 - MAP USING CFG95 COEFFICIENTS

Efficiency under Caudill, Ford & Gropper 1995

References

Aguilar Gutiérrez, G. (2011). "Eficiencia industrial en las regiones de México." EconoQuantum 7.2: 93-113.

Aigner, D., C.A.K. Lovell and P. Schmidt. (1977). "Formulation and Estimation of Stochastic Frontier Production Function Models", Journal of Econometrics, 6, 21-37.

Álvarez, A., (2007), "Decomposing Regional Productivity Growth using an Aggregate Production Frontier", Annals of Regional Science, 41, 431-441.

Álvarez, A. and C. Arias, (2014), "A Selection of Relevant Issues in Applied Stochastic Frontier Analysis", Economics and Business Letters, 3(1), 3-11.

Aschauer, D. A. (1989). Does public capital crowd out private capital?, Journal of monetary economics, 24(2), 171-188.

Bannister, G. J., and Stolp, C. (1995). Regional concentration and efficiency in Mexican manufacturing. European Journal of Operational Research, 80(3), 672-690.

Battese, G.E. and T.J. Coelli (1992), "Frontier Production Functions, Technical Efficiency and Panel Data: With Applications to Paddy Farmers in India," *Journal of Productivity Analysis*, 3, 153-169.

Battese, G. and T. Coelli. (1995). "A model for technical inefficiency effects in a stochastic frontier production function for panel data". Empirical Economics, 20, 325–332.

Becerril-Torres, O., Álvarez Ayuso, I., del Moral Barrera, L, and Vergara González, R. (2009). Disparidades en eficiencia técnica e influencia de las infraestructuras sobre la convergencia en eficiencia en México. *Investigaciones Regionales*, 51–70.

Becerril-Torres, O., Álvarez-Ayuso, I., and del Moral-Barrera, L. (2010). Eficiencia técnica de las entidades federativas de México. *Economía, Sociedad y Territorio*, 10(33), 485-511.

Braun, F. G., and Cullmann, A. (2011). Regional differences of production and efficiency of Mexican manufacturing: an application of nested and stochastic frontier panel models. The Journal of Developing Areas, 45(1), 291-311.

Caudill, S.B., J.M. Ford and D.M. Gropper (1995), "Frontier Estimation and Firm-Specific Inefficiency Measures in the Presence of Heteroskedasticity," *Journal of Business and Economic Statistics*, 13, 105-111.

Chávez, J. C., and Fonseca, F. J. (2012). Technical and structural efficiency in Mexican manufacturing: A regional approach (No. 2012-03). Working Papers, Banco de México.

Chávez, J. C., and López Ornelas, L. F. (2013). Un enfoque no paramétrico para la descomposición de la productividad del trabajo en la industria manufacturera regional (No. 2013-08). Working Papers, Banco de México.

Chiquiar, D. (2008). Globalization, regional wage differentials and the Stolper–Samuelson theorem: evidence from Mexico. Journal of International Economics, 74(1), 70-93.

Garduño-Rivera R. (2014), "La apertura comercial y su efecto en la distribución regional de México". El Trimestre Económico. Volume LXXXI, Issue 2, April-June 2014. ISSN 0041-3011

Huang, C.J. and J.T. Liu (1994), "Estimation of a Non-Neutral Stochastic Frontier Cost Function", Journal of Productivity Analysis, 5, 171-180.

INEGI. (2008). Economic Census 1993, 1998, 2003 and 2008. Instituto Nacional de Estadística y Geografía. [Online] Available at: http://www.inegi.org.mx/est/contenidos/Proyectos/ce/Default.aspx

INEGI. (2009). Population Census 1989, 1994, 1999, 2004 and 2009. Instituto Nacional de Estadística y Geografía. [Online] Available at: http://www.inegi.org.mx/est/contenidos/proyectos/ccpv/default.aspx

INEGI. (2013). Anuario estadístico y geográfico por entidad federativa 2013. Instituto Nacional de Estadística y Geografía. [Online] Available at: http://www3.inegi.org.mx/sistemas/productos/default.aspx?c=265&s=inegi&upc=7028250540014&pf=Prod&ef=&f=2&cl=0&tg=7&pg=0&ct=106010000

Kumbhakar, S., S. Ghosh and J.T. McGuckin (1991), "A Generalized Production Frontier Approach for Estimating Determinants of Inefficiency in U.S. Dairy Farms", Journal of Business and Economic Statistics, 9, 279-286.

PEMEX. (2009). "Anuario Estadístico 2009: Exploración y Producción". Petróleos Mexicanos. [Online] Available at: http://www.ri.pemex.com/files/content/5_AE_EXPLORACION%20Y%20PRODUCCION.pdf

Reifschneider, D. and R. Stevenson (1991), "Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency," *International Economic Review*, 32, 715-723.

Sour, L. (2008). Regional differences in infrastructure investment at the state level in México, 1998-2005. Working Paper #220. Centro de Investigación y Docencia Económicas (CIDE).