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# An Empirical Analysis of Education, Infrastructure, and Regional Growth in Mexico

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**Abstract**

Various studies suggest that regions with larger stocks of physical infrastructure and human capital often exhibit comparatively robust economic performance. The research at hand examines whether this is the case for regions within Mexico using data from the 2010 Census and other sources. Aggregate production functions are estimated in order to analyze the determinants of economic performance across Mexican states. Explanatory variables include kilometers of highways, airport runway lengths, percentages of adults in each state with education beyond the primary level, and the number of certified researchers as a share of the national total. In line with prior research, results indicate that regional-level investments in transportation infrastructure and education will likely facilitate economic growth in Mexico. An out-of-sample policy simulation is used to further quantify regional economic throughout the country.

**Keywords:** Regional Growth; Physical Infrastructure; Education; Mexico

**JEL Classification:** O54, Latin American Studies; R11, Regional Economics

## I. Introduction

Education and infrastructure are key explanatory factors underpinning the economic development process. Education helps to increase the stock of human capital and investment in infrastructure expands the stock of public capital. Together, both have the potential to increase productivity and personal income. The principal research question investigated is whether, and to what extent, stocks of transportation infrastructure and human capital affect regional gross state product (GSP) and per capita GSP levels in Mexico. Analysis of factors that affect economic growth at the sub-national level in Mexico are potentially useful to policymakers and analysts. Recent decades have witnessed a general trend towards the decentralization of government expenditures in Mexico (Sobarzo-Fimbres, 2009). As states assume more control over public spending, there is a need for more information on the types of investments that have good prospects for facilitating economic development. Econometric quantification of the impacts of public expenditures on gross state product has yet to be carried out for many regions of this important Latin American Economy.

Mexico is characterized by dramatic regional economic disparities. Gross state product (GSP) varies sharply from state to state. If the oil industry is excluded, per capita GSP ranges from $245,044 pesos in Mexico City to $45,521 pesos in the state of Chiapas and the average for all states is $105,456 (INEGI, 2015).

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The variable used in the model to measure educational achievement also displays a great deal of variation across regions: the share of the population 15 years of age and older with education above the primary level ranges from 73.67 percent in Mexico City to 25.28 percent in Chiapas (INEGI, 2010). The stock of transport infrastructure likewise varies substantially from state to state. The main objective of this study is to quantify how variables such as education and infrastructure influence the large variations in per capita and aggregate GSP between the states.

The next section surveys the literature on the impacts of education and infrastructure on regional economies, with particular focus on prior studies for Mexico. In section 3, data and methodology are discussed. Section 4 reports empirical results, including simulations that illustrate potential gains available to states with low levels of educational achievement. Such estimates may be useful for evaluating various types of public policies designed to promote economic growth (Thompson, 1998; Arellano and Fullerton., 2005; Fullerton et al., 2010). Section 5 offers conclusions and policy recommendations. The last section includes appendices with data used in the econometric analysis.

## 2. Literature Review

Several studies have examined the role of an educated workforce in regional economic development. For twenty states that have dropout rates above the national average, Thompson (1998) estimates that income losses due to high school non-completion amount to a total of 45 billion dollars. Fullerton (2001) simulates the impacts of increased graduation rates on border county income levels in Texas. It is estimated that reducing the dropout rates of border counties to a level commensurate with the rest of the state could increase income per resident by over $2,600 US dollars. In an extension of that study, Almada et al. (2006) document that the Texas economy may have paid higher premiums for the level of education in 2000 than in 1990.

The initial endowment of human capital in an area may help explain changes in regional economic conditions over time. In a study of rural American counties that had poverty rates in excess of 20 percent in 1989, Partridge and Rickman (2005) examine the factors that made it possible for some of these counties to reduce their poverty rates by 1999. Levels of educational attainment in 1989 negatively affect the likelihood of having high poverty rates a decade later. Similarly, Gottlieb and Fogarty (2003) find that the initial level of education in a metropolitan area has a positive impact on the rate of growth in income and employment in that area.

The second strand of literature that is relevant to the topic of this study is that related to infrastructure and regional economic performance. In a study of Italian regions, Destefanis and Sena (2005) examine the relationship between public infrastructure and productivity. The average elasticity of total factor productivity with respect to basic infrastructure is estimated to be 0.17. In a study of rural areas of China, Fan and Zhang (2004) find that road density and the number of rural telephones per thousand rural residents have positive effects on agricultural production. The number of telephones is also an important determinant of non-agricultural production. Green (2007) evaluates whether airport activity in a metropolitan area helps predict population growth and employment. The study concludes that passenger activity is a powerful predictor of growth, but cargo activity is not.

Another group of studies considers the importance of both infrastructure and education for regional economic conditions. Garcia-Mila and McGuire (1992) specify a production function that, in addition to labor and capital, also includes two public goods, highways and education. The results of the analysis show that education plays an important role in determining aggregate output among US states, but that highways have a relatively small impact. In a study of Italian regions, Bronzini and Piselli (2009) report that human capital and public infrastructure both positively affect the total factor productivity. For the state of Arkansas, Fullerton et al. (2010) document that regional income and educational achievement are closely related. Also, the existence of a commercial airport in a county is found to increase per capita income. Similar results are obtained for the state of Missouri in Fullerton et al. (2014).

For Mexico, a number of studies examine the effects of infrastructure at the national level using time series data. Nuñez-Rodríguez (2006) presents evidence that productivity is affected by the growth rate in gross public capital formation. Similarly, Ramirez (2004) documents that investments in public infrastructure exert positive impacts on private capital formation and production. Noriega and Fontenla (2007) report that shocks to electricity and highway infrastructures have positive and significant effects on real production. Feltenstein and Ha (1995) examine the relationship between infrastructure and production costs. Categories of infrastructure that reduce production costs include communications and electricity systems, but not transportation systems.

Feltenstein and Ha (1999) show that investment in public infrastructure may have negative effects on economic growth if government debt increases to the extent that it crowds out private investment. The results of simulations indicate that an annual increase in public investment of 10 percent increases GDP in the first year, but it subsequently decreases GDP as a result of the crowding out effect.

Several studies conducted for Mexico analyze the impacts of infrastructure and education at the regional level. Fuentes (2003) investigates the effects of social infrastructure (education and public health facilities) and economic infrastructure (telecommunications, transportation, and energy systems). Both categories generally have positive economic impacts, but the effects of economic infrastructure are larger for states with higher levels of per capita GSP while the effects of social infrastructure are most notable in regions with lower income levels. In a study of income long-term income convergence among the states, Ruiz-Ochoa (2010) finds that improvements in education and infrastructure tend to dissipate regional inequalities. Finally, Torres-Preciado (2013) finds that output per capita grows faster in states with higher levels of educational attainment and more extensive rail, road, and port infrastructure.

Other studies report that infrastructure has little or no effect on regional economic growth in Mexico. Brock and Germán-Soto (2013) investigate the impact of human capital and infrastructure on industrial production in the states. Evidence on the impact of human capital is mixed but, in all cases, the results indicate that investment in infrastructure fails to generate positive returns. Similarly, Rodríguez-Oreggia (2005) documents that state stocks of public capital in 1970 and 1985 have no significant effect on their subsequent per capita GSP growth rates. However, initial stocks of human capital are found to positively impact economic growth. Rodríguez-Oreggia and Rodríguez-Pose (2004) obtain similar results.

Arellano and Fullerton (2005) simulate the increases in per capita GSP that could be achieved by increasing enrollment and graduation rates in different state economies in Mexico. The results indicate that regional economies across the nation are, from the point of view of productivity, operating below installed capacity. This analysis will also utilize simulations to quantify the economic costs of below-average levels of educational attainment for specific states in Mexico. Estimating the economic impact of an increase in the level of educational attainment can provide valuable information for the design of public policies (Thompson, 1998). The data used in this analysis are more recent. In addition, a broader set of explanatory variables is used, including public infrastructure variables in addition to indicators of educational achievement. By measuring the explanatory power of both types of variables, this analysis contributes to the body of scholarship that attempts to provide insight into appropriate economic development strategies for regions throughout Mexico.

## 3. Theoretical Model, Data, and Methodology

Models for assessing the impacts of education and transportation infrastructure on regional economic performance can be specified in fairly straightforward manners. For this study, a standard aggregate production function is augmented to include variables representing both public capital, in the form of transportation infrastructure, as well as human capital (Garcia-Mila and McGuire, 1992). These variables can be incorporated into a Cobb-Douglas production function as shown in Equation (1).

$$Y_i = A_i\ ^{b1}\ K_i^{b2}\ TK_i^{b3}\ HK_i^{b4} \qquad (1)$$

In this equation, $Y$ is aggregate output of goods and services, $A$ is a technology index, $L$ is total employment, $K$ represents the stock of non-residential private capital, $TK$ is transportation infrastructure capital, $HK$ stands for human capital, $i$ is an index for cross-sectional units, and the superscripts represent elasticities of output with respect to each of the inputs to the production process (Aschauer, 1989). Transformation using natural logarithms allows the equation to be re-expressed as shown in (2).

$$\ln(Y_i) = \ln(A_i) + b_1 \ln(L_i) + b_2 \ln(K_i) + b_3 \ln(TK_i) + b_4 \ln(HK_i) \qquad (2)$$

Other studies of income performance have employed logarithmically-transformed Cobb-Douglas production functions similar to that shown in Equation (2) to study the impacts of public capital stocks (Albala-Bertrand and Mamatzakis, 2001; Ramirez, 2004). The logarithmic functional form allows for diminishing marginal returns to public capital.

This is relevant because there is evidence that regions with relatively large public capital stocks tend to derive less marginal economic benefit from those infrastructure investments relative to regions where there are shortages of this type of capital (Costa et al., 1987).

Dividing both sides of Equation (1) by total employment yields an equation for output per worker. Empirical studies of regional income performance usually model output per capita rather than output per worker (Fuentes, 2003; Gottlieb and Fogarty, 2003; Fullerton et al., 2010; Fullerton et al., 2014). Because employment is typically highly correlated with total population, which is the denominator in the per capita output equation, employment does not appear as an explanatory variable in that equation (Torres-Preciado, 2013). This analysis will model both aggregate and per capita output in order to gauge the robustness of the empirical results.

A number of issues arise in attempting to measure the variables included in Equation (1). First, in some states, petroleum extraction makes up a disproportionate share of GSP, which will measure aggregate output (*Y*) in this analysis. In the case of Campeche, per capita GSP is 747 thousand pesos when the oil industry is included, which is seven times the national average. By comparison, when the oil industry is excluded, that state's per capita GSP is only 155 thousand pesos. Other studies of GSP variations in Mexico have chosen to omit states dominated by the oil industry from their sample (Jordaan and Rodríguez-Oreggia, 2012) or to distribute income from oil produced in territorial waters among all of the states in the country (Ruiz-Ochoa, 2010). While there is no general agreement on the appropriate procedure, this analysis will employ the simple solution of using GSP data that exclude the oil industry. GSP data are obtained from the System of National Accounts produced by Mexico's national statistics agency (INEGI, 2015).

Another obstacle to modeling GSP in Mexico is the paucity of data on private capital stocks at the regional level (Germán Soto, 2008). Several studies have utilized estimates of national-level private capital stocks to analyze the evolution of the Mexican economy over time (Feltenstein and Ha, 1995; 1999; Ramirez, 2004; Nuñez-Rodriguez, 2006). At the regional level, however, data on private capital are very limited. Rodriguez-Oreggia (2005) uses private capital estimates from the economic censuses of 1970 and 1985. The economic census is conducted every five years and, in recent years, does not match the timing of the Censuses of Population and Housing, which provide important information on the human capital measures utilized in this study. Data on gross physical capital formation are available by state for recent years (Torres-Preciado, 2013), but there are no complete time series data from official sources for the private capital stocks of the states.

Germán-Soto (2008) develops estimates of state-level industrial capital stocks in Mexico to fill in the data gaps between economic censuses. Depreciated industrial capital stocks are estimated using data on real capital investment and employment by industry. These capital stock data have previously been employed in the context of an aggregate production function analysis to examine industrial dynamics across Mexican regions (Brock and Germán-Soto, 2013). This study utilizes industrial capital stock estimates produced using the methodology employed by Germán-Soto (2008). Those capital stock data have been extended through 2013 for usage in this effort. The capital stock figures are measured in millions of 1993 pesos. Data on employment by state are available from the Statistical Yearbook of the States (INEGI, 2011). Population data are from the 2010 Census (INEGI, 2010).

A further data-related issue concerns how to measure the transportation infrastructure capital and human capital variables that appear in Equation (1). Two variables are used to measure transportation infrastructure: kilometers of paved highways (*HWY*) and meters of runway length at commercial service airports (*AIR*). These variables are similar to those employed by Torres-Preciado (2013). The data for both variables are from the Statistical Yearbook of States (INEGI, 2011). The principal measure of human capital employed in the analysis is the percentage of the population 15 years of age and older with education beyond the primary level (*PLUS*). That variable is also used as a measure of human capital in Arellano and Fullerton (2005). Education data are from the 2010 Census (INEGI, 2010). Another measure of human capital is the number of academic researchers in each state that belong to the National System of Researchers (Sistema Nacional de Investigadores) as a percentage of the nationwide total (*SNI*). Data for this variable are obtained from the Office of the President of Mexico (PR, 2011). The original source for those data is the National Council of Science and Technology (CONACYT).

All variables used for analysis are defined in Table 1. The data exhibit a substantial degree of variability (Table 2). The percentage of adults with education above the primary level ranges from 25.28 percent in the state of Chiapas to 73.67 percent in the national capital.

The correlation coefficient between this variable and per capita income is 0.76. Chiapas, Oaxaca, and Michoacán are the three states with the lowest levels of post-primary education and are also the three states with the lowest levels of per capita GSP. The correlation between per capita GSP and the other measure of human capital, *SNI*, is also relatively high at 0.59. The two measures of transportation infrastructure capital are also positively correlated with per capita GSP, though the estimated correlation coefficients are somewhat smaller.

**Table 1: Variable Names and Definitions**

| Variable | Definition |
|---|---|
| Y | Gross state product, excluding the oil extraction industry (millions of pesos) |
| P | Total state population |
| L | Total employed population |
| K | Industrial capital stock (millions of pesos) in each state |
| HWY | Length of paved highways (kilometers) in each state |
| AIR | Length of airport runways (meters) in each state |
| PLUS | Percentage of the population age 15 and over with post-primary education |
| SNI | Academic researchers in each state as a percentage of the national total |

**Table 2: Summary Statistics for 2010 Data**

| Variables | Mean | Median | Maximum | Minimum | Standard Deviation | Number of Obs. |
|---|---|---|---|---|---|---|
| Y | $371,835 | $227,031 | $2,168,903 | $70,714 | $414,273 | 32 |
| P | 3,510,517 | 2,706,705 | 15,175,862 | 637,026 | 2,981,381 | 32 |
| L | 1,395,370 | 1,032,210 | 6,189,557 | 260,360 | 1,228,332 | 32 |
| K | $222,425 | $148,126 | $767,364 | $13,087 | $221,661 | 32 |
| HWY | 4,791 | 4,885 | 10,200 | 1,141 | 2,413 | 32 |
| AIR | 6,317 | 5,800 | 14,534 | 0 | 3,379 | 32 |
| PLUS | 51.21% | 52.26% | 73.67% | 25.28% | 11.48% | 32 |
| SNI | 3.02% | 1.31% | 38.14% | 0.23% | 6.59% | 32 |

Equation (3) is an empirical specification based on the aggregate production function in Equation (1) that also includes the specific infrastructure and human capital variables discussed above. All of the variables are logarithmically transformed. Because one state (Tlaxcala) has no commercial service airports and thus has a value of zero for the variable *AIR*, one meter is added to all of the runway lengths to enable taking logarithms of that variable. Dividing by population (*P*), allows Equation (3) to be re-written in per capita form as shown in Equation (4). As mentioned above, total employment is not included in the per capita specification because it is highly correlated with total population ($r$ = 0.996). The variables *PLUS* and *SNI* are not divided by population because they are expressed as percentages. Both $\varepsilon$ and $\eta$ are error terms.

$$\ln(Y_i) = \alpha_0 + \alpha_1\ln(L_i) + \alpha_2\ln(K_i) + \alpha_3\ln(HWY_i) + \alpha_4\ln(AIR_i{+}1) + \alpha_5\ln(PLUS_i) + \alpha_6\ln(SNI_i) + \varepsilon_i \quad (3)$$

$$\ln(Y_i/P_i) = \beta_0 + \beta_1\ln(K_i/P_i) + \beta_2\ln(HWY_i/P_i) + \beta_3\ln((AIR_i{+}1)/P_i) + \beta_4\ln(PLUS_i) + \beta_5\ln(SNI_i) + \eta_i \quad (4)$$

The central hypothesis examined is that output levels in the Mexican states are positively correlated with educational achievement and transportation infrastructure variables. Transportation infrastructure facilitates the movement of workers, inputs, and consumer goods, and thus has the potential to increase productivity and positively impact income (Garcia-Mila and McGuire, 1992). Consequently, the elasticities of output with respect to highway and airport infrastructure are expected to be positive. Prior empirical research also indicates that regions characterized by high levels of educational attainment are likely to have higher productivity and higher incomes (Gottlieb and Fogarty, 2003). Furthermore, research and knowledge accumulation are important factors in economic development (Romer, 1986). Therefore, the elasticities of output with respect to *PLUS* and *SNI* are also expected to be positive.

The parameters in Equations (3) and (4) will be estimated using least squares regression. The data employed are for the major sub-national political units in Mexico, which consist of states as well as the Federal District, where the national capital is located. All data are from the most recent census year, 2010. Because cross-sectional data are employed in the analysis, heteroscedasticity tests are conducted (Fullerton, 2001; Almada et al., 2006). Simulations are carried out to analyze the potential impacts of different public policies.

## 4. Empirical Results

The estimation results for Equations (3) and (4) are presented in Tables (3) and (4). An important issue that arises in estimating the equations with cross-sectional data is the possibility that the error term may be heteroscedastic. To evaluate this possibility, the Breusch- Pagan and White tests are applied to both the total and per capita output equations (Pindyck and Rubinfeld, 1998). For both equations, the tests fail to reject the null hypothesis that the error term is homoscedastic using a 5-percent significance criterion. The computed test statistics and accompanying probability values are reported in the last two rows of Tables (3) and (4).

All of the estimated parameters in the aggregate output equation have the expected signs and are significant at the 95-percent confidence level (Table 3). A 10 percent expansion in the size of a state's highway network is associated with a 1.6 percent increase in GSP. The 0.156 estimated elasticity of output with respect to highway capital is somewhat larger than the estimate of 0.045 reported by Garcia-Mila and McGuire (1992) for regions of the United States. It also accords well with results obtained by Noriega and Fontenla (2007) for Mexico. Similarly, airport infrastructure has a positive impact on GSP, though the effect is somewhat smaller than that of highways. These results, like those documented by Ramirez (2004) at the national level, indicate that investment in physical infrastructure in Mexico yields economic benefits.

The results also indicate that states where larger proportions of adults have education beyond the primary level tend to have higher levels of output after controlling for other factors. The educational attainment variable *PLUS* has a nearly unit-elastic relationship with aggregate GSP. Furthermore, the proportion of researchers based in a particular state positively impacts that state's income levels. Research likely contributes to regional income growth by facilitating innovation (Ríos-Bolívar and Marroquín-Arreola, 2013). The coefficient of determination adjusted for degrees of freedom indicates that the model explains 96.2 percent of the variation in GSP.

**Table 3: Determinants of total GSP**

Dependent Variable: Ln(*Y*)
Method: Least Squares
Included observations: 32

| Variable | Coefficient | Std. Error | *t*-Statistic | Prob. |
|---|---|---|---|---|
| C | -3.0453 | 1.1432 | -2.6637 | 0.0133 |
| Ln(*L*) | 0.6431 | 0.0755 | 8.5214 | 0.0000 |
| Ln(*K*) | 0.1040 | 0.0397 | 2.6187 | 0.0148 |
| Ln(*HWY*) | 0.1555 | 0.0730 | 2.1290 | 0.0433 |
| Ln(*AIR*+1) | 0.0606 | 0.0194 | 3.1166 | 0.0046 |
| Ln(*PLUS*) | 0.9015 | 0.1451 | 6.2130 | 0.0000 |
| Ln(*SNI*) | 0.1233 | 0.0411 | 3.0004 | 0.0060 |

| | | | |
|---|---|---|---|
| R-squared | 0.9692 | Mean dependent var. | 12.470 |
| Adjusted R-squared | 0.9618 | S.D. dependent var. | 0.7967 |
| Log likelihood | 18.045 | Akaike info. criterion | -0.6903 |
| S.E. of regression | 0.1558 | Schwarz criterion | -0.3697 |
| *F*-statistic | 130.98 | Prob. *F*-statistic | 0.0000 |
| White test statistic | 29.395 | Prob. Chi-Square | 0.3420 |
| Breusch-Pagan stat. | 2.7580 | Prob. Chi-Square | 0.8385 |

Table 4 shows the determinants of per capita GSP. The elasticities for the human capital and infrastructure variables are very close to those reported in Table 3 for aggregate GSP. Contrary to the findings reported by Rodriguez-Oreggia (2005), the elasticities for the highway and airport variables indicate that infrastructure has positive and statistically significant impacts on per capita GSP in Mexico. Elasticities of output with respect to highway infrastructure are similar to those documented by Torres-Preciado (2013) for Mexican states. Also, similar to what has been reported by Green (2007) and Fullerton et al. (2014) for regions of the United States, airport infrastructure has a significant impact on regional economies in Mexico.

Additional years of schooling beyond the primary level are found to generate positive economic returns. As in the aggregate output results summarized in Table 3, changes in educational attainment levels produce proportional changes in per capita GSP (Table 4). This result runs counter to the findings of González-Rivas (2007) and Jordaan and Rodriguez-Oreggia (2012) that education does not positively affect per capita income in Mexican states. It suggests that policies designed to increase access to post-primary education will likely generate economic benefits. Finally, research intensity also seems to stimulate regional economic growth as indicated by the coefficient on *SNI*. This is consistent with results documented in prior studies that indicate a positive relationship between innovation and economic development in Mexico (Ríos-Bolívar and Marroquín-Arreola, 2013; Aragón-Jiménez et al., 2014).

**Table 4: Determinants of per capita GSP**

Dependent Variable: Ln(*Y*/*P*)
Method: Least Squares
Included observations: 32

| Variable | Coefficient | Std. Error | *t*-Statistic | Prob. |
|---|---|---|---|---|
| C | -4.7122 | 0.6271 | -7.5142 | 0.0000 |
| Ln(*K*/*P*) | 0.0779 | 0.0410 | 1.9023 | 0.0683 |
| Ln(*HWY*/*P*) | 0.1754 | 0.0658 | 2.6655 | 0.0130 |
| Ln((*AIR*+1)/*P*) | 0.0683 | 0.0198 | 3.4454 | 0.0019 |
| Ln(*PLUS*) | 1.0629 | 0.1272 | 8.3527 | 0.0000 |
| Ln(*SNI*) | 0.1120 | 0.0315 | 3.5522 | 0.0015 |

| | | | |
|---|---|---|---|
| R-squared | 0.8504 | Mean dependent var. | -2.3195 |
| Adjusted R-squared | 0.8216 | S.D. dependent var. | 0.3758 |
| S.E. of regression | 0.1587 | Akaike info. criterion | -0.6758 |
| Log likelihood | 16.813 | Schwarz criterion | -0.4010 |
| *F*-statistic | 29.552 | Prob. *F*-statistic | 0.0000 |
| White test statistic | 29.106 | Prob. Chi-Square | 0.0857 |
| Breusch-Pagan stat. | 2.3911 | Prob. Chi-Square | 0.7928 |

The educational attainment variable, *PLUS*, consistently has the largest elasticity of any of the explanatory variables. It is interesting to examine how a policy that increases the percentage of adults with education beyond the primary level would affect per capita income levels for individual states (Thompson, 1998; Fullerton, 2001). Such effects are illustrated in Table 5 for 15 states that currently have below-average levels of educational attainment, as measured by *PLUS*. Of these 15 states, only one has a value of GSP per capita that is above the national average. The second column of Table 5 shows the increases in income (in terms of 2010 pesos) that would be predicted to occur if each of those states were to raise its level of post-primary educational attainment to the national average of 51.2 percent. The third column shows the estimated income changes as percentages of per capita 2010 GSP in each state.

As seen in Table 5, the economic benefits of increasing levels of education are quite substantial for some states. If the state of Chiapas were to increase the proportion of adults with education beyond the primary level to the national average, per capita income there is predicted to double.

Raising the post-primary education variable to the national average is also estimated to increase the per capita incomes of nine other states by more than 10 percent each. However, it is important to note that increasing educational attainment levels this much represents an enormous challenge. For example, increasing the *PLUS* variable for Chiapas to the national average would entail doubling the current percentage of adults with schooling beyond the primary level in that state. Although such changes are feasible, achieving those gaoins would only materialize over a period of several years.

**Table 5: Simulated effects of an increase in educational attainment (2010 pesos)**

| State | Estimated change in per capita GSP | Percentage of 2010 per capita GSP |
|---|---|---|
| Chiapas | $45,513 | 100.0% |
| Oaxaca | $40,897 | 77.9% |
| Michoacán | $37,919 | 55.4% |
| Veracruz | $30,843 | 36.8% |
| Zacatecas | $27,541 | 29.9% |
| Guerrero | $24,572 | 42.2% |
| Puebla | $22,608 | 32.7% |
| Yucatan | $20,606 | 21.1% |
| Guanajuato | $17,776 | 20.2% |
| San Luis Potosí | $10,556 | 11.6% |
| Hidalgo | $5,717 | 7.4% |
| Campeche | $5,690 | 3.7% |
| Durango | $3,437 | 3.6% |
| Tabasco | $3,398 | 4.5% |
| Nayarit | $758 | 1.0% |

## 5. Conclusions and Recommendations

This study documents that regional stocks of transportation infrastructure and human capital are important factors influencing GSP performance in Mexico. Results indicate that states offering more extensive highway networks tend to produce higher levels of output. Airport infrastructure is also found to generate positive, though somewhat smaller, effects on regional output levels. These outcomes indicate that transport infrastructure generates economic benefits. To allow for diminishing marginal returns associated with investments in these items, a logarithmic functional form is used for all of the parameter estimates. That step is taken because in states that have infrastructure deficiencies, expansion of airports and road networks can facilitate the production and distribution of goods. On the other hand, in states where there are no such deficiencies the construction of new infrastructure will probably have less dramatic economic effects.

The impact of human capital on state economies is also studied. The proportion of adults completing additional education beyond the primary level has very pronounced impacts on both aggregate and per capita GSP. The econometric results imply that expanding access to post-primary education will yield relatively large dividends in the form of higher GSP levels. Likewise, simulations indicate that states with below-average levels of educational attainment can reap impressive per capita GSP gains by increasing the number of students that pursue additional education after completing primary school. Another measure of human capital, the proportion of nationally recognized researchers in each state, is found to generate proportionally smaller, but still positive and statistically significant, impacts on aggregate and per capita GSP levels. The positive marginal effect of research is consistent with previous studies which find that the generation and application of new technical knowledge is a key ingredient in economic growth.

The dependent variable in this analysis, GSP, varies dramatically from one region of Mexico to another. This effort indicates that a portion of the observed regional disparity in income performance is attributed to differences in transportation infrastructure and human capital endowments.

Investing in the educational and transportation systems of regions where those systems are currently underdeveloped is likely to help close the existing inter-regional gaps in economic performance across Mexico. In particular, it seems that policies oriented towards expanding access to post-primary education in states that have low levels of educational attainment are likely to yield relatively large economic payoffs.

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**Appendix A1**

| State | Y | P | Y/P | L | K |
|---|---|---|---|---|---|
| Aguascalientes | $140,853 | 1,184,996 | $118,864 | 458,865 | $99,536 |
| Baja California | $370,359 | 3,155,070 | $117,385 | 1,342,728 | $166,523 |
| Baja California Sur | $97,340 | 637,026 | $152,804 | 260,360 | $24,362 |
| Campeche | $127,337 | 822,441 | $154,828 | 344,807 | $270,738 |
| Coahuila | $407,739 | 2,748,391 | $148,355 | 1,052,299 | $389,195 |
| Colima | $72,721 | 650,555 | $111,783 | 287,471 | $42,189 |
| Chiapas | $218,343 | 4,796,580 | $45,521 | 1,748,529 | $70,012 |
| Chihuahua | $351,184 | 3,406,465 | $103,093 | 1,309,494 | $169,883 |
| Distrito Federal | $2,168,903 | 8,851,080 | $245,044 | 3,928,222 | $696,849 |
| Durango | $153,985 | 1,632,934 | $94,299 | 574,065 | $64,659 |
| Guanajuato | $482,971 | 5,486,372 | $88,031 | 1,963,596 | $155,475 |
| Guerrero | $197,175 | 3,388,768 | $58,185 | 1,311,092 | $184,278 |
| Hidalgo | $205,030 | 2,665,018 | $76,934 | 965,187 | $238,760 |
| Jalisco | $800,178 | 7,350,682 | $108,858 | 3,050,172 | $400,473 |
| México | $1,191,185 | 15,175,862 | $78,492 | 6,189,557 | $710,303 |
| Michoacán | $297,543 | 4,351,037 | $68,384 | 1,534,947 | $140,776 |
| Morelos | $149,285 | 1,777,227 | $83,999 | 724,569 | $35,222 |
| Nayarit | $86,059 | 1,084,979 | $79,319 | 433,991 | $53,543 |
| Nuevo León | $900,209 | 4,653,458 | $193,449 | 1,994,462 | $767,364 |
| Oaxaca | $199,699 | 3,801,962 | $52,525 | 1,474,976 | $54,441 |
| Puebla | $399,700 | 5,779,829 | $69,154 | 2,307,448 | $325,829 |
| Querétaro | $249,251 | 1,827,937 | $136,356 | 677,357 | $170,345 |
| Quintana Roo | $189,536 | 1,325,578 | $142,984 | 663,338 | $13,087 |
| San Luis Potosí | $235,718 | 2,585,518 | $91,169 | 988,227 | $103,112 |
| Sinaloa | $274,444 | 2,767,761 | $99,157 | 1,134,439 | $83,778 |
| Sonora | $355,521 | 2,662,480 | $133,530 | 1,012,120 | $107,455 |
| Tabasco | $167,566 | 2,238,603 | $74,853 | 801,572 | $485,798 |
| Tamaulipas | $369,467 | 3,268,554 | $113,037 | 1,318,425 | $211,192 |
| Tlaxcala | $70,714 | 1,169,936 | $60,443 | 446,288 | $50,794 |
| Veracruz | $639,943 | 7,643,194 | $83,727 | 2,942,496 | $680,394 |
| Yucatan | $191,376 | 1,955,577 | $97,862 | 890,060 | $69,847 |
| Zacatecas | $137,398 | 1,490,668 | $92,172 | 520,673 | $81,375 |

Variable definitions: Y = Gross State Product, excluding the petroleum extraction industry (millions of 2010 pesos); P = Population; Y/P = Per Capita Gross State Product, excluding petroleum extraction (2010 pesos); L = Employed population; K = Industrial capital stock (millions of 1993 pesos)

Data sources: Gross State Product, population, and employment data are from INEGI; Industrial capital stock data are developed using the methodology in Germán-Soto (2008) and were provided to the authors by Vicente Germán-Soto.

**Appendix A2**

| | HWY | AIR | PLUS | SNI |
|---|---|---|---|---|
| Aguascalientes | 1,315 | 3,000 | 58.83 % | 0.50 % |
| Baja California | 2,470 | 8,551 | 63.29 % | 3.05 % |
| Baja California Sur | 2,135 | 7,700 | 61.88 % | 1.11 % |
| Campeche | 4,489 | 4,700 | 49.25 % | 0.46 % |
| Coahuila | 3,843 | 14,534 | 63.77 % | 1.30 % |
| Colima | 1,223 | 4,500 | 54.75 % | 0.78 % |
| Chiapas | 7,093 | 6,000 | 25.28 % | 1.07 % |
| Chihuahua | 5,961 | 10,570 | 53.75 % | 1.34 % |
| Distrito Federal | 10,200 | 7,948 | 73.67 % | 38.14 % |
| Durango | 4,933 | 2,900 | 49.52 % | 0.44 % |
| Guanajuato | 6,406 | 5,438 | 42.29 % | 3.09 % |
| Guerrero | 5,087 | 7,500 | 37.26 % | 0.28 % |
| Hidalgo | 3,080 | 1,800 | 48.21 % | 1.13 % |
| Jalisco | 7,507 | 7,100 | 52.05 % | 5.32 % |
| México | 6,105 | 5,500 | 61.04 % | 5.99 % |
| Michoacán | 8,792 | 8,840 | 34.75 % | 2.95 % |
| Morelos | 1,543 | 2,800 | 57.45 % | 4.94 % |
| Nayarit | 2,317 | 2,300 | 50.80 % | 0.23 % |
| Nuevo León | 4,517 | 5,011 | 68.37 % | 3.72 % |
| Oaxaca | 4,836 | 8,250 | 28.27 % | 1.10 % |
| Puebla | 6,424 | 5,600 | 40.52 % | 3.59 % |
| Querétaro | 1,141 | 3,500 | 57.24 % | 2.33 % |
| Quintana Roo | 2,643 | 11,392 | 61.62 % | 0.45 % |
| San Luis Potosí | 5,568 | 4,500 | 46.56 % | 2.07 % |
| Sinaloa | 4,317 | 7,002 | 52.46 % | 1.31 % |
| Sonora | 7,247 | 11,250 | 62.83 % | 2.05 % |
| Tabasco | 5,705 | 2,200 | 49.67 % | 0.52 % |
| Tamaulipas | 4,732 | 10,950 | 57.96 % | 0.93 % |
| Tlaxcala | 1,298 | 0 | 55.90 % | 0.54 % |
| Veracruz | 8,799 | 9,523 | 37.03 % | 2.79 % |
| Yucatan | 6,178 | 8,300 | 43.23 % | 2.27 % |
| Zacatecas | 5,394 | 3,000 | 39.34 % | 0.86 % |

Variable definitions: HWY = Paved highways (kilometers); AIR = Length of runways at commercial service airports (meters); PLUS = Percentage of the population 15 years of age and older with education beyond the primary level; SNI = Researchers in the National System of Researchers (SNI) as a percentage of the national total

Data sources: Infrastructure and educational attainment data are from INEGI; SNI data are obtained from the Office of the President of Mexico – originally the data were collected by the National Council of Science and Technology (CONACYT)