ENERGY, CAPITAL AND TECHNOLOGICAL CHANGE IN COLOMBIA:

A COMPARATIVE ANALYSIS WITH THE UNITED STATES

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Abstract

John Moroney, in his article "Energy, Capital and Technological Change in the United States" (1991), specifies and estimates aggregated production functions designed to identify the roles of capitallabor substitution, energylabor substitution and technological change as sources of labor productivity growth.

My work is based on the paper of John Moroney mentioned above, and has the objective of making an analysis similar to that made by Moroney but in the Colombian context.

The goal of this work is to identify the impact on labor productivity of energy, capital and technological change, using appropriated CobbDouglas models. The paper also presents a comparative analysis of two cases.

1. INTRODUCTION

A permanent topic of interest in the econometric research area is the study of the sources of a country's labor productivity growth. In a recent book published by the National Department of Planning of Colombia, the Colombian Sciences National Institution and FONADE, Ricardo Chica (1996) presents a summary of a national study on the determinants of productivity growth in Colombia. In its first chapter, the book presents the results of a study conducted by Sánchez, Rodríguez and Méndez, (1996) that attempts to identify the macroeconomic variables of infrastructure, human capital, and external sector that explain the dynamics of the productivity in Colombia. John Moroney, in his article "Energy, Capital and Technological Change in the United States" (1991), specifies and estimates aggregated production functions designed to identify the roles of capital-labor substitution, energy-labor substitution and technological change as sources of labor productivity growth.

My work, is based on the paper of John Moroney mentioned above, and has the objective of making an analysis similar to that made by Moroney but in the Colombian context. The paper also presents a comparative analysis of two cases. It is important to note that I am aware that big differences exist between the U.S. and Colombian economies not only with respect to

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their sizes, but also with respect to their structures. Besides, the available information in Colombia is not as reliable and precise as that of the United States.

Following Moroney (1991), the goal of this work is to identify the impact on labor productivity of energy, capital and technological change, using appropriated Cobb-Douglas models. The first of the Moroney's models corresponds to a Cobb-Douglas function where the technological change is explicit (disembodied); in the second model he assumes that the technological change is implicit in the capital investment.

My principal hypothesis is that in the Colombian economy, energy consumption does not play an so important and clear role in productivity as energy consumption does in the U.S. economy. This statement of course does not mean that energy is not an important input for the economy growth, but in the Colombian case the changes in energy consumption are not so clearly associated to changes in productivity. This fact can be explained by some weakness of the Colombian economy and the fact that the energy capacity growth does not always correspond to a consistent and detailed planning process. Moreover, the Colombian economy is not an industrialized economy.

Taking into account that a part of my work is to make some comparative analyses with the results of Moroney´s paper, and that he uses in his analysis Cobb-Douglas functions, I have preferred to use the same type of models in order to make the comparative analysis relevant.

2. Related works

As Aschauer (1989) analyzes in his paper "Is public expenditure productive?", one important concern for any country's economy, especially for emergent countries such as Colombia, is the efficiency of investment in infrastructure and its impact on productivity. Aschauer in this paper analyzes the behavior of productivity in the private United States economy and the impact of public-sector capital accumulation and the flow of government expenditures on goods and services, on productivity changes. He writes that "It may be argued that a 'core' infrastructure consisting of streets and highways, airports, electrical and gas facilities, mass transit, water systems, and sewers should possess greatest explanatory power for productivity". And, in fact, in his work he estimates the elasticity for the core infrastructure, finding that it account for the 55% of nonmilitary stock of public capital and that it is highly significant.

Thus, an important input variable in productivity models is energy. In the case of United States, Moroney (1991) shows that "the association between declining energy consumption and slower labor productivity growth, quite apart from other macroeconomic influences, is more than coincidental". To reach this conclusion, he analyzes two classes of aggregate-production functions to study how energy, utilized capital, and technological change interact to affect labor productivity and potential growth. The first is based on disembodied, Hicks-neutral technological change; in the second, the capital-augmenting technological change is analyzed through the gross investment.

One can summarize Moroney´s two most important conclusions as follows: first, energy, capital, and technological progress are essential in productivity growth in the United States. Second, energy represents a source of productivity growth independent of capital and new technology.

Sánchez, Rodríguez and Núñez, in their work "Evolution and determinant of the productivity in Colombia: a global and sectorial analysis, 1950-1994", (1996) intend to determine the macroeconomic variables, as well as the infrastructure,-the human capital,- and the external-sectör associated variables, that explain the total productivity of the factors (TPF) in Colombia. They define the rate of growth of the TPF as the difference between the real product growth rate and the factors' growth rate, that is, the part of the economic growth that is not explained by the factors' accumulation. They start from the Cobb-Douglas function with constant returns to scale,

$$Y = A(t) * K^{\propto} * L^{1-\propto},$$

with Y = GNP, A is a scaling factor representing productivity and time depending,

K = capital stock, and L = labor (number of workers). Then, they formulate the following model:

$$TPF = Y / K^{\propto} * L^{1-\propto} = A(t) = A(X),$$

where the growth on time of A(t) (productivity), gathers the influence of variables such as physical infrastructure, human capital, inflation, devaluation, and other economic and social indexes, all them contained in the matrix X. Making several regression analyses with TPF as the dependent variable, and with the variables just mentioned above as independent variables, they arrive at the following conclusions among others (at a significance level of .005): a) public capital and human capital are positively related with the TPF; b)

Infrastructure, as a principal component, has the correct sign but is significant only at a level of .10; c) analyzing some infrastructure variables separately and other social variables, they find that the coefficients associated with those variables have the correct sign but are not significant. In particular, the impact of energy capacity on the TPF is not significant in their model.

3. THE MODEL

There are several important differences between Moroney´s model, that I follow in my analysis, and that of Sánchez et al. First, Moroney´s model emphasizes in two important economic variables in addition to capital and labor: energy consumption and technology. Second, even if they start from the same type of Cobb-Douglas functions, the transformed models are completely different and correspond to distinct approaches to the problem of explaining productivity. The purposes of these two works are also quit different: Moroney wants to show, and in fact he does, that in the United States' case the energy consumption has an identifiable impact on productivity. Sánchez et al., through the TPF estimate the evolution and sources of the productivity growth. In particular, they estimate the contribution of each factor and ofthe productivity to the economical growth rate.

As mentioned above, I am going to base my analysis for the Colombian case on the Moroney´s models (1991), which correspond to two slightly different Cobb-Douglas functions, as summarize below:

Model 1

$$Q_t = \delta J_t^{\alpha} Z_t^{\beta} L_t^{1-\alpha-\beta} e^{\varepsilon_{1t}},$$

where Q_t is the actual GNP, Z_t is the real energy input, L_t is the real labor input, and J_t represents the stock of surviving capital goods, that can be expressed as:

$$J_t = \sum_{v=-\infty}^{t} (1+\lambda_k)^v M_{t-v} I_v ,$$

λ and M_{t-v} represent embodied-technical-change rate and gross-investment survival rate, respectively.

Model 2

$$Q_t = A_0 e^{\lambda t} K_t^{\alpha} Z_t^{\beta} L_t^{1-\alpha-\beta} e^{\varepsilon_{2t}},$$

where Q_t is actual GNP, technical changes occur as $A(t) = A_0 e^{\lambda t}$, K_t is the capital stock, Z_t is the real energy input and L_t is the real labor input. Both models assume that e^{ε_t} are lognormal disturbances.

To express the production functions in labor-intensive form, Moroney divides equations of models 1 and 2 by Lt, and then applies logarithm to obtain the regression equations:

(1) $\ln q_t = \ln\delta + \alpha \ln j_t + \beta \ln z_t + e_{1t}$, for model 1 and

(2) $\ln q_t = \ln A_0 + \lambda t + \alpha \ln K_t + \beta \ln z_t + e_{2t}$, for model 2,

where $q_t = Q_t / L_t$, $j_t = J_t / L_t$, $K_t = .$

$Z_t = Z_t / L_t$ and $Z_t = Z_t / L_t$.

For more details about the theoretical and conceptual justification of two models described before, see Moroney (1991) p. 366-370.

Even if I am going to base my analysis on exactly the same models developed by Moroney, some of the variables are not the same because of some deficiencies in Colombia´s economic information. Consequently, instead of hours of labor input, L_t, I use the number of employees. For similar reasons, I cannot differentiate between rates of embodied-technical-change (λ_k) and survival rates (M_{t-v}) for structures and equipment; therefore, I use the same λ for structures and equipment, as well as the same survival rate M_{t-v}. According to what is used in some of most important Colombian works in productivity analysis, the embodied technical change for Colombia can range between 0.5 % and 2 %, and the survival rate can be set as $M_{t-v} = 1 - \delta = .95$, where $\delta = .05$ is the depreciation rate for equipment and structures.

4. THE DATA

In my analysis I use some of the data that Sánchez, Rodríguez and Méndez, (1996) use in their work. I am happy to thank them for their disposition to share the very valuable information that they gathered from different sources. In addition of these data, I use other sources for data of energy generation and gross investments. All the series cover the period 1950 to 1995. In Appendix 1, I present the file with the basic variables used in this work. To keep comparative analysis between the United States and Colombia cases clearer, I use the same variables names and notation that Moroney does. Q_t, the Colombian Gross National Product is given in constant-Colombian pesos of 1975. Total Capital, K_t, is also given in constant-Colombian pesos of 1975. I_t is the gross investment in Colombian pesos of 1975, and was taken from a publication of the Colombian National Planning Department, *Estadísticas Históricas de Colombia*.

Because of the lack of reliable information about energy consumption for an important part of the period considered in this work, I use and analyze two different variables as proxies of energy consumption: energy capacity, Z_t, which is given in megawatts and corresponds to the total annual electricity capacity, and energy generation, $Zgen_t$, which is given in gigawatts/hour, and corresponds to the total annual energy generated. L_t is the total number of employees, which is the equivalent but less precise, of the number of total worked hours used in Moroney's paper. The series of surviving capital goods, J_t, is constructed according to the expression that appears in the description of model 1 of Moroney. I construct three different J_t's series, $J_t(1), J_t(2), J_t(3)$, taking a fixed survival rate $M_{t-v} = 1-\delta = .95$ where $\delta = .05$ is the depreciation rate for equipment and structures, and taking three distinct values for embodied technical change, $\lambda = .005, \lambda = .01$ and $\lambda = .02$, respectively.

TABLE 1

a. Models with variable energy capacity(z)

EQUATION	TECH. CHANGE AND DEPRECIATION RATES	$\alpha(\ln(j,k))$	$\beta(\ln z)$	$\lambda(time)$	R^2	D - W
(1)	Tech.Ch.=.005 M_{t-v} = .95	0.351*** (0.575)	0.031 (0.043)	-	0.994	1.69
	Tech.Ch.=.01 M_{t-v} = .95	0.322*** (0.052)	0.028 (0.043)	-	0.994	1.69
	Tech.Ch.=.02 M_{t-v} = .95	0.271*** (0.043)	0.025 (0.043)	-	0.994	1.68
(2)		0.392*** (0.116)	0.028 (0.042)	0.005 (0.003)	0.994	1.97

*** significant at $P \leq 0.01$

** significant at $P \leq 0.05$

* significant at $P \leq 0.10$

TABLE 1

b. Models with variable energy generated (zgen)

EQUATION	TECH. CHANGE AND DEPRECIATION RATES	α(capital)	β(lnzgen)	$\lambda(time)$	$\eta = 1-\alpha-\beta$ (labor)	R^2	D - W
(1)	Tech.Ch.=.005 M_{t-v} = .95	0.278*** (0.067)	0.087* (0.049)	-	0.635	0.994	1.74
	Tech.Ch.=.01 M_{t-v} = .95	0.253*** (0.061)	0.085* (0.049)	-	0.662	1.69	1.76
	Tech.Ch.=.02 M_{t-v} = .95	0.210*** (0.049)	0.086* (0.48)	-	0.704	0.994	1.77
(2)	--	0.292*** (0.105)	0.120** (0.047)	0.004 (0.003)	0.588	0.994	1.91

*** significant at $P \leq 0.01$

** significant at $P \leq 0.05$

* significant at $P \leq 0.10$

5. Results of the model for the Colombian case

Based on the Colombian data described above, I initially estimated equations (1) and (2), using Ordinary Least Squares of Econometrics Views. But given that the regression models presented problems of residuals first order correlation, I use the procedure AR(1) in E-Views, which is a procedure for eliminating first order autocorrelation in the regression models, and is based on Marquandt method.

The results obtained for the estimation of equations (1) and (2) are presented in Table 1. Additionally, I have estimated both equations replacing the variable energy capacity, Z_t, by the variable Zgent, which represents the number of gigawatts hour by year generated, which is a better proxy of the energy consumption that the energy capacity Z_t.

By observing table 1, we note that all the models for both equations 1 and 2, have a very high adjusted R squared, R^2, which indicates that the equations formulated fit the data analyzed particularly well. Also, we can observe that all the vintage models have a similar behavior, independently of the specific values of the parameter λ, representing the Colombian embodied technological change rate. In fact, the value of the parameter a, associated to variable capital goes from 0.322 to 0.351(always at a significance level of .001 or less), for the models that include the variable energy capacity, table 1a. For the purposes of this work it is important to see in table 1a that the variable energy capacity, Z_t, has very low associated coefficients along the different models, and that it is not significant in none of the models. This result can be interpreted as a clear signal that in Colombia the energy capacity does not have an identifiable direct impact on productivity. This is not the case, as we will see soon, for the variable energy generated, Zgent, which, as expected, is a better proxy of energy consumption than energy capacity.

In table 1b, we can observe that, as with the models of table 1a, all the vintage models have a similar behavior, independently of the specific values of the parameter λ, which representa the Colombian embodied technological change rate. For the vintage models, the values of the parameter a, associated with the variable capital are lower than in the case just analyzed, going from 0.210 to 0.278, always at a significance level of 0.001 or less. The values of the coefficient associated with energy generated are pretty small, but greater than for the case of models with variable energy capacity, going from 0.085 to 0.087, and significant only at a level of 0.10. The highest value for the coefficient associated with the variable energy generated appears in the estimate of equation (2), in table 1b, taking a value of 0.120, with a significance level of 0.05. Thus, after observing the results presented in table 1, one can remark that unlike variable energy capacity, the variable energy generated is a better approximation of the variableenergy consumption, and that it has an identifiable, even if not very strong , impact on productivity in Colombia.

Another important result is that for both cases analyzed (the case with variable energy capacity and the case with variable energy generated), the estimates of the parameter λ of equation (2), which represent the disembodied technological change, are remarkably low and not significant. This is a disturbing result, that could indicates that the Colombian economy and, particularly productivity, has a very low technological component and that the economy's growth is almost completely dependent only on capital.

7. Comparison between United States and Colombian results

Taking into account that the models that have the variable energy generated, Zgen, are more appropriate for representing the Colombian labor productivity model, as I have already said, all the comparisons with the U.S. case will be done using the results of those models, which are presented in table 1b.

With respect to models fit, in both cases, the models have a high adjusted R squared going from 0.897 to 0.993, in the regression models estimated by Moroney for the U.S. data, and equal to 0.994 for the regression models estimated in my work. Thus, the data fit very well in both cases.

In the US case, the estimates of α, the parameter associated with capital, have an average value of 0.344 for the four vintage models analyzed by Moroney, and is relatively close to the average value, 0.464, of β, the parameter associated with energy for these models. In the Colombian case, the estimates of a, have an average value of 0.247 for the three vintage models that I analyzed, and this average is grater by far than the average value, 0.086, of b, the parameter associated with energy for these models.

For the model with disembodied technical change in the U.S. case, the estimate of α is 0.142, approximately a half of the estimate of β, 0.289. In the Colombian case, the estimate of a is 0.292, more than twice the estimate of β, 0.120.

8. Conclusions

Energy generated is a good proxy of energy consumption and it has an identifiable impact on labor productivity in Colombia. However, energy consumption does not play an so important and clear role in productivity in Colombia as energy consumption does in the U.S. economy.

In the Colombian case different that in the U.S. case, the estimate of β, the parameter associated with energy generated, increases for the model with disembodied technical change and its significance level improve. I would think that the reason for this fact is that the model with disembodied technical change represents better the Colombian economy, where labor productivity is not clearly associated with technological change, as it shows the very low, 0.004, and non significant estimate of parameter λ, which represents disembodied technical change.

This behavior of parameter λ, which represents disembodied technical change, lead us to conclude that Colombian labor productivity, unlike the U.S. case, has a very low technological component and that the Colombian economy's growth is almost completely dependent on capital.

Taking into account the characteristics of Colombian economy mentioned above, the results of my study seem very reasonable and useful for the analysis of labor productivity in Colombia. The results obtained produce some concern about the low impact of technology on economy and productivity growth.

As mentioned above, Sánchez, Rodríguez and Núñez (1996), in their work "Evolution and determinant of the productivity in Colombia: a global and sectorial analysis, 19501994", use in their TPF model the variable energy capacity instead of energy generated. Given that energy generated is a better proxy of energy consumption, it would be interesting to suggest them to incorporate this variable in their analysis.

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