PRODUCTIVITY ANALYSIS IN LATIN AMERICA: EXPLAINING THE LOST DECADE OF THE 1970'S

Joshua J. Lewer, West Texas A&M University

ABSTRACT

Latin American economic history suggests that nothing is predetermined about the region's mixed and often slow terms of economic growth and development. The purpose of this article is to examine productivity growth for nine Latin American countries during the turbulent period of the 1970's. Using neoclassical growth theory and applying the Malmquist index of (Fare *et al.*, 1994), estimation of productivity growth and its components are identified for each country. The findings of this paper indicate that productivity growth of the nine countries is mixed; several countries experienced a decline in productivity levels due to large declines in domestic innovation.

INTRODUCTION

Productivity is defined as the efficiency with which inputs are transformed into output in the production process (Van den Berg, 2001). According to the neoclassical growth model and later confirmed by several empirical studies, productivity growth is a significant determinant of long-run economic performance (see for example, Solow, 1957; Denison, 1985; Hall and Jones, 1999; Senhadji, 1999; Dallas Federal Reserve Bank, 2003). However, measuring the total factor productivity residual has proven difficult for researchers (Solow, 1957; and Mankiw, Romer, and Weil, 1992). One of the most popular contemporary methods of quantifying productivity is to use non-parametric estimation of indexes.

Historically, Divisia indexing, which is based on the ratio of aggregate indexes of outputs to the aggregate indexes of all factor inputs, has been used. For example, the Tornqvist index can be applied to calculate total factor productivity growth (Tornqvist, 1936; Theil 1967). It is based on discrete information and applies shares as weights to aggregate inputs/outputs. However, one cannot obtain and decompose the productivity change into movements along and changes in the frontier because the Tornqvist index assumes observed output is the same as best practice frontier.

There is an alternative index that can estimate productivity non-parametrically. The Malmquist index allows for non-parametric estimation as well as the decomposition of productivity change into efficiency and technology (see, Fare *et al.*, 1994; Lall *et al.*, 2002; Grosskopf, 2003; Kruger *et al.*, 2003; Lovell, 2003; Asmild, 2004). With this extra information, multilateral comparisons can be made and growth patterns for different countries can be examined. The Malmquist technique has become the preferred method of calculating productivity change due to its accuracy and flexibility. The index will be examined in more detail in the following section of the paper.

This article applies the Malmquist index for the purpose of determining the sources and differences in productivity growth for nine Latin American countries during what has become known as Latin America's lost decade of the 1970's. Economic conditions in the 1970's for most Latin American countries were tenuous at best. Years of import substitution policies, political unrest, and macroeconomic instabilities had taken its toll on economic growth in the region. While many studies have examined the determinants of stagnant output growth, there has been little research on productivity growth during the decade. The results of this study provide insight into overall productivity change, efficiency change, and domestic innovation through the decomposition of the Malmquist productivity index.

THE DECOMPOSTION OF THE MALMQUIST PRODUCTIVITY INDEX

The initial theory behind the output-based Malmquist productivity index comes from (Caves *et al.*, 1982) who apply distance functions of output and inputs to capture quantifiable estimates of productivity growth. The output-based Malmquist index assumes that for each time period t = 1,...,T, the production technology F^t models the transformation of inputs, x^t, into outputs, y^t. Stated below as,

$$F^t = \{(x^t,y^t): x^t \text{ can produce } y^t\}. \tag{1}$$

The distance function at time t can be defined as,

$$D^t_0(x^t, y^t) = \inf\{\theta:(x^t, y^t/\theta) \in Ft\}, \tag{2}$$

where the distance function $D^t_0(x^t, y^t)$ measures the maximal proportional change in outputs
required to make (x^t, y^t) feasible in relation to the technology at t. If $D^t_0(x^t, y^t) < 1$ then the country is producing at a point that is less than efficient, say inside the production possibilities frontier (PPF). If $D^t_0(x^t, y^t) = 1$, then a country is technically efficient and is producing on the frontier. Lastly, if $D^t_0(x^t, y^t) > 1$, then a country is engaged in expanding its frontier outward toward the best practice frontier.

To complete the Malmquist index with technology in period t, distance functions from two different time periods are needed, time t and t + 1. The distance function at time t + 1 relative to technology in period t is defined as:

$$D^t_0(x^{t+1}, y^{t+1}) = \inf\{\theta:(x^{t+1}, y^{t+1}/\theta) \in Ft\}, \tag{3}$$

Similarly, this distance function, measures the maximal proportional change in outputs required to make x^{t+1} and y^{t+1} feasible in relation to the technology at t. Dividing equation (3) by equation (2) yields the Malmquist productivity index with technology in period t (Caves, Christensen, and Diewert, 1982),

$$M^t = \frac{D^t_0(x^{t+1}, y^{t+1})}{D^t_0(x^t, y^t)}. \tag{4}$$

By employing the same techniques as above, one may also define distance functions that measure the maximum proportional change in output required to make (x^t, y^t) and (x^{t+1}, y^{t+1}) feasible in relation to the technology at t +1. The Malmquist productivity index with technology in period t + 1 is

$$M^{t+1} = \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}. \quad (5)$$

Now one can calculate the Malmquist productivity-change index. It is formed from the geometric mean of the two output-based Malmquist productivity indexes of equations (4) and (5). (Fare *et al.*, 1989; Fare *et al.*, 1992; Lall *et al.*, 2002; Grosskopf, 2003; Kruger *et al.*, 2003; Lovell, 2003; Asmild, 2004) have shown that the index can decompose productivity change into changes in relative efficiency and shifts in technology over time. The Malmquist productivity-change index is shown in equation (6) below,

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right] * \left[\left(\frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)}\right)\left(\frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^t, y^t)}\right)\right]^{1/2}. \quad (6)$$

The first bracketed expression on the right hand side of the equal sign illustrates the change in relative efficiency, and shows to what extent observed production is moving closer (or farther) from the best practice frontier between years t and t + 1. The best practice frontier is constructed from the best practice country of the nine. Therefore, the relative efficiency component will relate how well or how poorly a country is performing relative to the grand frontier country. That is, it measures the "catching-up" effect.

The second expression on the right hand side is nothing but a geometric mean of the two ratios inside the brackets. It can be interpreted as the change in technical progress (i.e. the "innovation effect"). It measures the change and rate of change in the best practice production frontier.

The Malmquist index is the product of efficiency change and technical change. A Malmquist index greater than one shows improvement in productivity, whereas an index less than one represents a deterioration in productivity. Note that an index equal to one shows a country that is on the grand frontier. This same analysis also holds true with the two components, moreover, they (i.e. efficiency and technical change) can move in opposite directions.

The method used to find the Malmquist productivity change index as defined in equation (6) follows the linear programming approach of (Fare *et al.*, 1989). In this case technology in a certain period is just the distance functions, an individual can apply non-parametric programming to create the grand best frontier, and then view each of the countries position and directional change in relation to the best practice frontier. This article employs GAMS programming to estimate the non-parametric calculations.

DATA AND RESULTS

This paper is concerned with productivity growth in a sample of nine Latin American countries from 1970-1980. Countries include: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, and Venezuela. This paper's model stems from the neoclassical Cobb-Douglas production function,

$$Y = F^t L^{\alpha} K^{1-\alpha}, \qquad (7)$$

where Y is real gross domestic product (GDP), F is the Solow residual or total factor productivity, L is the labor force, K is the capital stock, and α and $(1-\alpha)$ are the relative income shares of income going to labor and capital, respectively. The IMF International Financial Statistics 2003 Yearbook is the source for all data.

The Malmquist index summary of regional annual means is located in Table 1. After the year, the table presents efficiency change in column two, technical change in column three, pure efficiency change in column four, scale efficiency change in column five and the total factor productivity change (i.e. the Malmquist index) in the final column. Pure efficiency change assumes a situation where there is variable returns to scale (vrs), and is calculated by taking the distance function at time

Table 1
Malmquist Index Summary Of Regional Annual Means

Year	Efficiency Change	Technical Change	Pure Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change (M_0)
1970	1.008	0.895	1.010	0.998	0.902
1971	1.021	1.075	1.018	1.003	1.098
1972	1.023	0.986	1.026	0.997	1.008
1973	0.998	1.010	1.003	0.996	1.009
1974	0.986	0.965	0.984	1.002	0.952
1975	1.003	0.988	1.012	0.991	0.991
1976	1.004	1.013	0.996	1.009	1.017
1977	1.023	0.962	1.042	0.982	0.984
1978	1.000	0.995	0.999	1.001	0.995
1979	0.987	1.026	1.000	0.987	1.013
1980	1.049	0.943	1.033	1.016	0.990
Mean	1.009	0.987	1.011	0.999	0.996

t+l and dividing it by the distance function at time t. Scale efficiency uses both constant returns to scale (crs) and vrs. Specifically, scale efficiency is the ratio of two ratios where the numerator is the vrs distance function at time t+1 over the crs distance function at time t+l, and the denominator is the vrs distance function at time t over the crs distance function at time t. It is important to note that, an alternative way to calculate efficiency change is to multiply pure efficiency change by scale efficiency change. For example, in year 1970 efficiency change is 1.008 (1.010 * 0.998 = 1.008). As equation (6) indicates, total factor productivity change (M_0) equals the product of efficiency change and technical change. For example, in year 1970 total factor productivity change is 0.902 (1.008 * 0.895 = 0.902).

One of the significant findings from Table 1 is that during the years 1972-1973, the two components of the Malmquist move in opposite directions. Efficiency change decreased from 1.023 to 0.998 and technical efficiency rose from 0.986 to 1.010 causing total factor productivity to be slightly higher in 1974.

Another significant result from Table 1 is that efficiency change tends to be a positive contributor to total factor productivity change in the selected Latin American countries (i.e. it is greater than unity), and technical change tends to be a negative contributor (i.e. it is often less than unity), suggesting that productivity gains due to such things as learning-by-doing, technological diffusion, and other short run adjustments are substantial for these countries. During the eleven year analysis, efficiency change is only below unity three times, and has a mean of 1.009 for the period. Thus, it is pushing them toward the best practice frontier; however, the technical change component had a mean of 0.996 and is pushing the region toward inefficient production. (De Soto, 1989; De Soto, 2000) suggests that the reason for Latin America's (and other developing region's) stagnant and/or declining technical change (i.e. innovation) has been due to the lack of property and intellectual property rights. The lack of intellectual and property protection is a disincentive to invest in research and development (R&D) projects because of the intertemporal nature of profits from R&D activity. That is, the costs from innovation are incurred at the beginning of the project, while the revenue stream comes sometime in the future. Rational individuals tend not to invest in new projects the weaker property rights are in a country. When property rights are well established and respected, researchers and entrepreneurs feel free to engage in intertemporal activities. This result is confirmed by (Nishimizu's, 1982) parametric estimation of developing eastern European countries.

Another meaningful result from Table 1 is the mean of total factor productivity growth (Malmquist index, M_0) is less than one at 0.996 for the eleven year period. This would suggest that the amount of output per unit of input shrunk for the region over the decade. The lowest year mean was in 1971 when the index was 0.902, this was the year that the Bretton Woods system collapsed. After the initial shock, however, industrialized countries found themselves freed from pegged exchange rate obligation, and world equity became much looser than before. Moreover, primary commodities such as oil reached record prices. This tended to help all countries, but certainly the three largest oil exporting countries in South America: Bolivia, Ecuador, and Venezuela.

Table 2 reports the Malmquist index and its components for all nine countries. The results suggest that Ecuador made the greatest strides toward efficiency changes over the decade with a value of 1.041. Chile, however, had the lowest efficiency change value of 0.996. This low number may partially be attributed to Chile's socialist experiment under President Allende during the early 1970's, where private investment in the country nearly collapsed and learning how to use new capital decreased.

Another result is that there is no single country that can be described as an innovator in the group because technical efficiency is never greater than one. The lack of domestic innovation is not surprising, and can be partially explained by the broad economic uncertainty that existed during the time. Entrepreneurs, scientists, engineers, and researchers faced political unrest, macroeconomic instabilities, and tenuous property and intellectual property rights. A study by Lall *et al.* (2002)

reinforces the findings of this paper. Using Malmquist decomposition techniques, Lall *et al.* found that domestic innovation in Latin America remained weak until the mid-to-late 1980's. They find that poor institutions and uncertainties were major factors for the stagnant to modest domestic innovation in Latin America during the late 1970's to mid 1980's.

Table 2
Malmquist Index Summary Of Country Means

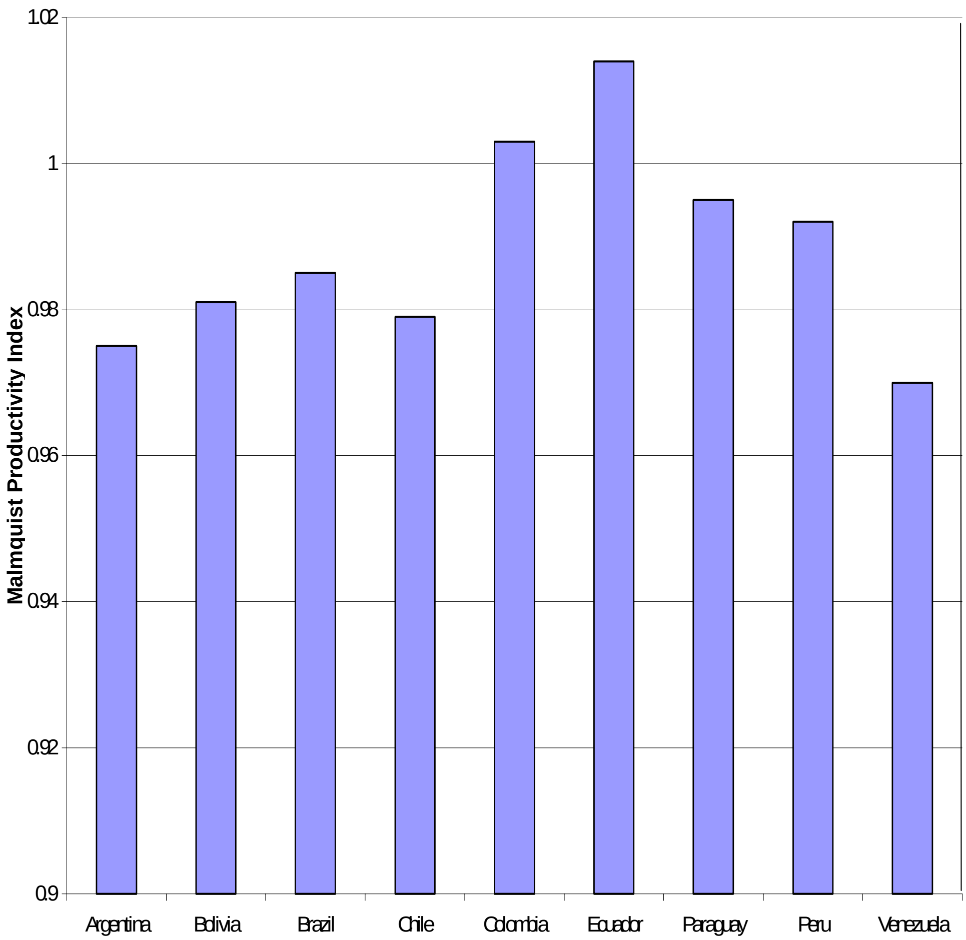
Country	Efficiency Change	Technical Change	Pure Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change (M_0)
Argentina	0.999	0.975	1.000	0.996	0.975
Bolivia	0.999	0.984	0.997	0.998	0.981
Brazil	1.002	0.984	1.003	0.999	0.985
Chile	0.996	0.983	1.005	0.992	0.979
Colombia	1.028	0.975	1.027	1.001	1.003
Ecuador	1.041	0.974	1.041	0.999	1.014
Paraguay	1.000	0.994	1.000	1.000	0.995
Peru	1.016	0.997	1.021	0.996	0.992
Venezuela	1.000	0.970	1.000	1.000	0.970
Mean	1.009	0.979	1.010	0.998	0.988

Of the nine countries, only two had a Malmquist index greater than one: Ecuador (1.014) and Colombia (1.003). The other countries found their overall productivity declined away from potential. See Figure 1 for cross-sectional comparisons. One interesting case study is Venezuela. They had the lowest technical change score of 0.970. However, when reviewing the output from a year-to-year basis, Venezuela is actually a good choice for the best frontier because of its relatively fast economic growth rate (i.e. real GDP growth) compared to the other countries in the sample. This is a paradox of having declines in productivity, and at the same time enjoying modest increases in economic growth. This can be partially explained by the sale of Venezuela's natural resources. That is, Venezuela has large reserves of oil and is one of the OPEC founders.

This analysis does not give an overall good report of productivity growth and patterns for the given countries during the years 1970-1980. These uninspiring results indicate that there is no real innovator country. This result confirms (Elias, 1992) parametric study on low productivity growth in Latin American countries over the same period.

As mentioned above, because innovators make rational decisions about R&D, and they employ resources when the discounted expected future profits from innovation exceed the costs of the resources employed, domestic innovation declines when the future is uncertain. In terms of policy measures to improve Latin American productivity growth, emphasis on macroeconomic stability and securing intellectual and property rights are paramount.

Figure 1
Malmquist Productivity Indexes



CONCLUSION

The purpose of this paper is to estimate productivity growth and its components using the distance based Malmquist index. This non-parametric approach constructs a best practice frontier (potential frontier), and allows for the decomposition of technology into two measures: technical change (the innovation effect) and efficiency change (the catching-up effect). Countries are compared multilaterally to determine which countries are high/low performers.

Several significant results were found in this study. Efficiency change tends to be a positive contributor to total factor productivity change, but technical change tends to be a negative contributor for the nine Latin American countries. One explanation of poor technical change performance in Latin America was the lack of stable institutions and secure intellectual and property rights. No single country can be described as an innovator (i.e. technical efficiency greater than one). Also, the mean of total factor productivity growth is less than one at 0.996 for the eleven year period suggesting that the amount of output returned for a given amount of input decreased during the "lost decade." Only two countries, Ecuador and Columbia, had a total factor productivity change value that was greater than one. The other countries moved further away from their potential production function. This article points to the lack of overall domestic innovation as a partial explanation as to why the 1970's were a slow growth period for many Latin American countries.

REFERENCES

Asmild, M., J.C. Paradi, V. Aggarwall, & C.Schaffnit (2004) Combining dea window analysis with the malmquist index approach in a study of the Canadian banking industry. *Journal of Productivity Analysis*, 21(1), 67-89.

Caves, D.W., L.R. Christensen & D.W. Erwin (1982). Multilateral comparisons of output, input, and productivity using superlative index numbers. *Economic Journal*, 92(365), 73-86.

Dallas Federal Reserve Bank (2003). *A Better Way: Productivity and Reorganization in the American Economy*. 2003 Annual Report.

De Soto, H. (1989). *The Other Path: The Invisible Revolution in the Third World*. New York, NY: Harper & Row Publishers.

De Soto, H. (2000). *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else*. New York, NY: Basic Books.

Denison, E.F. (1985). *Trends in American Economic Growth, 1929-1982*. Washington, D.C.: Brookings Institution.

Elias, V. (1992). *A Study of Seven Latin American Economies: Sources of Growth*. New York, NY: International Center for Economic Growth.

Fare, R., S. Grosskopf, B. Lindren, & P. Roos (1989). Productivity developments in Swedish hospitals: a Malmquist output index approach. *Discussion Paper N. 89-3*, Southern Illinois University.

Fare, R., S. Grosskopf, & C.A. Lovell. (1992). Productivity change in Swedish pharmacies 1980-1989: a nonparametric Malmquist approach. *Journal of Productivity Analysis*, 3(3), 85-101.

Fare, R., S. Grosskopf, M. Norris, & Z. Zhang (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *American Economic Review*, 84(1), 66-83.

Grosskopf, S. (2003). Some remarks on productivity and its decompositions. *Journal of Productivity Analysis*, 20(3), 459-474.

Hall, R.E. & C.I. Jones (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics*, 114(1), 173-177.

Kruger, V.J, U. Canter, & H. Hanusch (2003). Explaining international productivity differences. *Jahrbucher fur Nationalokonomie und Statistik*, 223(6), 659-679.

Lall, P., A.M. Featherstone, & D.W. Norman (2002). Productivity growth in the western hemisphere (1978-94): the Caribbean in perspective. *Journal of*

Productivity Analysis, 17(3), 213-231.
Lovell, C.A. (2003). The decomposition of malmquist productivity indexes. *Journal of Productivity Analysis*, 20(3), 437-458.
Mankiw, N.G., D. Romer, & D.N. Weil (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, 107(2), 407-437.
Nishimizu, M. & J.M. Page (1982). Total factor productivity growth, technological progress and technical efficiency change: dimensions of productivity change in Yugoslavia, 1956-78. *The Economic Journal*, 92(368), 920-936.
Senhadji, A. (1999). Sources of economic growth: an extensive growth accounting exercise. *IMF Working Paper WP/99/77*.
Solow, R.M. (1957). Technical change and the aggregate production function. *Review of Economics and Statistic*s, 39(2), 312-320.
Theil, H. (1967). *Economics and Information Theory*. Amsterdam: North-Holland.
Tornquist, L. (1936). The bank of Finland's consumption index. *Bank of Finland Bulletin*, 10(1), 1-8.
Van den Berg, H. (2001). *Economic Growth and Development*. New York, NY: Irwin-McGrawHill.