Mexico's Industrial Engine of Growth: Cointegration and Causality

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Summary

The present study applies the techniques of cointegration and Granger causality to examine the causal relationship between industrial growth and overall economic performance in the Mexican economy. The empirical evidence presented in the paper tries to find support in Mexico for the Kaldor's engine of economic growth hypothesis.

JEL Classification: C22, C52, O41.

Keywords: Cointegation, Causality, Economic Growth, Mexico.

1. Introduction

The purpose of a theory of economic growth is to show the nature of the economic variables which ultimately determine the rate at which the general level of production of an economy is growing, and thereby contribute to an understanding of the question of why some societies grow faster than others.

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Endogenous growth theory stresses the importance of increasing returns in generating economic growth. However, none of the endogenous growth models acknowledge the simple empirical tests made by Nicholas Kaldor in the 1960's demonstrating the existence of increasing returns in the industrial economies. Nevertheless, there are important differences from the theoretical point of view. Endogenous growth theory starts from the basic hypothesis that the supply of labor and capital constrains the growth of output in the economy, whereas Kaldor starts from the premise that demand constrains the growth of output. Most of the endogenous growth models introduce some variable that is external to the enterprise (externalities) such as R&D and improved human capital that help to overcome the supply constraints and sustain growth in the long run. Kaldor's (1957) model had already recognized the importance of endogenously determined technical change and technological learning, but emphasized the importance of the expanding market to explain the presence of increasing returns. Kaldor's empirical analysis of economic growth is generally seen as being macroeconomic due to economies of scale that are generated endogenously through technical change and technological learning.

A review of studies of twentieth century economic growth reveals a conviction, held alike by many economists in Britain, that industrial expansion has been the prime mover of British economic growth. The popularity of Kaldor's engine-of-growth (KEG) among economists demonstrates the extent to which the industrial sector is regarded as the prime source of productivity growth. The critics of Kaldor's theory have tended to concentrate on problems of modeling this relationship rather than questioning the applicability of the theory to modern economic growth.

The (KEG) hypothesis that industrial sector is the engine of the economic growth is recently attracting considerable interest in the industrialized world as seen in papers such as (Bairam, 1991) , (Atesoglu, 1993) and (Scott, 1999).[1] Recent studies found a significant statistical association between growth rate of industrial production and economic growth in industrial and developing countries. Such a finding has been used to support the KEG hypothesis. The testing methodology employed in all three studies, however, has concentrated upon simple regression analyses. Previous studies tested the validity of the KEG hypothesis by regressing real output growth on the growth rate of industrial output. If the coefficient of the growth rate of industrial output is found to be statistically significant and positive, it is then concluded that the growth rate of industrial output totally or partially determines the overall economic growth. We observe that this kind of methodology is not appropriate and sufficient to test the KEG hypothesis because simple regression equations used in the previous studies can only show the presence of the statistical correlation between growth of industrial output and economic growth, but have no bearing on the causal relationship between the two variables. We also observe that the validity of the KEG hypothesis requires not only the existence of the significant correlation between industrial and economic growth but also the causality running from the growth in the industrial sector to the overall economic performance.

The objective of this paper is to re-examine the KEG hypothesis in Mexico using the Granger causality technique. The test is applied on the quarterly Mexican data on GNP and industrial sector production from the first quarter of 1980 to the third quarter of 2000.

[1] Scott (1999) shows that with increasing returns of scale in industry, a long-run equilibrium growth path with strictly positive growth rates may exist, even if agriculture is subject to decreasing returns; thus the industrial sector is the engine of growth in the economy.

The data used in this study is quarterly in thousands of pesos, with base 1993 and comes from Bank of Mexico's website and publications. The methodology employed in this study is that Granger causality which is carried out as well as the cointegration test. Engle and Granger (1987), in a seminal work show that the logarithm of the level of the industrial production (log IND) and the logarithm of the level of the real GNP (log GNP) are cointegrated if each is non-stationary but there exists a linear combination of two that is stationary.

2. Development of the Engle and Granger Technique to Test the KEG Hypothesis

As an initial step in the cointegration test, stationarity tests must be performed for each of the relevant variables. There have been a variety of proposed methods for implementing stationarity tests and each has been widely used in the world applied economics literature. However, there is now a growing consensus that the stationarity test procedure due to Dickey and Fuller (1979) has superior small sample properties compared to its alternatives if we assume that the disturbance term, e_t, is an iid process. If this assumption is incorrect then the limiting distributions and critical values obtained by Dickey and Fuller cannot be assumed to hold. Dickey and Fuller (1981) demonstrate that the limiting distributions and critical values that they obtain under the assumption that e_t is an iid process are in fact also valid when e_t is autoregressive if the augmented Dickey-Fuller (ADF) regression is run. Therefore, in this study, the augmented Dickey-Fuller (ADF) test procedure was employed in the GNP and industrial production series to conduct stationarity tests.

Table A and B report the ADF tests of the null hypothesis that a single unit root exists in the level logarithm as well as first (logged) difference of each series. The number of lags used in the ADF regressions have to be selected using the Akaike information criterion (AIC). Based on the ADF-t statistics, the null hypothesis of a unit root in log levels cannot be rejected, while using the ADF test with difference of the series show that the null hypothesis of a unit root is rejected. Thus, the evidence suggests that the levels of log GNP and log IND are characterized by a I(1) process.[2]

Since both variables, log IND and log GNP, are suspected not to be individually stationary in their levels but in their first differences, performing cointegration tests for both variables is theoretically possible. The long-run relationship between log IND and log GNP can be detected by the cointegration method developed by Johansen (1988) and Johansen and Juselius (1990). The Johansen method applies the maximum likelihood procedure to determine the presence of cointegrating vector(s) in non-stationary time series. The number of lags applied in the cointegration tests was based on the information provided by the AIC. Table C reports the results of the cointegration tests between log IND and log GNP. The AIC indicated that one lag was appropriate for the VAR system. Two test statistics were used to test for the number of cointegrating vectors: the maximum eigenvalue and trace test statistics. Table D reports the results of cointegration between log GNP and log IND. Results based on both statistics indicate the presence of a stationary long-run relationship at 5% level between log GNP and log IND.

[2] Standard unit root tests as the ones developed by Dickey-Fuller and Phillips-Perron are designed to reject the null hypothesis unless there is strong evidence against it. The null hypothesis is, in general, that there exists a unit root in the series being tested. As a result, standard tests fail to reject the null of a unit root (non-stationarity) in several economic series. The procedure developed by Kwiatkowski, Phillips, Schmidt and Shin (1992) to directly test the null hypothesis of stationarity (absence of a unit root) is shown in the appendix.

Granger (1986) and Engle and Granger (1987) argue that as long as variables are cointegrated, causality has to exist at least in one direction.[3] Following the methodology of Engle and Granger (1987) the direction of causality between D log IND and D log GNP can be detected by estimating the following error-correction models:

$$\Delta \log GNP_t = \alpha_0 + \sum_{s=1}^{k} \alpha_{1s} \Delta \log GNP_{t-s} + \sum_{s=1}^{1} \alpha_{2s} \Delta \log IND_{t-s} + \psi_1 RES1_{t-1} + \varepsilon_{1t} \tag{1}$$

$$\Delta \log IND_t = \beta_0 + \sum_{s=1}^{m} \beta_{1s} \Delta \log IND_{t-s} + \sum_{s=1}^{n} \beta_{2s} \Delta \log GNP_{t-s} + \psi_2 RES2_{t-1} + \varepsilon_{2t} \tag{2}$$

where RES1 is the residual from the cointegrating GNP regression and RES2 the residual from the cointegrating IND regression. In the difference log GNP equation, if either the α_{2s} 's are jointly significant or if one of the α_{2s} is significant, then the null hypothesis that DlogGNP does not Granger cause DlogIND is rejected. A similar interpretation should also be attached to log IND equation.

Table E and F present the results of error-correction estimations. The one lag structure in the error-correction models was determined by means of Akaike's final prediction error criterion. Based on the coefficient of the error-correction term, the null hypothesis of no-causality from industrial output to overall output is rejected. The null hypothesis of no-causality from the overall economic growth to the growth in the industrial is rejected through error-correction term at a 5% level.

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[3] Recall that the two-step procedure developed by Engle and Granger involves estimating the long run relationship using the cointegrating regression and in the second step, a general dynamic model is estimated usually expressed in an error correction form which incorporates the estimated disequilibrium errors from the first step.

The Granger Causality F-test was also performed with P-values at 95% significance levels. Consider first the hypothesis that D log GNP does not Granger-cause D log IND. The p-value of 0.027, calls for rejecting the null hypothesis of no granger causality and accepting the alternative hypothesis that D log GNP does cause D log IND. Furthermore, we reject the hypothesis that D log IND does not Granger-cause D log GNP since the p-value is 0.021. The Granger Causality F Test leaves us to accept the hypothesis that D log IND does Granger-cause D log GNP. Thus, there's enough evidence to show a two-way linear granger causality between real GNP and industrial output.[4] The fact that the growth rate of the industrial output does cause the overall economic growth leaves us to support the KEG hypothesis for Mexico during the period under consideration.

The validity of the KEG hypothesis for Mexico is demonstrated in the study by showing the existence of significant correlation between industrial output and economic growth and by the bi-directional causality running from the growth of the industrial sector to the overall economic performance.

[4] Further evidence of bi-directional causality can be found by using the nonlinear Granger causality method proposed by Hiemstra and Jones (1994). Hiemstra and Jones (1994) have found bidirectional non-linear Granger causality between stock returns and trading activity in the New York Stock Exchange.

3. Conclusions

A well-established body of theoretical and empirical research supports the conclusion that industries are engines of growth. In this paper, the KEG hypothesis is tested using Mexican data, with cointegration and Granger causality techniques that were used to identify the long run and causal relationships between industrial output and real GNP in Mexico. The empirical results indicate that industrial sector and overall economy are cointegrated and have a long run relationship in Mexico. The Granger causality test shows evidence that there exists a two way causal relationship supporting completely the KEG hypothesis and findings that industrial output causes the overall economic growth for Mexico during the period under consideration.

4. References

Atesolgu, H.S. (1993), "Manufacturing and economic growth in the United States", *Applied Economics*, 25, 67-69.

Bairam, E. (1991) , "Economic growth and Kaldor's law: the case of Turkey, 1925-78", *Applied Economics*, 23, 1277-1280.

Banco de México, Indicadores Económicos y Financieros, varios años. Cuentas Nacionales (valores, estructura 1993). Producción Industrial y Producto Interno Bruto.
http://www.banxico.org.mx/eInfoFinanciera

Dickey , D. and W. Fuller (1979), "Distribution of the estimators for autoregressive time series with a unit root", *Journal of the American Statistical Association*, 74, 427-431.

Dickey, D. and Fuller, W. (1981), "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root", *Econometrica*, 49 : 1057 - 1072

Engle, R.F. and C.W.J. Granger (1987), "Cointegration and error correction: representation, estimation and testing", *Econometrica*, 55, 251-76.

Granger, C.W.J. (1986), " Developments in the study of cointegrated economic variables", *Oxford Bulletin of Economics and Statistics*, 48, 213-228.

Granger, C.W.J. (1988), "Some recent developments in a concept of causality", *Journal of Econometrics*", 39, 213-28.

Hamilton, James D. (1994), *Time Series Analysis*, Princeton University Press.

Hiemstra, C. and Jones, J.D. (1994), "Testing for linear and non-linear Granger Causality in the Stock price-volume Relation", *The Journal of Finance*, 49, 1639-1664.

Johansen, S. (1988), "Statistical analysis of cointegration vectors", *Journal of Economic Dynamics and Control*, 12, 231-254.

Johansen, S. and K. Juselius (1990), "Maximum likelihood estimation and inference on cointegration- with applications to the demand for money", *Oxford Bulletin of Economics and Statistics,* 52, 169-210.

Johnston, J and Dinardo, J. (1997), *Econometrics Methods*, Fourth Edition, McGraw Hill.

Kaldor, N. (1957), "A Model of Economic Growth", *Economic Journal*, 67: 591-624.

Kaldor, N. (1966), *Causes of the Slow Rate of Economic Growth in the UK* , England, First Edition, Cambridge University Press, 1966.

Kwiatkowski, D.; Phillips, P.; Schmidt, P., & Shin, Y. (1992), "Testing the null hypothesis of stationarity against the alternative of a unit root". *Journal of Econometrics,* 54:159-78.

Mackinnon, J. J. (1991), " Critical values for cointegration tests", in *Readings in cointegration* (Ed) R.F. Engle and C.W. Granger, Oxford University Press, Oxford, pp. 267-276.

Skott, Peter (1999), "Growth and Stagnation in a Two-Sector Model: Kaldor's Mattioli Lectures: Review Article", *Cambridge Journal of Economics*,1999, Vol. 23, (3), p. 353-70.

Table A. ADF Test Statistics for the Log of (IND) Industrial Production (with intercept)		
Lags	**ADF Test Statistics**	**Critical Value MacKinnon (5%)**
1	-0.054743	(-2.8959)
2	-0.262379	(-2.8963)
3	0.286682	(-2.8967)
4	0.080584	(-2.8972)
First Difference of log of IND (with intercept)		
Lags	**ADF Test Statistics**	**Critical Value MacKinnon (5%)**
1	-5.364734	(-2.8963)
2	-5.565385	(-2.8967)
3	-4.098304	(-2.8972)
4	-4.240005	(-2.8976)
Note: Figures in parenthesis refer to 95% confidence level critical values taken from Mackinnon (1991). The ADF test statistic is greater than the critical values and we fail to reject the hypothesis of a unit root at levels but we find stationarity in the first difference. IND is I(1).		

Table B. ADF Test Statistics for Log of (GNP) Gross National Product (with intercept)		
Lags	**ADF Test Statistics**	**Critical Value MacKinnon (5%)**
1	0.122174	(-2.8959)
2	-0.154929	(-2.8963)
3	1.237595	(-2.8967)
4	0.188490	(-2.8972)
First Difference of Log of GNP (with intercept)		
Lags	**ADF Test Statistics**	**Critical Value MacKinnon (5%)**
1	-7.278462	(-2.8963)
2	-10.45492	(-2.8967)
3	-3.399779	(-2.8972)
4	-4.003081	(-2.8976)
Note: Figures in parentheses refer to 95% confidence level critical values taken from MacKinnon (1991). The ADF test statistic is greater than the critical values and we fail to reject the hypothesis of a unit root at levels but we find stationarity in the first difference. GNP is I(1).		

Table C. Cointegration Test

Variables included in the cointegration vector: Log IND – Log GNP

Sample: 1980.1 2000.3
Included Observations: 83
Test assumption: No deterministic trend in the data
Series: DLOGIND DLOGGNP
Lags interval: No lags

Hypothesized Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	No. of CE(s)
0.453118	27.11362	19.96	24.60	None **
0.216339	7.800904	9.24	12.97	At most 1

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
L.R. test indicates 1 cointegrating equation(s) at 5% significance level
Unnormalized Cointegrating Coefficients:

DLOGIND	DLOGGNP	C
8.623825	-9.388106	-0.000210
3.216092	-9.021678	0.245110

Normalized Cointegrating Coefficients: 1 Cointegrating Equation(s)

DLOGIND	DLOGGNP	C
1.000000	-1.088624	-2.43E-05
(0.12473)	(0.00709)	

Log likelihood 177.1458

Note: Figures in parentheses refer to critical values taken from Johansen. The likelihood values are greater than the critical values at 5 and 1% for no Cointegrating equations, and the likelihood ratio is less than the critical values at the 5 and 1% level showing at least one cointegrating equation. The eigenvalues are presented in the first column, while the second column (Likelihood Ratio) gives the LR test statistic. The first row in the upper table tests the hypothesis of no cointegration, the second row tests the hypothesis of one cointegrating relation, against the alternative hypothesis of full rank.

Table D. Cointegration Test
Variables included in the cointegration vector: Log GNP - Log IND

Sample: 1980.1 2000.3
Included observations: 83
Test assumption: No deterministic trend in the data
Series: DLOGPIBIND DLOGGNP
Lags interval: 1 to 4

Eigenvalue	Likelihood Ratio	5% Critical Value	1% Critical Value	No. of CE(s)
0.128713	6.420420	12.53	16.31	None
0.087454	2.562469	3.84	6.51	At most 1

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
L.R. test indicates at least 1 cointegration at 5% significance level

Unnormalized Cointegrating Coefficients:

DLOGPIBIND	DLOGGNP
-21.44187	22.78436
-1.229966	5.072564

Normalized Cointegrating Coefficients: 1 Cointegrating Equation(s)

DLOGIND	DLOGGNP
1.000000	-1.062611
(0.08635)	

Log likelihood 170.5433

Note: Figures in parentheses refer to critical values taken from Johansen. The likelihood values are greater than the critical values at 5 and 1% for no Cointegrating equations, and the likelihood ratio is less than the critical values at the 5 and 1% level showing at least one cointegrating equation. We observe at least one cointegrating equation with 5% significance. The eigenvalues are presented in the first column, while the second column (likelihood ratio) gives the LR test statistic. The first row in the upper table tests the hypothesis of no cointegration, the second row tests the hypothesis of one cointegrating relation, against the alternative hypothesis of full rank.

Table E: Granger Causality Test
Error Correction Model (ECM)

$$\Delta \log GNP_t = \alpha_0 + \sum_{s=1}^{k} \alpha_{1s} \Delta \log GNP_{t-s} + \sum_{s=1}^{l} \alpha_{2s} \Delta \log IND_{t-s} + \psi_1 RES1_{t-1} + \varepsilon_{1t}$$

Dependent Variable is DLOGGNP

Sample(adjusted): 1980.1 2000.3

Variable	Coefficient	Std. Error	t-Statistic
C	0.007294	7.01E-18	1.04E+15
DLOGGNP	0.172136	1.22E-16	1.41E+15
DLOGIND	0.610158	8.56E-17	7.13E+15
RESID1	1.000000	3.15E-16	3.17E+15

R-squared	1.000000	Mean dependent var	0.045655
Adjusted R-squared	1.000000	S.D. dependent var	0.034822
S.E. of regression	2.22E-17	Sum squared resid	1.43E-32
F-statistic	2.62	Durbin-Watson stat	2.104264
P-Value	[0.027]*		

Note: Granger (1986) and Engle y Granger (1987) mention that if we see one cointegrating equation, causality must run in at least one direction. If individual coefficient elements are close to zero, this would imply the absence of particular cointegrating relationships in particular equations of the ECM. It also has implications of weak exogeneity of the variables with respect to the parameter of interest.
The null hypothesis of no-causality from the growth of the industrial sector to the growth of GNP is also rejected through error-correction term at a 1% and 5% level. Thus, there appears to be bidirectional causality between real GNP and industrial output. P-values for the Granger F test are in [ ] and * denotes a 95% confidence level.

Table F. Granger Causality Test
Error Correction Model (ECM)

$$\Delta \log IND_t = \beta_0 + \sum_{s=1}^{m} \beta_{1s} \Delta \log IND_{t-s} + \sum_{s=1}^{n} \beta_{2s} \Delta \log GNP_{t-s} + \psi_2 RES2_{t-1} + \varepsilon_{2t}$$

Dependent Variable is DLOGIND

Sample(adjusted): 1980.1 2000.3

Variable	Coefficient	Std. Error	t-Statistic
C	-0.008101	1.98E-17	-4.08E+14
DLOGIND	-0.058793	2.58E-16	-2.28E+14
DLOGGNP	1.328934	3.58E-16	3.71E+15
RESID2	1.000000	5.99E-16	1.67E+15

R-squared	1.000000	Mean dependent var	0.049721
Adjusted R-squared	1.000000	S.D. dependent var	0.049792
S.E. of regression	6.43E-17	Sum squared resid	1.16E-31
F-statistic	6.19	Durbin-Watson stat	1.58174
P-Value	[0.021]*		

Note: Granger (1986) and Engle y Granger (1987) mention that if we see one cointegrating equation, causality must run in at least one direction. If individual coefficient elements are close to zero, this would imply the absence of particular cointegrating relationships in particular equations of the ECM. It also has implications of weak exogeneity of the variables with respect to the parameter of interest.
The null hypothesis of no-causality from the growth of GNP to the growth is also rejected through error-correction term at a 1% and 5% level. Thus, there appears to be bidirectional causality between real GNP and the growth of industrial output. P-values for the Granger F Test are in [ ] and * denotes a 95% confidence level.

Appendix A. The Kwiatkowski, Phillips, Schmidt and Shin (1992) Procedure

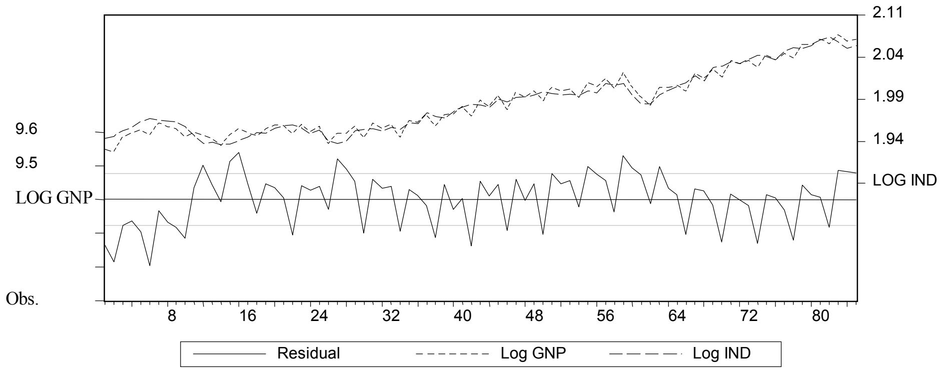
The procedure is to test the null hypothesis that an observable series is stationary around a deterministic trend. The test for level stationarity is based on the statistic $\hat{\eta}_{\mu} = T^{-2} \frac{\sum_{t=1}^{T} S_t^2}{s^2(l)}$, where $S_t = \sum_{i=1}^{t} e_i$, $t=1,2,\ldots T$ is the partial process of the residuals from the regression $y_t = \bar{y} + e_t$; $s^2(l) = T^{-1}\sum_{t=1}^{T} e_t^2 + 2T^{-1}\sum_{s=1}^{l} w(s,l) \sum_{t=s+1}^{T} e_t e_{t-s}$ is a consistent estimator of the error variance; $w(s,l) = 1 - s/(l+1)$ is a weighting function which guarantees the nonnegativity of $s^2(l)$; and l is the lag truncation parameter. The larger the truncation lag, the larger must be the sample size in order for the asymptotic results to be relevant and, unfortunately, the values of the test statistic decreases as the lag truncation increases. An adequate truncation lag can be obtained by using the integer of the value $\left(T/100\right)^{0.25}$, where T is the number of observations. A sample of 83 observations gives a truncation lag of 0.95 or 1. The critical values at 5 and 10 percent levels are 0.463 and 0.347, respectively. In our case, the null hypothesis of stationarity in the series levels is rejected at the 5 percent level, results that are consistent with those previously obtained.

TABLE G. The Kwiatkowski, Phillips, Schmidt and Shin (1992) Stationarity Test

$\hat{\eta}_{\mu} = T^{-2} \frac{\sum_{t=1}^{T} S_t^2}{s^2(l)}$	
l = 0	2.08
l = 1	1.11
l = 2	0.46
l = 4	0.36
l = 8	0.14
η_{μ} critical values	0.463 (5%)
	0.347 (10%)

Upper tail critical values, level stationarity test.

Graph A. Level Series for LOG GNP and LOG IND



Graph B and C. Difference Series for D Log GNP and D Log IND