



An Investigation of Technical Progress and Output Growth in Nigeria's Manufacturing Sector: Theory and Empirics

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Abstract

The paper seeks to examine the impact of technical progress on output growth in Nigeria's manufacturing sector for the last four decades (1985-2015). This paper uses the Cobb-Douglas production function and econometric analysis to shed more light on the impact of technical progress on the manufacturing output growth in Nigeria. The method of data analysis was the simple least square regression technique applied on time series data obtained from the Annual Statistical Abstract and Industrial Surveys of the Nigerian Bureau of Statistics (NBS) for the period under consideration. The paper reveals that the contribution of technical progress to output growth in the manufacturing sector is low. The weak performance confirms the existence of weak technological base which is largely responsible for the stunted growth of manufacturing output in the country. The paper recommends that government and policymakers should focus on practical science and technology development as well as encouraging research and development (R&D) at the enterprise level so as to boost manufacturing output and expand the production possibility frontier of Nigeria, amongst other recommendations.

Keywords: *Technical Progress, Output Growth, Impact, Manufacturing, Productivity*

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Background to the Study

In the face of the recent global economic crisis that ravaged humankind in both developed and developing countries, governments across the world are more interested today than ever before in the growth and development of their economies. Technical break-through is a major cause of rapid growth of aggregate output and output per capita in Western Europe, which later spread to other countries that are today advanced (Elueni, 2000). Rational thinking indicates that growth in output may originate from two sources. These are the increase in output that results from increase in factor inputs and those that result from increase in output per unit of factor input. The source of growth which causes increase in output but which is not a result of increase in factor input is known as technical progress (Katz, 1969). It means that the sign and magnitude of technical progress are measurable. As a result, there has been a tremendous shift of interest to the qualitative measures of the factors that causes economic growth from the quantitative factors that are capable of stimulating growth.

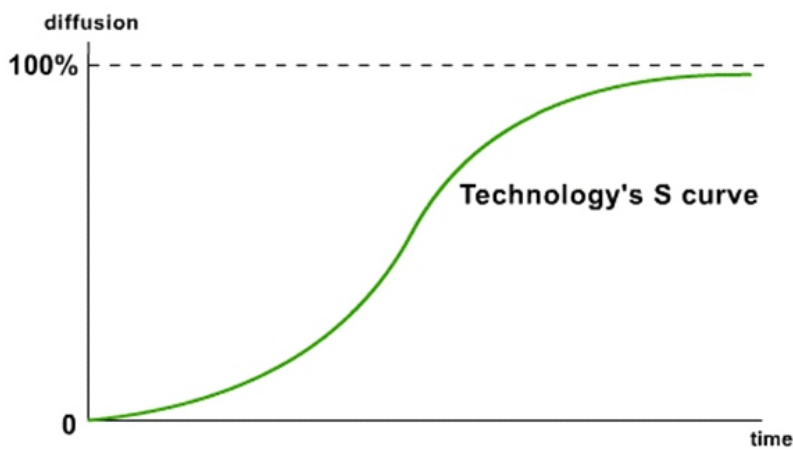
In view of the above, technical progress could impact on growth that ensures the viability of an economy, which is derived from aggregate production function. Since the production function is a technological relationship between input and output, it could be seen as closely related to technical progress. Technical progress is therefore viewed as the growth momentum that results from the application of factor input (qualitative and quantitative) in an economy. For a developing country like Nigeria, technical progress would likely tend to show a low coefficient – an indication of weak technological change. The problem that provokes this study arises from the low level of growth and development, high marginal propensity to import, and high external debt burden. These predicaments presuppose that technical progress is critical to Nigeria's development efforts. The major sectors that easily attract change and improvement in technology in an economy are; manufacturing, agriculture, mining and quarrying (including petroleum industry). Unfortunately, Nigeria has witnessed a declining performance in the manufacturing sector since the mid 1980s.

Most of the studies conducted to examine the growth performance of many developing countries were based on the traditional neoclassical growth frameworks. This paper takes an alternative path of the Cobb-Douglas production function and econometric analysis to shed more light on the impact of technical progress on output growth in Nigeria's manufacturing sector. This study seeks to examine the quality of factor input and technical progress in terms of impact on growth of manufacturing output in Nigeria in the last four decades (1985-2015). The paper is structured into six sections. Section one is the introduction. Section two expounds the literature review. Section three gives the theoretical framework of the paper. Section four devotes to methodology and modelling. While section five commits to data analysis and discussion of findings, section six concludes with policy recommendations.

Conceptual Clarifications

In illustrational way, technical or technological progress is a gradual process consisting of a sequence of small increments lying along a continuous path as demonstrated in figure 1:

Figure 1: Technological Progress Curve



For examples, a generator and electric lights were demonstrated in 1876. Until six years later, Thomas Edison opened the first commercial generator to power electric lights in the Wall Street district of New York. Only in the 1930s, 60 years later, the Rural Electrification Act provided the financing to bring electric power to most rural areas of the United States. It seems that the new idea spreads slowly initially, then it begins to be applied more often, gradually attaining widespread acceptance and adoption; and finally it reaches 100% diffusion as the last potential users are won over. While the growth path of technology is continuous, it does not generally exhibit a constant slope or growth rate; technology can grow rapidly, stagnate, or even decline. The path may take sudden sharp turns.

The paper sees technical progress as new and better ways of doing things, and new techniques for using scarce resources more productively. It means an improved technology that yields greater output from the same quantity of resources through process innovation and product innovation. Therefore, technology is a complex set of knowledge, ideas and methods as a result of variety of different activities that improve productivity and output growth. Output growth is an increase in the capacity of an economy to produce goods and services, compared from one period of time to another. It represents economic growth (GDP growth) in an economy. The manufacturing sector is part of the goods-producing industries super-sector group. The Manufacturing sector comprises establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products.

Literature and Empirical Review

A number of studies have been carried out on the role of technical progress in economic growth of countries. One of the earliest was Solow (1952) who studied technical progress and growth in the United States of America (USA) for the period (1909-1949). Solow's finding reveals that about 87.8% of the growth resulted from technical progress, and only 12.2% was attributable to increase in capital per head. The high impact of technical progress on growth during the period was because of the high level of investments in new machines and other technical requirements.

Denison (1967) estimates the impact of technical progress on economic growth in USA by deriving his model from the production function similar to the Solow framework. Denison however, employed a more systematic approach by breaking up Solow's technical progress residual into its two component parts considered as the engines of growth. These are; technical progress and contribution of growth made possible by advancement in science and technology. Denison used the marginal productivity theory and Cobb-Douglas production function to estimate the impact of technical progress on growth in the USA, and the result shows that out of the growth rate of 2.29%, about 1.18% (about 51%) was attributable to technical progress. The disparity between Denison's findings and Solow's result was due to differences in method of estimation employed. Katz (1969) produces evidence from fourteen Argentinean industries, where 8% to 9% of the total change in productivity was a result of technological change. Odoma and Kazi (1982) conduct a similar study in Nigeria using data from 19 industries for the period (1962-1975) and found that technical progress contributed about 2.46% to the growth of output per annum. However, of the 19 industries considered, 11 indicated that they contributed positively from the point of view of industry to industry, which are regarded as relatively efficient and profitable for new investments in the economy.

Bradford and Summers (undated) found a strong statistical correlation between investment in productive equipment and the countries' rate of economic growth. Their statistical analysis found that equipment investment causes economic growth. New ideas and technologies are in some ways linked to the specific equipment, buildings, and tools used in production. Some statistical studies suggest that the effect of equipment investment on economic growth is stronger than development investment on economic growth in developing economies in the early stages of industrialization than it is in the more developed economies. New technologies often seemed to be embodied in new machines, and the introduction of a new technology usually coincided with the introduction of new machines or equipment. It implies that without an investment in education and training, much new technology would not be used.

Application of related production functions to actual growth experience involves the determination of the corresponding technology parameters by fitting the functions to empirical time-series data of value added, capital, labour, and energy by non-linear OLS, subject to the constraints of non-negative elasticities of production (Dietmar, 2003). A number of such studies have been carried out for various sectors of the US, the Japanese, and the German economy (Ayres, 2001; Ayres and Warr, 2003; Beaudreau; 1998; Kümmel et al., 1992, 1985, 2000, 2002; Lindenberger, 2000; Lindenberger et al. 2001). Their findings can be summarized as follows: Observed economic growth is reproduced with minor residuals. Even at constant technology parameters over periods of one-and-a-half decades, including the recessions after the oil crises in the 1970s, value-added is reproduced as well. Thus, by taking into account the indispensable production factor energy appropriately besides capital and labour, the activation of the increasingly automated capital stock can be modelled endogenously, and the Solow residual is mostly resolved.

Theoretical Framework

Proponents or protagonists of microeconomic and research fertility theory such as Romer (1989), Grossman and Helpman (1991), Hilten (1991), and Vladimir (2014) would posit that a firm is a unit of production, and the production function of a firm defines the combination of inputs usually of capital (K), Land (Z) and Labour (L) that produce a unit of output (Q). Since land is assumed to be traditionally given, the production function is reduced to the combination of capital and labour only. This production function is assumed to be continuous, homogeneous of degree one and twice differentiable as follows:

$$Q = f(K,L) \quad \dots (1)$$

If this relationship is true for all firms, then it should be possible to aggregate this relationship for all firms, and all industries with a view to determining an aggregate production function for the whole economy. Consequently, Kazuo (1975) opines that all micro production functions are identical to macro production functions with parametric values, which differs in scale. Hence, equation (1) can represent the aggregate output (Q) as a function of aggregate capital stock (K) and total labour force (L) employed in an economy.

A positive shift in the production possibility curve of a country may be due to increases in the use of either capital or labour or both. However, a shift in the production possibility curve may occur, which is not induced by increase in factor input. Such a shift is explained by the effect of technical progress. Along the production possibility curve, the relationship between factors define the marginal rate of substitution. The slope of the production possibility curve also defines the marginal rate of substitution between the factors. The capital-labour ratio is given as a change in any of the factors that affects the slope of the production possibility frontier. If the marginal rate of substitution defined by the ratio of marginal rate of capital to the marginal rate of labour increases, the resulting technical change is labour saving. If unchanged technical progress is Hicks-neutral. If however, it decreases, the technical progress is regarded as capital saving. The neutrality of technical progress as given above gives the indication of the nature of elasticity of substitution of factors of production.

In the industrialised countries the cost shares of the production factors are typically 0.7 for labour, 0.25 for capital, and 0.05 for energy (Dietmar, 2003). By using these cost shares as technological factor-input weights, i.e. as values for the elasticities of production, neither the recessions during the energy crises in the 1970s, nor long-term economic growth can be explained. Dietmar posits that large residuals, interpreted as the effects of 'technical progress', remain. This has led to a criticism of the neoclassical model as being a theory of growth that leaves the main factor in economic growth unexplained (Solow, 1994). One response to the 'Solow residual' was the emergence of new growth theories initiated by Romer (1986). While the new theories have enriched the perspectives on growth in many ways, e.g. by introducing endogenous innovation, imperfect competition, or the accumulation of human capital, their shortcomings include the problem of 'growth on the knife's edge', e.g., tiny deviations from the constant-returns-to-capital assumption result

in either a loss of permanent growth or infinite growth in finite time (Solow 1994), and the almost entire abstraction from the physical sphere of production. This Letter reviews a complementary approach to production and growth theory, which reproduces empirical growth with small residuals while keeping the conventional diminishing-returns-to-capital assumption: it takes into account the production factors capital, labour, and energy, and technology parameters whose time-changes model innovation and technological change.

Protagonists or proponents of technical progress such as Sthiti (2015) would opine that technical progress contributes to economic development through intensive utilisation of resources, efficient use of potential resources, increase in the efficiency of human resources, availability of foreign capital, etc, that can translate into capital formation, change in social and economic structure, agricultural development, industrialisation, export promotion and import substitution.

Research fertility theory argues that if research is very fertile, it means R&D spending leads to many new products. Firms will have more incentives to do R&D, and R&D and technological progress will be higher. If firms cannot fully capture the profits from the development of new products, they will not engage in R&D and technological progress will be slow. If it is widely believed that the discovery of a new product will lead to a subsequent quicker pace in the discovery of other better products, there may be little payoff to bring first. Thus, a highly fertile field of research may not generate high levels of R&D. Technology is partially non-rival in nature. If one person uses an idea or method, that does not prevent another from using it. Thus the marginal cost of using a particular form of technology is zero, meaning that competitive market forces will tend to drive the price of existing technology toward zero. Creativity and innovation will tend to be very low if non-rival ideas are freely used by anyone. Therefore, the creators of the new ideas get no reward from their creative efforts. That is why new ideas may be excludable by patent laws which seek to give the creator of an idea to use the product or process exclusively for a specified number of years. For example, the Coca-Cola Company has kept its formula secret for over 100 years; its idea is protected by the complexity of a formula that no one has been able to reproduce exactly.

Some growth economists describe technology as path-dependent. The ability to create new technologies depends on the level of technology already accumulated. It means that previous technologies are often difficult to abandon. Often, technology is not excludable. If old knowledge is not available, then others cannot create new knowledge. Thus, patent laws set limits on the length of time that a patent remains in effect. No wonder, the formal recognition of intellectual property rights is likely to facilitate the spread of technology. But, patents and copyrights permit the owners of intellectual property to sell and rent their rights to others. Economically, as long as the price for the use of the idea exceeds the possible loss of monopoly profit, the owner of the idea should be willing to let others use the idea. Yet, if a certain idea can be productively used elsewhere in the economy, others should be willing to pay for the right to use the idea.

Philippe and Howitt (1997), Grossman and Helpman (1994), and Romer (1990) are those who have developed models of endogenous growth based on the assumption that R&D activities are carried out by profit – seeking entrepreneurs. R&D is regarded as a costly activity that is carried out with the intent to produce new products and earn temporary profits. Since the cost of R&D activities must be covered, the assumption of imperfect competition is introduced. The greater the potential profit earned by the monopolistic producer, the greater will be the amount of innovative activity. From the above theories, technical progress is not an independent process, completely separate from investment in equipment, structures, and human capital. It means that for output growth to continue to expand, we have to continuously learn to create new methods, tools, and ideas at a more rapid pace.

Modelling of Output Growth

From the equation (1) in the theoretical framework, it is usual to assume that the function is homogeneous of degree one which implies that the units of labour and capital are divisible into infinitely small units and are continuously substitutable for each other. The first derivative of the function given the marginal productivity of capital ($MRS_K = dQ/dK$) and of labour ($MRS_L = dQ/dL$). It is further assumed that the production function exhibits constant returns to scale.

This means that, if both inputs are simultaneously increased by a certain proportion, output will increase by the same proportion. It implies that if both inputs are simultaneously increased by a certain proportion, output will increase by the same proportion. This agrees with Euler's theorem which states that output produced is shared between the factors weighted by their respective factor productivity as demonstrated in the following equation:

$$Q = dQK/dK + dQL/dL \quad \dots (2)$$

Where; dQK/dK is the total payment to capital, while dQL/dL is the total payment to labour. It therefore means that total payments to the two factors just exhaust the product. With the assumption of constant return to scale, the production function in per capital terms can be specified as:

$$dQ/dK = f(K,1)L \quad \dots (3)$$

The differentiated equation (3) gives:

$$q = f(k) \quad \dots (4)$$

Equation (4) implies that output per man will increase as capital per man increases, in the absence of technical progress. Technical progress can be present in equation (4) with regard to the two assumptions that technical progress is either embodied or disembodied, and the rate of the technical progress is exogenously determined and hence it can be influenced by any other economic variable. It is disembodied if such a change affects both old and new machines given the assumption that machines or capital are homogeneous and equally efficient. A technical change is embodied if it affects only the new capital investments as observed by Norris and Vaizey (1973), and Elueni (2000).

A shift in the production function can thus be explained partly by the technical change which occurred in time (t). The precise form of the vertical shift in the production possibility curve depends on the nature of the technical progress – whether it is neutral or not. Therefore, equation (1) can be represented with slight modification to take account of technical progress as:

$$Q = A(t)f(K,L) \quad \dots (5)$$

Where; A(t) is a shift factor to account for technical progress. It is assumed to be disembodied and neutral in the sense that it does not alter the marginal rate of substitution between capital and labour. By differentiating equation (5) with respect to time (t) and dividing through by Q, it is transformed to:

$$dQ/dt = dA.f(K,L)/dt + Adf.dK/dK.dt + Adf.d/dL.dt \quad \dots (6)$$

$$dQ/dt/Q = dA/dt/A + Adf.dKK/dK.dtKQ + AdtdLL/dLdtQ \quad \dots (7)$$

But: $dfK/dtKQ$ represents the capital share of the total output denoted by SK
 $dfL/dtLQ$ represents the labour share of the total output denoted by SL

Hence the equation may be represented as:

$$q/Q = a/A + SK.k/K + SL.L/L \quad \dots (8)$$

Equation (7) states that the rate of growth of output is equal to the rate of technical progress a/A plus the rate of increase of each inputs weighted by its share in the national income. This conclusion can be obtained through the assumption of constant returns to scale. In this case, factor shares must sum to unity, such that:

$$SL + SK = 1 \text{ or } SL = 1 - SK \quad \dots (9)$$

Let y denote Q/L ; and k denotes K/L ;

Therefore, $dy/dt/dy = dQ/dt/Q - dL/dt/L$

Similarly, residual output can be expressed as:

$$y/Y = a/A + SKk/K \quad \dots (10)$$

From equation (9), technical progress is a residual, being the rate of output per head less the rate of growth of the capital stock per man weighted by the proportionate share of profit in the national income. The same model can be obtained using the marginal productivity theory of distribution and the Cobb-Douglas production function as used by (Solow, 1952) stated as:

$$Q = AL_1\mu K^{1-\mu} \quad \dots (11)$$

This could be re-written as:

$$Q = \mu A L_1 \mu^{-1} K^{1-\mu} \quad \dots (12)$$

If we assume a perfectly competitive factor market, then the total payment to labour will be the marginal product of labour multiplied by the number of workers employed as follows:

$$LdQ/dL = L_1 \mu A L_1 \mu^{-1} K^{1-\mu} \quad \dots (13)$$

$$LdQ/dL = \mu A L_1 \mu K^{1-\mu} \quad \dots (14)$$

$$LdQ/dL = \mu Q \quad \dots (15)$$

This could be interpreted that the share of labour to the national income (Q) is μ and the share of capital to the national income (Q) is $1-\mu$.

Choice of the Structural Model for Estimation

The paper tracks the estimation model from the work of Elueni (2000), and in this case, equation (8) or (11) can be used as the structural equation to estimate the impact of technical progress on output growth of the manufacturing sector in Nigeria. For ease of analysis, equation (8) was adopted in this paper and econometrically re-specified as:

$$q/Q = a/A + SK.k/K + SL.L/L + e \quad \dots (16)$$

Where; e is the stochastic term (disturbance term)

Let: a/A is α = alpha, $SK = \beta_1$, $SL = \beta_2$

$$\text{Therefore, } q/Q_t = \alpha + \beta_1 k/K_t + \beta_2 L/L_t + e \quad \dots (17)$$

Where, t = time trend

Methods of Data Analysis

Time series data was obtained from the Annual Statistical Abstract and Industrial Surveys of the Nigerian Bureau of Statistics (NBS) for the period under consideration. The method of data analysis was the simple least square regression technique. The scope of the paper covers the manufacturing sector where substantial impact of technical progress is assumed to occur as data availability on the sector was reliable. It implies that the existence of an accounting identity in a fairly structured formation has made manufacturing data more reliable. Other sectors of the economy were not considered due to paucity of reliable data and this was a limitation of the study. It means that the paper assumes that the input-output relationship of the manufacturing sector is a proxy for the aggregate production function of the economy. This is so because, with the exception of the petroleum sector whose information is distorted and often guided as national security, other sectors of the economy are hardly industrialised. For example, the agricultural sector which is the largest employer of labour is still depended on peasant farming where crude implements and tools are used without sufficient records of actual output. The paper notes that it is only the manufacturing sector that could provide data for the study based on its relative structural modernity and dependence on technology.

Result and Discussion

The structural econometric model (equation 17) was regressed using ordinary least square (OLS) as the analytical technique and the following result was obtained:

$$q/Q_t = 0.08431 + 0.1286k/K_t + 0.4885L/L_t$$
$$(0.1648)^* (0.3479)^{**} (0.1750)^{**}$$
$$R^2 = 0.82, \bar{R}^2 = 0.68, F = 6.15, DW = 1.87$$

The figures in parenthesis are the standard errors while the single asterisk indicates significance at 10% confidence level. Double asterisks imply a level of significance at 5% confidence level. The result shows that about 82% of the changes in manufacturing output in Nigeria are explained by the explanatory variables. This is indicated by coefficient of determination (0.82). The adjusted r-squared ($\bar{R}^2 = 0.68$) is also satisfactory in terms of the explanatory power of the input-output synthesis. The F-statistic test shows that the model is statistically different from zero at 5% level of significance. Overall, the coefficients or parameters of estimation have the expected positive signs at 5% level of significance.

The estimated parameters represent the rate of change in total output that is attributable to changes in technical progress while the coefficients of k/K and L/L represent the change in output attributable to capital and labour respectively. From the result, the value of $\alpha = 0.08$ means that the technical progress that occurred during the review period was 8%. The rate of change in manufacturing output is given by the addition of estimated coefficient values ($0.08 + 0.12 + 0.49 = 0.69$). It implies that between 1985 and 2015, about 69% of output growth achieved in the manufacturing sector was comprised 0.08 due to technical progress, while 0.12 and 0.49 were due to capital and labour respectively. It is clear that the relatively higher contribution to output growth was by labour input. This is not surprising since the Nigerian economy is basically agrarian and rural, characterised by poor technological base or know-how, where a significant amount of operations or economic activities are manually done. With the increase in educational turnover of graduates in Nigeria, labour is in high supply than its demand as population growth rate increases, and without commensurate increase in technology.

The level of contribution of labour was followed by capital with little or no addition to stock of capital during the period. A 0.12 or 12% level of contribution of capital to total manufacturing output during the period would imply that most existing capital investments and machines have either become obsolete or are highly expensive to maintain. This is an indication that a low level of technological advancement is prevalent in the country. The result presents a positive correlation between output growth of the manufacturing sector and the proportionate share of capital and labour. The high share of labour to output growth relative to capital could be attributed to the impact of education on technical progress. However, the impact of technical progress (0.08 or 8% for a period of four decades) on output in the manufacturing sector is insignificant. This requires strategic policies that will stimulate technical progress to contribute to GDP in the country.

Conclusion

The paper focuses on the contribution of technical progress to the growth of manufacturing output in Nigeria. This is to put the economy on the pedestal of growth and development while acknowledging the role and synthesis of technical progress, capital requirement and labour input. The analysis has shown that the contribution of technical progress to output growth in the manufacturing sector is low. The weak performance confirms the existence of weak technological base which is largely responsible for the stunted growth of manufacturing output in the country. The policy implication is that deliberate attention through concrete policy intervention in the Nigeria's manufacturing sector has become most desirable.

Recommendations

In order to promote output growth and productivity in the manufacturing industry through improved technical know-how, the paper recommends that government and policymakers are advised to focus on practical science and technology development as well as research and development (R&D) at the enterprise level so as to boost manufacturing output and expand the production possibility frontier of Nigeria. This will curtail the overdependence on imported goods by enhancing domestic production. It should be noted that (R&D) spending decisions made by firms is a major cause of technological progress in the manufacturing process. With the increase of R&D spending, it is more likely for a firm to discover and develop a new product. If the new product is successful, the firm's future profits will increase. If the expected present value of profits exceeds the expected cost of research, the firm will start on a new R&D project. Again, the agricultural sector should be given the top most precedence in order to supply raw materials to the manufacturing sector. Processing of raw farm products through value addition should be made a policy priority to enable the country benefit from agricultural value chains. This will have a positive implication on Nigeria's foreign exchange earnings, external reserves, economic diversification, and the growth of domestic output, employment creation and national income.

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Appendix

Regression Results

Dependent Variable: (q/Q)

Method: Least Squares

Date: 16/06/16 Time: 10:34

Sample(adjusted): 1985 2015

Included observations: 40 after adjusting endpoints

Variable	Coefficien t	Std. Error	t-Statistic	Prob.
(k/K)	0.128621	0.347912	-0.876733	0.3954
(L/L)	0.488534	0.175073	-1.094026	0.2924
TREND	57836.75	19128.98	3.023514	0.0091
C	0.084314	0.164841	-2.406397	0.0305
R-squared	0.821364	Mean dependent var	-494993.6	
Adjusted R-squared	0.682496	S.D. dependent var	2958238.	
S.E. of regression	311723.7	Akaike info criterion	28.35856	
Sum squared resid	1.36E+12	Schwarz criterion	28.60709	
Log likelihood	-264.4063	F-statistic	6.147652	
Durbin-Watson stat	1.86881	Prob(F-statistic)	0.000000	