Testing the Structural Empirical Dynamics of the Economic Growth Path of Egypt, 1950-1997

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28 October 1999

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SUMMARY

The objective of this research is to model and test aggregate production functions on the Egyptian economy and to analyze the effect of physical and human capital formation on the economic growth path of Egypt, using a vector-autoregressive (VAR) structural econometric approach. Economic data from 1950 to 1997 have been tested for unit roots, orders of integration, auto-regressive distributed lags, growth causation, weak & strong exogeneity, and co-integration, using a general to specific modeling technique. An error correction model utilizing all growth causation factors was estimated and tested using a model typology of simple dynamic systems. Factor inputs (physical capital, labor, human capital, and technological progress) and structural macroeconomic factors (inflation shifts and exchange rate adjustments) have been analyzed within a dynamic distributed lag system (ADL). Three inter-dependent models resulted in a nested VAR system describing the economy's balanced growth path: a *conditional* ADL model for long-run growth, a short-run *co-integration* model describing marginal rates of substitution, and a *marginal* model describing learning by doing effects in technology. The dynamics of the nested system show that the economy behaves with a relatively constant marginal rate of substitution between factor inputs and with production isoquants correlated with inflation, but these behavioral conditions are neither necessary nor sufficient for balanced sustainable growth. The solved long-run solution shows decreasing returns to scale in production, with quasiconcave output with respect to physical capital accumulation and strict concavity of output with respect to human capital formation, significant but weak learning-by-doing effects, positive output returns for primary-school educational attainment and expenditures, and negative returns for post-primary educational attainment, and the aggregate savings rate shown to follow a random walk process with no drift. Human capital was found to be a weakly exogenous factor to short-run output while maintaining a causal effect to long-run income. The allocative efficiency of physical capital accumulation along with marginal learning-by-doing effects in technology were shown to be the two significant driving forces to the growth of real income. Speeds of adjustments towards equilibrium levels show relatively high speeds of adjustment for physical capital with human capital shown to cyclically diverge from its equilibrium path. Among the different policy recommendations discussed, one policy target proposed has been to foster local competitiveness for capital-intensive technological innovations which can shift the economy’s resource capacity constraint onto a higher welfare-enhancing production-possibilities frontier, for a more sustainable growth path for the economy.

Paper Submitted for the Sixth Annual Economic Research Forum and World Bank Global Development Conference– MENA Region on October 28-31, 1999 in Cairo, Egypt. My thanks to Dr. Heba Handoussa, Dr. Adel Bishai, Dr. Hana Al-Sagban, Dr. Ismail Serageldin, Dr. Ahmed Galal, Dr. Hamed Mohtadi, Dr. Khaled Sakr, Dr. Fred Joutz, Dr. Steven Smith, Dr. Xiang Lee, Dr. Samiha Fawzi, Dr. Heba El-Laithy, Dr. Mahmoud El-Gamal, and Dr. Alexei Kireyev for suggestions, comments and helpful criticisms.

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ABSTRACT

This work has been an original research with the objective of empirically testing a dynamic structural system describing the Egyptian economy's growth behavior spanning its past half-century of economic performance. Three inter-dependent models have been derived: an auto-regressive distributed lag model as a *conditional* model for long-run growth, a *co-integration* model with constant rate of marginal substitution between factor inputs, and a *marginal* learning-by-doing model for residual technological progress. These models have been integrated within a *nested vector-auto-regressive (VAR) system* to arrive at short-run and long-run causation factors affecting growth including physical and human capital accumulation in addition to relevant fiscal and monetary variables. The long-run error correction solution to the simultaneous *VAR* system provides sharp behavioral conclusions affecting the main aggregate variables, a long-run factor-input production function for the economy, equilibrium convergence, and suggests policy recommendations which can shift the economy's dynamics onto a higher growth path.

I. INTRODUCTION AND SCOPE OF ANALYSIS

The main objective of this research is to model and test the economic growth path of Egypt for its past half-century of economic performance (1950 to 1997) and to analyze the effects of physical and human capital formation on the economy's production process. First, an integrated autoregressive framework is set as a baseline model in describing the productive inputs of the economy with relevant fiscal and monetary variables, followed by a co-integrated error-correction model to account for marginal substitution between factor inputs. Then, a dynamic learning-by-doing model is analyzed to account for output fluctuations with respect to endogenous technological change. These three models are then encompassed into a *nested VAR system* to arrive at the behavioral balanced growth path of the economy. Testing different production technologies and interpreting growth-causation factors on long-run income using a general to specific modeling technique is the main approach undertaken in this paper. The approach is not Neoclassical in its essence but rather *structural* with a Neoclassical face: *a structured endogenous growth model with learning-by-doing effects is set within the framework of a vector-autoregressive co-integrated system*. This approach has two main advantages. First, it captures the true long-run behavior of the economy with its dynamic effects without ignoring short-run volatility of main economic variables (such as inflation shifts and exchange rate adjustments). Second, given the long-run behavior and short-run fluctuations of the economy, the estimated system does not take as given the standard Neoclassical assumptions of complete and perfect markets, perfect information, full employment, flexible prices and wages, and that factor inputs are paid their marginal products. Rather, it relaxes these assumptions and imposes structural counterparts for them based on the results of the relevant econometric model under study. With this approach in mind, the structure of the economy is assumed to be that of an aggregate production function with four main inputs: labor, physical capital, human capital, and technological progress with learning-by-doing effects. A structural system is the engine behind the growth of this research, and it is therefore imperative to introduce the reader to the *unrestricted reduced form* of an economic structural system as a form of introduction to the more advanced models further analyzed in this paper. But before doing that, the reader is first introduced to a short non-mathematical survey of Neoclassical growth models.

I.1: A Short Survey on Growth Models

Origins of economic growth literature which predict sustainability within a Neoclassical setting all stem out of Robert Solow's 1956 'technical progress' model which assumes an aggregate production function for the economy with an exogenous savings rate [64,65]. A cornerstone for long-run growth models in general, Solow's model predicts that an increase in the aggregate savings rate will not affect real economic growth in the long-run, with income per labor having a short-run shifting response to an increase in the savings rate with convergence back to its old steady growth path. Technological progress was seen as the main driving force behind long-run growth, and this was proven analytically using a rather abstract growth accounting technique. The extended Solow-Swan model incorporates break-even investments as a function of population growth, rate of technical progress, and the rate of capital depreciation. It also has similar implications: countries are found to have different growth rates because they incorporate different production technologies. But since technology is assumed to be a public good with perfect international mobility, it was concluded that there has to be a convergence in growth rates between different nations as technology and capital crosses national boundaries. Convergence and equilibrium stability were proven analytically, but were criticized by their inapplicability to real economic data spanning a cross-section of countries. An extension of the Solow model to incorporate human capital [10,48,51,59,66] and knowledge production and acquisition [58,60] into the economy's growth path succeeded to narrow the gap in the convergence controversy and made a positive move in explaining movements of international capital flows across nations and in introducing quality of human labor (i.e. human capital) into the Neoclassical literature. Learning-by-doing effects on output were then introduced as a variant of human capital models with endogenous technologies, the latter pioneered by Becker [10] and Lucas [48]. On the empirical side, the Lucas model was empirically tested using cross-country data and the historical facts turned out to fit the model's theoretical results rather closely. Specifically, Mankiw, Romer and Weil [51] provide an empirical estimate of growth rates with human capital as an important added variable to the classical Solow model, and their research finding prove that the human capital model provides a much better description of cross-country empirical data in comparison to the Solow model, given certain restrictions on capital depreciation.

Behind the Solow model and its extensions, infinite horizon and overlapping generations models took the evolution of the capital stock as an endogenous phenomenon arising from the utility-maximizing behavior of individuals. In the Ramsey-Cass-Koopmans models [56,16,47], the economy is assumed to be composed of a large number of identical households who are infinitely-lived and whose utility is heavily dependent on consumption. The dynamics of the economy takes two steady paths for stability: one for consumption (the Euler equation), and one for the capital stock (the State equation), with long-run equilibrium assumed to occur when both steady paths are binding and with transversality conditions imposed. In the short-run, the economy moves along a saddle path that converges towards the long-run equilibrium only for certain behavioral zones in consumption-capital space. However, the central drive for growth is still the same as that of the Solow model: only technological progress will shift the economy's dynamics unto a higher welfare path. Therefore it seems that the central predictions of the Solow model were not based on its assumption of an exogenous savings rate. Even if individuals choose their own savings behavior, the growth of the economy is only dependent on the rate of technological progress. Another approach to growth theory which assumes finitely-lived individuals with overlapping generations is attributed to Peter Diamond [21]. The Diamond model assumes a more realistic assumption of turnover in population, with new individuals continually being born and others dying. Working with discrete time and assuming a constant discount rate for consumption, the model predicts that the saving rate is extremely sensitive to the degree of relative risk aversion of individuals and that the evolution of the capital stock behaves accordingly. Although the welfare implications of the Diamond model involve the possibility of dynamic inefficiencies, never-the-less its implications and central results are quite similar to the Solow and Ramsey models.

In response to the widening scope of added variables into growth models and the unwavering interest in the field (especially in the articles of the Journal of Monetary Economics), several ideas and extensions have been introduced into the literature. 'Idea gaps and object gaps' and their contribution to growth have been pioneered by Paul Romer [60] while others, like Stanley Fischer [32] and Harris Dellas [19], made major contributions to the role of macroeconomic stabilization factors in growth and the incorporation of shifting (usually fiscal) and adjustment (usually monetary) factors in a growth model framework [32,33,34,35]. The Fischer-style models incorporated key macroeconomic indicators into growth in addition to the main factor inputs assumed before. Exchange rate stabilization, current account balance, and inflation shifts were introduced and empirically tested with sound results. Inflation modeling and its implications to short-run fluctuations of real stock balances, along with the need to address uncertainty and dynamic autoregressive shocks in real-business-cycle economies, all made certain the foundations of stochastic growth models in the economic growth literature. Several analytical models have been suggested [in 7,8,9,52] but all culminated in a Campbell [15] solution to the stochastic real business cycle model, an 'inspection' of growth mechanics from an analytical perspective. Campbell's influential article fostered the need to include short-term aggregate shocks to the economy in addition to analyzing long-run responses. These shocks were assumed to be either governmental (fiscal) shocks or endogenous technological shocks, each having a real effect on output (thus the name real business cycle models or RBC models). Campbell's article created an RBC boom into the growth literature after its initial publication and soon these class of Neoclassical models were worthy to be treated as a separate class of growth models on their own. From another side, sectoral analysis of growth and development [5,6,13,63] have taken different perspectives, such as an industrial policy perspective [63,68] or the perspective of analyzing direct foreign investment's impact on growth rates [14], but unfortunately these kind of models were treated single-handedly with no subsequent interest in their research mainly because they emphasized specific assumptions in their formulation, and were usually made to be applied to a single specific case or country. In general, it seems that the role of abstract theory and empirical findings complement each other in most cases, with country-specific approaches to growth modeling being the current trend in the economic growth literature. Also, RBC models have recently tended to include Keynesian short-run fluctuations into their assessment, and it is forecasted that RBC models with nominal and real rigidities will soon appear on the table, creating new hybrid models of economic growth and stability.

Egypt, as a developing nation, has been analyzed from an exogenous or comparative perspective rather closely [11,12,25,39,53,61,62,67]. However, no literature so far has incorporated a structural empirical finding of the sources of real growth for Egypt nor the dynamic share of different factors of production unto its balanced growth path from an economy-wide scope, with human capital and learning-by-doing effects in technology. Along the education sector, Nemat Shafik finds big spending with low returns for human capital accumulation [62]. Expenditures on human capital have been excessive with low output returns which imply excess supply of skilled labor, ultimately working in disguised unemployment. Jeffrey Sachs' work [61] resulted in an optimistic rapid growth path for Egypt's economic future if current structural adjustment programs are implemented with good governance. Subramanian [67] concurs Sach's optimism from an analytical stabilization viewpoint and concludes that the Egyptian economy "stands out as a remarkable success story" during the 1990s. He points out, however, several challenges ahead: utilizing financial stability to boost economic growth, raise living standards, and generate employment benefits to be shared by all sectors of society. Howard Handy [39] analyzes the Egyptian economy descriptively and suggests policy recommendations for a dynamic market economy 'beyond stabilization'. Medium-term outlooks are stressed especially those pertaining to fiscal consolidation and the management of capital inflows. The equilibrium real exchange rate for Egypt was estimated using Edward's model and results show convergence towards a stable exchange rate especially after the Paris Club debt relief efforts during 1991-1996, in addition to debt reductions after the 1991 Gulf War. Although the results are rather optimistic, the paper warns of a large dissaving shock to the economy if privatization of state-owned enterprises are not efficiently implemented: if large-scaled loss-making state firms are liquidated and profitable state companies are privatized, the net result may be biased towards a lower savings account for the economy if improved management practices and a change in ownership structure do not take effect. Among the different growth models suggested, El-Erian and Bisat [11,12] find the savings rate to be the main critical parameter to growth in the Egyptian economy in addition to good governance and a more private-sector led development effort. The accumulation of investments was found to yield positive returns to output but detailed sectoral analysis shows that more efficient capital accumulation is needed targeting different social sectors in the economy. Strengthening the institutional and information base was stressed as a critical policy implication for sustainable growth. Within the scope of regional integration in the MENA

(Middle-East-North-Africa) region, Fischer and El-Erian compare and contrast different MENA economies and analyze their gains in an economic integration framework [25]. They arguably find positive gains through regional integration whenever countries' socio-economic systems are similar. El-Gamal and Bisat [26] model a simplistic view of investment and growth for Egypt from the 1970s through the 1990s at the aggregate and sectoral levels. An important conclusion with sharp policy implications is that private investment has been extensive in sectors with excessively high short-term yields and that economic reform efforts should foster longer-term investments that exhibit long-lived capital in addition to removal of price distortions, with an improved legal system and increased information transparency. Their paper concludes that economic policy towards growth for Egypt should target long-run yields with positive capital externalities.

Although most of the literature on the Egyptian economy so far is rather non-abstract in nature, there seems to be a gap that needs to be filled in structuring an empirical growth model which can capture the true dynamics of the economy during its past half-century of economic performance and provide valid policy recommendations for its long-run future, based on new modern growth theory which incorporates human as well as physical capital accumulation, labor, and technological progress with learning-by-doing effects. This is the main drive behind this work[1].

I.2: The URF Structural System

A structural econometric model is a system representation of time-series data. The essence of the model is defined by endogenous and exogenous variables of interest and by the lagged polynomials applicable to every variable. In other words, a set of dependent variables [$\mathbf{y_t}$] can be modeled as a function of an independent vector of variables [$\mathbf{x_t}$] by:

$$\boldsymbol{B}(\boldsymbol{L})\boldsymbol{y_t} = \boldsymbol{E}[\boldsymbol{A}(\boldsymbol{L})\boldsymbol{x_t} | \Gamma_{\boldsymbol{t}}]$$

where $\boldsymbol{B(L)}$ and $\boldsymbol{A(L)}$ are polynomial lag operators and $\Gamma_{\boldsymbol{t}}$ is information available at time *t*. The function $\boldsymbol{E}[\bullet]$ is the conditional expectations operator of information available at time *t* upon all endogenous and implicit variables of the model. Therefore, the behavior of the variables of interest (characterized as the vector $\boldsymbol{y_t}$) is dependent on conditional rational expectations whereby agents are assumed to behave rationally using all information available to them at the start of their decision-making process. [$\mathbf{x_t}$] is the observable (or measurable) variables suggested by previous research, by economic theory, or by mere logical assumption, available for a sample period of size *T* [28,36]. The statistical Haavelmo distribution of [$\mathbf{x_t}$] is denoted by $\boldsymbol{D_x}(\boldsymbol{X_T^1} | \boldsymbol{X_0}, \theta)$, where $\boldsymbol{X_0}$ are the set of initial conditions and the parameter(s) θ account for any necessary transient factors. The density function $\boldsymbol{D_x}(\bullet)$ can be factorized into parsimonious and lagged values of the $\boldsymbol{x}$'s to be written as [41,30]:

$$\boldsymbol{D_x}(\boldsymbol{X_T^1} | \boldsymbol{X}_0, \theta) = \prod_{\boldsymbol{t}=1}^{\boldsymbol{T}} \boldsymbol{D_x}(\boldsymbol{x_t} | \boldsymbol{X}_0 \boldsymbol{x}_1 \boldsymbol{x}_2 ... \boldsymbol{x}_{\boldsymbol{t}-1}, \theta).$$

Given this specification, the conditional system for *t=(1…T)* is an autoregressive distributed lag model or *ADL(m,r)* model, of the following form:

[1] It should be noted that the scope of this paper is to model and test sources of real economic growth for Egypt during its past half-century of economic performance using modern growth theory with learning by doing effects as outlined within a nested VAR system. However, the paper should mainly be viewed as an *initial baseline model* for further advanced research. It is hoped that enough interest be motivated by reading it so that subsequent research can either expand on derived models, or deepen the findings of a specific research area undertaken in its work.

$$y_t = \sum_{i=1}^{m} \Pi_{1i} y_{t-i} + \sum_{j=0}^{r} \Pi_{2j} x_{t-j} + v_t$$

where $v_t \sim N[0, \Omega]$ (a 'white noise' process),
and Ω is an *unrestricted*, symmetric, positive-definite matrix [28,30,41].

The above specification is a congruent statistical system [28,41] and is often called the *unrestricted reduced form* (URF) of a structural statistical system, taken as an initial testable specification of the economic problem at hand. It is therefore a general formulation of the interdependence between the different variables under study, and is used as a baseline model for testing degrees of integration, co-integration, error-correction, coefficient restrictions, parameter constancies, and is also used in short-run and long-run dynamic causation tests, weak exogeneity tests, strong exogeneity tests, and model encompassing. The URF specification is often used as a cornerstone for a new technique in applied econometrics termed the *'general-to-specific'* modeling technique. General-to-specific modeling is a modeling strategy used by economic researchers who take the URF structural system as their baseline model and follow their causation and hypothesis tests from the bottom upwards (in contrast to the usual top-down statistical approach). The modeling strategy undertaken in this paper is from the general to the specific for each model analyzed, whereas the three main models derived (aggregate production, learning-by-doing, and co-integration models) are integrated and encompassed together as a *VAR* structural system. Thus, each model is analyzed from a general *ADL(m,r)* URF system to a more specific congruent system through reductions based on a series of tests. These tests usually start as unit root tests and/or order of integration tests, and are then followed by causality and exogeneity tests. After each model has been tested, analyzed, and reduced to its long-run path, the three models are then encompassed together as a *VAR* system for further analysis. This approach has several advantages to its favor, which we deal with in the following section, and is often used as a modeling strategy for non-stationary time-series data.

I.3: Modeling Strategy: General to Specific Modeling

General-to-specific modeling is a new technique used in econometrics for efficient model reduction and encompassing and is characterized by yielding a more effective parameter testing of the model under investigation [3,28,42]. The norm in empirical modeling is to develop a theory explaining the behavior of the data and subsequently test hypotheses on specific functional formats to try to explain the true relationships between the different variables [50,55]. In the general-to-specific modeling approach, a general model is postulated with all possible variables affecting the theory under study dynamically analyzed, followed by lag structure analysis, co-integration testing, and error-correction modeling in long-run solutions. Model evaluation, testing for significance of each lag or variable, testing for significance of co-integration relationships between the variables, and finding both short-run and long-run responses to changes in these variables on the long-run solution is what constitutes the power of analysis used in the general to specific modeling technique. This allows for efficient model reduction and effective model encompassing of rival models into the econometric problem under study [28,42,43]. Moreover, most aggregate economic variables tend to be non-stationary over time, and using standard statistical tests may therefore lead to biased or unreliable results. Transformation of non-stationary data into stationary variables is thus an important step which is sometimes missing in the classical approach to econometric modeling [3,4,28]. These data transformations can be done through unit root analysis or through other integrative processes (such as an auto-regressive process or a distributed lag process or a combination of both). In this paper, a general to specific approach of analysis is used in estimating the economic growth path of Egypt using annual data from 1950 until 1997. The main steps involved in the general to specific modeling technique are as follows [3,28,40,41,42,43]:

1. Identify the main variables of interest (endogenous and exogenous) and provide real and filtered time-series data for these variables, and specify a general functional format and/or general system formulation to be tested. The general formulation should include all variables which are thought to be either directly or indirectly affecting the long-run solution of the system.
2. Test for unit roots and stationarity of the time series for each variable specified in the system using *AR(n)*, *ADL(m,r=0)*, or other data transformations. Exponential, lag structure, power or other transformations could also be conducted for the purpose of obtaining a stationary series with appropriate re-parameterizations.
3. Based on the stationarity results, conduct a preliminary test for each variable using significant lag structures and obtain the long-run error-correction solution for the different models in the system under study. Also test for causality and weak /strong exogeneity for each significant variable in the system.
4. Test for co-integration relationships between the different significant variables and for linear and general restrictions on the estimated parameters of the error-correction solution, and test for system reduction, re-formulation and stability (convergence). In addition, test whether the co-integration relationship can stand alone as an added model into the system under investigation.
5. Based on previous test results, provide a complete dynamic specification for the structural behavior of the system, augmenting static models with dynamic specifications of the reduced solution.
6. Repeat above procedure for a different model specification and/or additional models of interest, and test for model encompassing for the simultaneous equation structure to arrive at the *VAR* system structure.
7. Test the *VAR* system for model causality and encompassing and provide for the final error-correction solution.

The above seven steps are considered a general guideline for analysis and do not necessarily imply that doing them all will generate an optimal converging solution. Statistics is a tool and should be treated as such so that logical assumptions, economic intuition, and human intelligence are not lost in its process. Therefore, the above steps will only be taken as a guideline for research in this paper and will not be followed blindly. Having outlined our modeling strategy, it is now desirable to outline the main variables used in our *VAR* analysis for estimating the economic growth path of Egypt.

II. DYNAMIC BEHAVIOR OF THE MAIN VARIABLES

The main variables used throughout the analysis done in this research have been the following: Real GDP *(Y)*, Real GDP per working labor population *(YL)*, Real capital stock *(K)*, Labor force *(L)*, Total population *(POP)*, Primary educational attainment *(PrEduc)*, Post-primary educational attainment *(SecEduc)*, Combined school enrollment *(SCH)*, Human capital *(H)*, Inflation *(R)*, Effective exchange rate *(E)*, and Technological progress *(A)*. There are 48 annual observations for all the variables, spanning from 1950 until 1997, and the base year used for all real data was 1990. Endogenous variables for the models tested were real income, *Y*, real income per working labor population, *YL*, and residual technological progress, *A*. Logarithmic transformations *(ln)* of the variables were used in estimation and model testing, model reduction, and model evaluation. The error term, *v*, is dependent to the specific equation or model at hand and takes differing values for each model tested as a stochastic error term. Sources for the data have been the IMF's International Financial Statistics (IFS), UNESCO Statistical Yearbooks, World Tables (WT), World Bank's World Development Reports (WDR), International Historical Statistics: Africa and Asia (IHS), and Social Indicators of Development (SID). The complete set of variables used in this paper (name, description, and data source), is outlined in the Box below.

Box: Main Variables Analyzed in Estimating a *VAR* Co-Integrated Model for Egypt's Economic Growth Path

Variable Name	Variable Description	Source
Y	Real Gross Domestic Product (LE, billion)	IFS
YL	Real GDP per working labor population[a] (LE, thousands)	---[2]
K	Real Capital Stock (LE, billion)	IFS[3]
L	Labor force (million)	WT, UNESCO
I	Investment (LE, billion)	IFS
POP	Total Population (million)	WT, UNESCO
C	Real Consumption (LE, billion)	IFS
PrEduc	Primary Educational Attainment (years of schooling)	SID, WDR, and IHS
SecEduc	Post-primary Educational Attainment (years of schooling)	SID, WDR, and IHS
SCH	Combined Primary and Secondary School Enrollment Rates[c] (%)	SID, WDR, and IHS[4]
H	Human Capital defined as the 'Human Educational Attainment index' (the stock of available human resources in terms of number of primary-school, secondary-school, and higher educated students)[d]	SID, WDR, and IHS[5]
CPI	Consumer Price Index	IFS
R	Inflation rate[e]	---[6]
E	Effective Exchange Rate (LE per US $)	IFS
A	Technological Progress[f] (residual parameter in LE, billion)	---[7]
Trend	Trend variable (1 to 48 for annual observations)	---
Year	1950 to 1997	---
V, v, u, ε	Error term	---
SE, σ^2	Standard error for model estimates	---

II.1: Comments on Graphical Output

Graphical output of the data is shown in Graphs A, B, C, and D. Income per working labor population is shown to have a real growth path with short-run disturbances and some cyclic fluctuations within its business cycle and is visually always converging to its long-run trend. It is also evident that the most

[2] Real GDP per working labor population is calculated as *Y* divided by *L*.
[3] Cumulative Capital Formation, with initial capital stock assumed to be that of 1950, and assuming a 5% annual depreciation rate. A 5% depreciation rate has been assumed from the literature, yet the models in this paper have been re-tested using a 3% depreciation rate and comparative results have been found (only when human capital depreciates at the same rate as physical capital).
[4] School Enrollment Rate = number of children enrolled in schooling divided by those eligible.
[5] Human Capital as a stock variable to the flowrate variable, SCH. Cumulative stock as SCH weighted by the effective labor force population.
[6] Inflation as measured by the percentage change in CPI.
[7] Technological progress is considered a residual parameter to growth, although it has been treated as a causal factor (its growth causation on income have been tested). Lack of data on Egypt concerning patent rights and research institutional databases caused the assumption of using the Solow residuals criterion [57,64] in measuring technological progress. Augmented residuals using log-linear and log-exponential trend variables have been used in constructing technological progress as a parameter in the models tested.

stagnant period of the economy was that between the mid-sixties to the early seventies where the post-1967 war economy was plagued by the social and political shocks that have erupted after the country's defeat in the 1967 war. By the mid-seventies, the economy was back on track with the partial victory of 1973 carved on its backdoor. The economy has moved forward since with a relative decline in real output in the very late eighties and early nineties, followed by a catch-up after 1992 and steady growth to-date. Human capital seems to positively complement the economy's labor force and vice-versa, with a smooth exponential increase in human capital accumulation with labor and with time. Inflation is persistent in the economy's growth path with excessive inflationary periods during the seventies and eighties. Consumption as a function of income is relatively stable implying a consumption smoothing behavior, yet there is an increase in consumption expenditures relative to income after the open-door policy of the seventies, and the marginal propensity to consume (*mpc*) is seen to be gradually rising to an upward trend. It is important to note that although the economy's welfare is heavily dependent on consumption, the basket of consumption goods consumed lays an important criterion in determining whether an increase in the *mpc* implies an increase in social welfare or not. Demonstration effects of imported goods seems to be the current trend in the consumption behavior of individuals, therefore it seems plausible to assume that the recent increase in the *mpc* may be attributed to the increased marginal utility of consuming imported goods in comparison to domestically produced goods, which does not necessarily imply an increase in social welfare (although an increase in per capita income may still persist) [9,13]. The aggregate savings rate is seen as a random walk process with or without a drift component, whereas if a drift component did exist it would probably be insignificant.

The exchange-rate of the economy has seen dramatic shocks in the early nineties and is reported as officially stable before and after its devaluations. Exchange-rate devaluation shocks to the economy were severe enough to heavily impact physical capital accumulation in the short-run, thus affecting the short-run output of the economy. Labor and human capital are not seen to be directly affected by the exchange-rate changes. Output is increasing in labor and capital, with a quasiconcave production function with respect to physical capital accumulation (through investment supply and its respective rents and wages paid) and with a strictly concave production function with respect to human capital accumulation (through education and training). As the accumulation of physical capital proceeds, output increases rather slowly up to a level of saturation beyond which there is a relatively sharp decline in its marginal product. The accumulation of human capital, on the other hand, has a more dramatic decline in its marginal product throughout all its levels of accumulation. This may imply that the economy is in dire need of additional investments beyond which excess supply may prevail, and that the return to physical capital obeys a quasiconcave function in its transformation to real output. Also, human capital is seen to positively contribute to the economy's production process but with sharp diminishing returns in its transformation to real output, with zero value-added returns beyond a certain saturation level.

II.2: Normality, Unit-Root Analysis and Orders of Integration

Normality tests (Table 1) for *K*, *L*, *Y*, *YL* and *H* yielded a non-asymptotic form of normality for all variables with a 1% significance level (5% for *L* and 6.88% for *YL*), implying that all variables are unlikely to be generated by a normal distribution. Large standard deviations (exceeding half-means) for *K*, *Y*, *YL* and *H* have been reported, while the standard deviation of *L* was found to be about one-third of its mean. Correlation between variables have been found to be very high with all correlation matrix coefficients in excess of 0.9 for all the variables considered (see Table 2).

Unit root analysis (Table 3) with five lags using an augmented Dickey-Fuller test [22,40] yielded a first order autoregressive data generating process, *AR(1)*, for *K* (t-prob=3.14%), *Y* (t-prob=0.14%), *YL* (t-prob=0.43%), and *H* (t-prob=1.34%). These variables were tested for orders of integration and were found to be integrated of order one, therefore they follow an I(1) process. Income per labor, *YL*, is also I(1) and is shown to be highly correlated with its own lag. In general, an *AR(n)* model for a variable *y* can be written as [3,28]:

$$y_t = \alpha + \sum_{i=1}^{n} \gamma_i y_{t-i} + u_t$$

For a first-order integrated process {I(1)} i.e. an integrated I(1) process, the summation term in the above equation reduces down to a single lag with *i=n=1*. Thus, the first difference Δy_t would be stationary and therefore be integrated of order zero {I(0)}. This is true for *YL*, *K*, *H*, *E*, and *R*, thus they follow an *AR(1)* process of the form:

$$y_t = \alpha + \beta y_{t-1} + v_t$$

with $E(v_t)=0$ *and* $E(v_t^2)=\sigma^2$. The augmented Dickey-Fuller test for integration (unit root) tests the null hypothesis of a unit root as { $\mathbf{H_0} : \beta = 0$ } for

$$\Delta x_t = \alpha + \mu t + \beta x_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta x_{t-1} + u_t$$

Failing to reject the null implies that Δx_t is stationary, so [*x*] is {I(1)}.

Table 4 shows ADL tests conducted on *lnK*, *lnY*, *lnYL*, *lnH*, *lnE*, and *lnR*, showing that all these variables follow an autoregressive process with significant distributed lags as specified in the results.

II.3: Descriptive Summary of the Main Variables

Analysis of data from 1950 to 1997 on the past half-century of economic performance for Egypt show a smooth real income per working labor population with cyclic fluctuations around its trend, exponential human capital formation with time even after accounting for rapid population growth, persistence of high inflation especially during the last two decades with recent dis-inflationary growth, aggregate consumption smoothing to real income with a recent upward trend, a probable random walk behavior for the savings rate[8], exchange rate devaluation shocks to the economy during the early 1990s with significant impact on short-run physical capital, positive increasing returns to labor and capital accumulation with diminishing marginal products, an ever-persistent trade deficit to-date, a relatively constant marginal rate of substitution between factor inputs, a quasiconcave production function for physical capital accumulation, and strict concavity of real output with respect to human capital formation. Main factor inputs (labor, physical capital, and human capital) are integrated of order one with large standard deviations around their means and with high correlation coefficients between them, and they all follow an autoregressive process with significant distributed lags along with real output and with real output per working labor population.

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[8] In addition to graphical exposition, a unit root test for the savings rate was conducted for the entire sample period (48 observations). Testing for the aggregate savings rate s=I/Y with depreciation and inflation-adjustments, the following model was tested: $s_t = \alpha + \beta s_{t-1} + \varepsilon_t$ using the augmented Dickey-Fuller test [22,41,42]. Results show a *failure* to reject the null hypothesis: H_0: $\beta = 1$; implying that the savings rate generates a random walk behavior and is integrated of order one , I(1). The drift coefficient, α, can take the value zero with 90.16% probability using a Wald test for linear restrictions. Thus, the behavior of the aggregate savings rate in the Egyptian economy is a probable random walk with no drift. Graphical output complements this result. Aggregate savings incorporates domestic as well as foreign savings. Further research efforts can dis-aggregate savings into its two components and analyze their effect on output, yet this is seen to be outside the scope of this paper since (1) savings are implicitly included as investments through physical capital accumulation in a Neoclassical model, and (2) analyzing foreign savings alone can lead to erroneous results if international trade issues are not addressed more thoroughly.

III. TESTING THE EMPIRICAL DYNAMICS: A *VAR* SYSTEM APPROACH FOR EGYPT'S ECONOMIC GROWTH PATH

III.1 The Research Agenda

As outlined above, the main objective of this research is to estimate the dynamic behavior of the economic growth path of Egypt through a structured endogenous growth model with learning-by-doing effects as set within the framework of a vector-auto-regressive co-integrated system. Having described the dynamic behavior of the main variables and the modeling strategy to be used, the remaining steps in our research agenda is to implement on this strategy using available data and perform the following tasks:

1. Test different aggregate production functions for the economy based on useful growth models in the literature, including all factor inputs assumed (labor, physical capital, human capital, and technological progress), and obtain the long-run solution.
2. Augment the long-run solution to include structural macroeconomic factors of inflation shifts and exchange-rate adjustments on the long-run growth path of the economy, and analyze the significance of each variable and its respective lags on the long-run solution.
3. Conduct weak and strong exogeneity analysis for the significant variables and causality tests for non-significant variables, and re-formulate the long-run solution as a generalized auto-regressive-distributed lag model with growth-causation factors using the general-to-specific error-correction technique.
4. Analyze the growth-causation model using linear and general Wald restrictions on the model parameters, test for serial auto-correlation using recursive *RALS*[9] esimation, re-formulate using an auto-regressive conditional heteroskedasticity *(ARCH)* specification if needed, and analyze model stability using Break-point Chow graphs.
5. Obtain all co-integration vectors in the growth-causation model and interpret their significance. Test for model encompassing to ensure whether the co-integration vectors can stand alone as an auxiliary model in the *VAR* system structure, and conduct co-integration restriction tests on the growth-causation model as a *conditional* model to obtain speeds of convergence of the significant variables towards their long-run growth paths.
6. Incorporate learning-by-doing effects for residual technological progress as a *marginal* model in explaining the true long-run balanced growth path of the economy, using a learning-by-doing power function with decreasing returns-to-scale in knowledge creation, and obtain the long-run solution of the model using all significant lags.
7. Integrate all three models derived (conditional, marginal, and learning-by-doing models) into a nested *VAR* system, and test for model inter-dependence, model encompassing, model reductions and obtain the long-run solution of the *VAR* system using null-restrictions for all significant parameters. Transform the long-run solution into level form and analyze the behavioral growth path of the economy.
8. Provide general conclusions and policy recommendations.

III.2: Testing for Aggregate Production Functions

There are several formulations on how an economy transforms its factor inputs and resources into real output. However, the main factors that enter into the aggregate production function of an economy are: labor, physical capital, human capital, and technological progress [7,52,57]. Labor enters as working labor population (sometimes classified as agricultural and non-agricultural labor), while physical capital enters as

[9] Recursive Auto-regressive Least Squares. *RALS* estimation involves estimating the model or system over a sub-sample of observations and then re-testing over successively larger sub-samples up to the full sample. Parameter instability can be tracked by comparing results of the estimated coefficients, and the Chow test [18] is based on a comparison of the residual variance as an *F*-test under the null hypothesis of parameter constancy [3,28].

a stock variable using a base year as initial capital stock and assuming a capital depreciation rate (a constant or linear depreciation rate is assumed, but on rare occasions an exponential depreciation rate is also used). The accumulation of physical capital is measured by the amount of cumulative investments the economy absorbs over a specified time period, including private as well as public investments. The accumulation of human capital, on the other hand, is measured by years of schooling of educational attainment in the primary, post-primary, and university study programs, and weighted by the labor force participation rate [6,7,8,9,10]. Sometimes the efficiency of human capital directly enters the production function of the economy when data is available [2,9]. In addition to material resources as factor inputs into the production process, effective technological progress - as a variable input in the production function - captures all non-material resources which can be used to produce real output. Technical progress is an important factor in the production process because it incorporates idea creation, knowledge acquisition and dispersion, and endogenous technological innovations (although it is sometimes defined in very vague terms in the economic literature) [2,13,57]. For developed economies, proxy variables are used to measure the degree of technical progress in an economy, such as the amount of research and development expenditures as a function of national product, number of patent rights, monetary measures of idea creation and innovation (through the amount of savings these innovations have brought to the profits of the holding firm, or through a measure of the opportunity cost of not holding the patent right of an innovation in a competitive market economy) [5,7,10,14,52]. Such proxy variables are usually not available for developing countries because of lackness in the institutional structure and/or asymmetric and incomplete information flows within different sectors or groups in the economy. Even when available, these proxy variables would be biased towards exogenous technologies via the conduct of multi-national firms operating in the economy or via borrowed technologies and will not be a reliable estimate for endogenous technological change [14,52]. To correctly account for effective technological change in a developing economy, the concept of Solow residuals have been introduced into the literature mainly from research papers in the area of growth accounting [1,7,20,57,69]. The Solow residuals criterion decomposes the growth of real output per worker into the contribution of physical capital per worker, human capital per worker and a remaining residual term, the Solow residual. The Solow residual therefore measures all sources of growth other than physical and human capital (and labor), namely all non-material resources which contribute to effective real output in the economy i.e. effective technological progress. Given this argument, there are several formulations in the economic literature for an aggregate production function that includes all factor inputs described above, and these are generally of the form [2,7,8,9,13,48,57]:

$Y(t)=F[Z(t),A(t)L(t)]$, "Harrod-neutral"
$Y(t)=F[A(t)Z(t),L(t)]$, "Capital-augmenting"
$Y(t)=A(t)F[Z(t),L(t)]$, "Hicks-neutral",

where $Z(t)$ is a vector of all capital resources in an economy. For our purposes, the above formulations include physical capital accumulation in addition to human capital accumulation as the two capital resources in the productive process of an economy[10]. Also, (t) is not static time but rather a vector of all significant time lags of the specified variable (for example: for a first-order integrated process, (t) and $(t-1)$ are both included in the above equations for the integrated variable, or its first-difference as $X(t)-X(t-1)$).

Testing for *AL*, *AZ*, and *AF(Z,L)* production functions for the Egyptian economy (1950-1997) resulted in rejecting *AL* and *AF(Z,L)* models and suggesting that the economy behaves as an *AZ*-type model in the long run (Table 5 gives results of production function tests on long-run income growth using error-correction

[10] A third capital resource is the amount of land and/or natural resources (such as petroleum, natural gas, coal, arable land, copper, gold etc), but it has been proven analytically that the inclusion of this type of capital does not alter the long-run growth outcome of the economy's production function when the elasticity of output with respect to natural resources is inelastic [2,57].

modeling). An autoregressive distributed lag (ADL) *AZ*-model was estimated (Table 6) and the solved long-run error-correction model was found to be:

ECM = lnYL + 0.917 - 0.461*lnK - 0.138*lnH

where *ECM* is the error-correction mechanism for the data-generating process[11,12].
The ADL model can be written of the form

$$\boldsymbol{y_t} = \alpha + \sum_{r=p}^{s} \beta_r \boldsymbol{x_{t-r}} + \sum_{i=m}^{n} \gamma_i \boldsymbol{y_{t-i}} + \varepsilon_t \quad \text{where} \quad \varepsilon_t \sim \boldsymbol{ID}(0, \sigma_\varepsilon^2) \quad \text{with the error term as white noise.}$$

The long-run solution of the model depicts the growth process as

$$\boldsymbol{y_t} = \boldsymbol{A_t k_t^{\alpha} h_t^{\beta}} \quad \text{with} \quad 0 \le \alpha \le 1, \text{ and } 0 \le \beta \le 1,$$

and the lower case letters signify variables per unit of working labor population. This specification implies that the economy's total capital resources (physical and human) are the driving force behind the economy's production process and therefore its real output. Technological progress acts as a residual parameter in the growth process yet it indirectly contributes to the efficiency of capital utilization into industrious output. In our case, given that all variables in the ADL model are {I(1)}, then *n=s=1 and m=p=0*. Note that both human as well as physical capital have been included into our specification since both forms of capital are assumed to positively contribute to long-run income. The model implies that physical capital's share of changes in long-run income per working population is 46.1% while human capital's share is 13.8%, without adjusting for behavioral fluctuations of other key macroeconomic variables. Imposing residual technological progress on the above outcome using the Solow residuals criterion in growth accounting [57,64,69] leads to technological innovation accounting for 40.1% of long-run income growth. In a more static analysis without dynamic adjustments of factors of production, shares of physical capital, human capital, and knowledge growth (as analogous to residual technological progress in the dynamic ADL model), have been found to be 42.2%, 28.3%, and 29.5% respectively (Table 7 and Graph E).

One should not rush to the optimistic conclusion evident thus far in that the dynamic share of technological innovation (40.1%) exceeds its static share (29.5%) implying substantive innovation and dynamically-increasing efficiencies in production and technology creation. Implicit in the dynamic residuals of the above model is not only effective technological progress, but also indirect factors that shift or adjust long-run income growth from its balanced growth path. Although such factors as measured macroeconomic variables do not directly enter into the production function of the economy, they nonetheless indirectly contribute to the allocation and utilization of factor inputs and do have a significant impact on the development of these

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[11] Testing validity of long-run income normalization to working labor input, coefficient of *lnL* is failed to be rejected as having a value equal to one, implying validity of using income per labor as the dependent variable:

lnY = -1.268 +1.212 lnL +0.3273 lnK +0.08568 lnH + V.

(SE) (0.149) (0.2758) (0.02913) (0.1301)

[12] For a simple, two-variable ADL model with one lag, $\boldsymbol{y_t} = \alpha_1 \boldsymbol{y_{t-1}} + \beta_0 \boldsymbol{x_t} + \beta_1 \boldsymbol{x_{t-1}} + \varepsilon_t$, and ε_t as white noise, an error-correction mechanism can be found by reparameterizing the above equation as:

$$\Delta \boldsymbol{y_t} = \beta_0 \Delta \boldsymbol{x_t} + (\alpha_1 - 1)(\boldsymbol{y_{t-1}} - \boldsymbol{K x_{t-1}}) + \varepsilon_t$$

where $\boldsymbol{K} = (\beta_0 + \beta_1)/(1 - \alpha_1)$.

The error-correction mechanism (*ECM*) is the $(y\text{-}Kx)_{t-1}$ term. It reflects the deviation from long-run equilibrium values, with a model correction of $(1 - \alpha_1)$ of the resulting disequilibrium each period. *ECM* approaches zero in the long-run [28,29]. This also follows Davidson et. al., 'Econometric modeling of the aggregate time-series relationship between consumers' expenditure and income in the United States', *Economic Journal*, vol 88, 661-692, 1978. [in 28].

factors and in their utilizability into effective output [32,34]. The shallow analysis thus far has ignored long-run fluctuations of key macroeconomic variables such as inflation shifts [32] and exchange-rate stabilization adjustments [33] to long-run output. It is therefore required research to deepen the analysis of factors of growth into an extended or generalized analysis encompassing not only the effect of direct factors of production and their contribution to real income growth but also to include other key macroeconomic factors which indirectly affect or shift the level of such growth into a converging equilibrium.

III.3: Generalized ADL Growth Model with Human Capital and Structural Macroeconomic Factors of Inflation and Exchange Rate Adjustments

Two most important factors pertaining to the Egyptian economy to be analyzed are the factors of inflation as measured by dynamic changes in the consumer price index, and the exchange rate stabilization factor as measured by the stabilization of the effective exchange rate (LE per US $) with its respective lag adjustments. Inflation is considered a *shifting* variable while exchange rate stabilization is considered an *adjustment* variable to the long-run growth of the economy. These two financial or monetary factors are considered critical parameters in analyzing ADL or *AZ*-growth models [34], however they can also serve as measured variables to achieve certain policy targets for the future [33].
The long-run solution for the generalized ADL model would therefore incorporate direct factors of production along with shifting and differenced-adjustment functions on long-run output. The generalized production function for the economy would therefore be of the form:

$$\boldsymbol{y_t = A_t k_t^{\alpha} h_t^{\beta} f(R_t) g(E_t^d)}$$

where the $\boldsymbol{f}$ function denotes shifting effects and the $\boldsymbol{g}$ function captures adjustment effects on output.

The above specification for a generalized production function has been applied and tested on the Egyptian economy as an augmented ADL *AZ*-model with structural macroeconomic factors of inflation and exchange rate adjustments. Results show strong significance for inflationary growth with exchange rate (and its lags) having little explanatory power on long-run income growth. Still, the augmented ADL model failed to explain any strong impact of human capital formation on long-run output, whether in level or in difference form. The solved long-run equation for the augmented ADL *AZ*-model with structural behavioral changes in inflation and exchange-rate stabilization was found to be (see Table 8):

lnYL = -1.12 + 0.4112 lnK + 0.8901 lnR +0.09147 lnH - 0.03015 DlnE + V
(SE) (0.1488) (0.05394) (0.4071) (0.07635) (0.1425)

Using a more general framework[13], the long-run solution using stationary and non-stationary variables, with actual and first-differenced values of the variables *K*, *H*, *R*, and *E*, have been found to be the following:

[13] Since the ADL model of aggregate production spans nearly half a century (1950-1997), including structural breaks is expected to be important. Analyzing dummy variables for war and inter-war periods, however, imply insignificance and a definite lack of causality to long-run output changes. This is only true because physical capital as an input factor in the production function of the economy is defined as the accumulation of total depreciated investments, state as well as private investments, within the scope of Neoclassical growth theory. Breaking down physical capital into public and private investments with different returns to capital has been addressed by Bisat, El-Erian, and El-Gamal [11,12,26]. Including sectoral analysis of investments and incorporating externalities to output via learning-by-doing effects with short-run/long-run causality analysis on the Egyptian economy is a stimulating subject which is hoped to be researched as an extension of this paper.

$$
\begin{aligned}
lnYL = \; & -1.209 + 0.3751\, lnK + 0.1575\, lnH + 0.6081\, lnR - 0.01032\, lnE + 0.1157\, DlnK \\
(SE) \quad & (0.1606) \quad (0.03195) \quad (0.08273) \quad (0.1819) \quad (0.03061) \quad (0.1495) \\
& -0.5422\, DlnH - 0.4085\, DlnR + 0.1146\, DlnE + V \\
& (0.3502) \quad (0.1658) \quad (0.04645)
\end{aligned}
$$

The model suggests that the behavior of the economy's production process is that of decreasing returns-to-scale in aggregate production with positive returns to individual input factors and diminishing marginal products. Growth is attributed mainly to effective capital accumulation with real inflationary growth, while exchange rate adjustments only contribute to short-run income responses, with a devaluation having a counter-cyclical effect on long-run income per labor. Lagged variables also have significant impacts on long-run growth. Model validity tests for short-run and long-run exchange rate adjustments to real income yielded strong significance for short-run income responses (Wald test χ^2 of 332.12 with zero t-prob at 1% significance level) and insignificant long-run responses (failing to reject null hypothesis for non-significance with 0.2835 t-prob at 5% significance level). This implies that exchange-rate adjustments do not have a significant influence on long-run growth (*ceteris paribus*), but do have a significant influence on short-run output through adjustments in the economy's capital stock. The model also suggests that physical and human capital formation positively contribute to the causation of more output in the economy (physical capital through investments and human capital through education). In addition, the labor force is seen to be an unquestioned causation variable to long-run income.

III.4: Testing for Weak Exogeneity and Granger Non-Causality for the ADL Growth Model

After the ADL model has been augmented to include inflation shifts and exchange-rate adjustments in addition to significant lagged values of the input variables, the next step is to test for the exogeneity of the significant variables in our model. Two types of analysis have to be conducted: weak exogeneity and strong exogeneity (Granger non-causality). A weakly exogenous variable is one which indirectly (or informally) contributes to the data generating process of the dependent variable(s), whereas a strongly exogenous variable is one which will add no new information on the forecast of the dependent variable(s) [3,30]. In other words, a weakly exogenous variable indirectly contributes to the long-run solution of the dependent variable through its interaction with other variables that do have a direct contribution on the dependent variable under investigation. A strongly exogenous variable, on the other hand, is a non-causal factor to the long-run solution of the dependent variable. In our framework, weak and strong exogeneity tests have been conducted for all significant variables using the augmented ADL model. Testing for weak exogeneity of the variables resulted in failing to reject all explanatory variables to be weakly exogenous except for human capital formation and exchange-rate adjustments (Table 9). Weak exogeneity tests were conducted using factorization of the joint density function $\boldsymbol{D}_{\boldsymbol{\chi}}(\bullet)$ into a conditional and marginal distribution:

$$\boldsymbol{D}_{\boldsymbol{x}}(\boldsymbol{x}_t | \theta, \boldsymbol{x}_{t-1}) = \boldsymbol{D}_{\boldsymbol{y}|\boldsymbol{z}}(\boldsymbol{y}_t | \boldsymbol{z}_t, \boldsymbol{x}_{t-1}, \phi)\boldsymbol{D}_{\boldsymbol{z}}(\boldsymbol{z}_t | \boldsymbol{x}_{t-1}, \phi)$$

where $\phi = \boldsymbol{f}(\theta)$.

Further testing on human capital using Granger's non-causality test [38] resulted in rejecting non-causality for human capital on long-run income growth, implying that human capital accumulation, although not highly significant, is a causation variable to income growth. Human capital is therefore weakly but not strongly exogenous to the system. Also, performing exogeneity and causality analysis on exchange-rate adjustments show that the exchange-rate is insignificant to long-run income growth although having a high degree of economic causality to short-run output, a result which complements previous analysis. Testing for model reduction for all relevant factors in the model resulted in *failing to reject* both physical and human capital formation with inflation as causation variables to changes in long-run income, while *rejecting* the exchange-rate stabilization factor as a causality variable to long-run income growth. Table 10 shows results for Granger non-causality testing, weak exogeneity tests, and causality analysis on the generalized ADL growth model.

Based on the exogeneity and causality results, the generalized ADL model including all growth-causation factors was estimated to be the following error-correction model (see Table 11 and Graph F):

$$lnYL = -0.8919 + 0.4346\, lnK + 0.789\, lnR + 0.1539\, lnH$$

(SE) (0.2115) (0.03774) (0.3212) (0.1142)

The behavior of the economy is decreasing returns-to-scale in output production with diminishing marginal products. Growth is attributed mainly to physical capital accumulation with a 0.4346 coefficient in long-run log format and a weakly exogenous human capital formation causality variable. Inflationary pressure is statistically evident with a 0.789 coefficient. In the generalized ADL model, all variables were found to have a casual relationship to long run growth, with their joint significance having a Wald test χ^2 of 325.3 (zero t probability at 1% significance level). The generalized ADL model with all relevant growth causation factors was found to have the best fit, highest explanatory power, smallest σ compared with the static and augmented models, reasonable Durbin-Watson statistic, and normality of residuals with convergence (see Graph F). The generalized model explains the variations in physical capital and its lag with variations in output, but fails to explain any strong impact of human capital formation on long-run output during the economy's past half-century of performance. One reason for this could be that the available data at-hand are in levels of human capital formation and not in measures of efficiencies in the formation of human capital. A measurement of the quality of education rather than quantity could change this outcome. It is not the number of students enrolled as a percentage of those eligible that can impact long-run income or growth, but it is the efficiency or quality of science that can only make this possible. However, the formation of human capital for which data is available can be taken as years of schooling for primary and post-primary educational attainment. Since education is the main drive for human capital formation as taken from its origin, a break-down for the causes of educational attainment on long-run income is desirable as a second-best prediction (a first-best prediction would include other factors in the learning process in the acquire of human capital, such as on-the-job training, other professional training, conferencing, travel etc).

Using *PrEduc* and *SecEduc* as variables for primary and secondary years of schooling[14] for the formation of human capital, the long-run error-correction model on income per labor was found to be:

$$ECM = lnYL + 1.05177 - 0.417892*lnK - 0.736288*lnR - 0.0317077*PrEduc + 0.0230434*SecEduc.$$

Testing long-run growth responses to primary and post-primary educational attainment, results show positive output returns for primary-school educational attainment, but also show negative decreasing returns for post-primary educational attainment; with both primary and post-primary variables significant in long-run income responses. This may suggest that a valid policy recommendation could be to shift some financial or budgetary resources away from the post-primary education sector towards infrastructure investments or improved financial intermediaries, paving the way for innovative investments and achieving positive environmental spill-over effects for a more efficient utilization of available resources, towards a sustainable growth path in the long-run. However, caution must be stressed in not to rush towards such a strategy before conducting a more thorough social welfare analysis. For it could be true that more funds are required in establishing a better quality educational system to achieve a lower class size, more lab and computer facilities, and better knowledge skills for the students, and that a higher educational budget may achieve a more positive response of income to the educational system in general, and to the post-primary educational sector in particular. However, historical facts show that the Egyptian educational system did not achieve high enough returns through the economy’s inefficient absorption of human capital, and that its impact on the economy’s growth path is weakly exogenous.

[14] The Egyptian educational system is divided into three tiers. Here, primary educational attainment means the weighted average of the first two tiers of schooling for which data is available. Post-primary educational attainment means the third tier of schooling. Human capital, as a stock variable, includes primary, post-primary and university education.

Further testing for first-order serial autocorrelation using recursive estimation with restrictions imposed (Table 13) yielded the lagged error-term to be non-significant. A recursive autoregressive least squares *(RALS)* model of the form:

$$\beta_0(\boldsymbol{L})\boldsymbol{y_t} = \sum_{i=1}^{m} \beta_i(\boldsymbol{L})\boldsymbol{z_{ti}} + \boldsymbol{u_t} \quad \text{with } \alpha(\boldsymbol{L})\boldsymbol{u_t} = \boldsymbol{v_t} \text{ , and } \quad \alpha(\boldsymbol{L}) = 1 - \sum_{i=s}^{r} \alpha_i \boldsymbol{L}^i$$

have been used for first-order serial autocorrelation.

An *ARCH* model (autoregressive conditional heteroskedaticity) was specified as

$$\boldsymbol{y_t} = \boldsymbol{z}'_t\beta + \boldsymbol{u_t} \text{ with } \boldsymbol{u_t} = \sigma_t\varepsilon_t \text{ and } \sigma_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j \boldsymbol{u}_{t-j}^2$$

and the log-likelihood function defined as

$$\boldsymbol{l_t}(\theta|\boldsymbol{I}_{t-1}) = \boldsymbol{c} - \tfrac{1}{2}\log(\sigma_t^2) - \tfrac{1}{2}\frac{(\boldsymbol{y_t} - \boldsymbol{z}'_t\beta)^2}{\sigma_t^2} .$$

ARCH model results are given in Table 14. Break-point Chow graphs [18,41] show high significance for the variables and show relative system stability for the tested ADL model (Graph G).

III.5: Exogeneity and Causality Results: a Discussion

Results show that physical capital accumulation is a causation variable to economic growth, and that one-period lags of physical capital are also significant to short-run output. This may have two meanings from an economic point of view. First, the return on investment capitalization takes some lead-time before actual returns on initial capital are observed, with one year a bare minimum requirement on an economy-wide scope. Second, first-differenced physical capital has a significant impact on output the next period, implying that the amount of investments in money terms is not the only factor that causes growth in the productive factors of the economy but rather, in addition to the amount of capital investments, the contribution of *value-added* capital is a second-runner to income growth in the long-run. These two observations combined signify that the *allocative efficiency* of physical capital has important growth effects in the long-run through the level and value-added returns on its accumulation. The long-run solution yields an expected positive effect of physical capital on growth in income per labor, and that there is a pro-cyclical co-movement between physical capital and the residuals (which implicitly include residual technological progress). As the economy absorbs more of its own investments, a positive effect on technological progress is achieved in the long-run as income and income per labor move up the development ladder. Another important observation is the negative effect of excessive inflation on physical capital: very high relative prices cause a relative decline in the effective physical capital stock in the economy, and in the long-run may cause a relative decline in the growth of income per labor.

Talking of high relative prices, causality analysis on the ADL growth model suggests that inflation shifts are considered a causation variable to growth, implying a growth behavior sometimes referred to as 'real inflationary growth' [2,13,32,35]. The long-run solution suggests that inflation has a positive effect on income per labor but also has a negative (counter-cyclical) effect on physical capital. There are therefore two conflicting forces acting on the long-run response of income per labor. The first is due to high inflationary pressure on assets and investments tending to decline their real value through time, causing a relative decline in physical capital accumulation and thus a relative decline in long-run output and income. The second, however, is that inflation shifts tend to have a positive effect on income per labor as a 'spill-over' effect to monetary shocks as the economy performs within its own business cycle. It is evident that these two forces work in opposite directions , but it is also evident from the ADL model results estimated earlier that the economy behaves with inflation spill-over effects (through the positive effect of inflationary pressure on the economy’s business cycle) dominating the direct effect on physical capital or investments. Therefore, inflation as evidenced by a relative increase in prices acts as a positive stimulus for economic growth in the long-run with the condition that excessive or hyper-inflation are not too severe to damage the business cycle effect. This is a sharp conclusion basically set for by the theory of pecuniary externalities new to the literature on growth theory [2,32].

Another important causality result on the Egyptian economy's growth behavior is that exchange rate adjustments are non-casual to the long-run growth of the economy. However, the level of static exchange does have an effect on short-run income with insignificant causation responses to their respective adjustments. This implies that a static analysis of growth will lead to the conclusion that the exchange rate is a significant causation variable to long-run income. A dynamic analysis, on the other hand, will conclude that static exchange rates only have short-run income responses with long run non-causality. If the performance of agents is more rational than adaptive, the results of the dynamic model would be a more accurate description of their behavior, whereas if the performance of agents is relatively more adaptive than rational, then the static outcome of long-run causality would be a more realistic conclusion. With the assumption that agents are more rational in their decision-making process than being passively adaptive (especially active financial agents – along with their financial expectations, in particular), the conclusion of short-run responses with long-run non-causality is a better description of actual agents' behavior. A rational agent is assumed to quickly adjust his prices and the amount of goods supplied to the magnitude of exchange rate changes or adjustments in the economy this period, along with his rational expectation of its changes the next period based upon all information available at his disposal. Therefore, exchange rate shocks to the economy will only have short-run responses with insignificant long-run changes to the economy's growth path, implying that exchange rate adjustments are a non-causal factor to long-run income growth[15].

Human capital, although a weakly exogenous variable in the ADL model, is *failed* to be rejected as a causal variable to long-run growth. Human capital is therefore weakly but not strongly exogenous to the productive system of the economy. The accumulation of quality skills through education or via the work-force positively contributes to the long-run welfare path of the economy. The long-run solution of the causality model for human capital suggests three possible effects: a positive effect on real output per labor (and real income per labor), a negative effect on physical capital accumulation, and a positive effect on the residuals. The first result is a consequence of human capital as an effective factor in the production process, with an increasing return to output, yet with a diminishing marginal product. The second result politely suggests that human and physical capital are considered (imperfect) substitutes in the production process of the economy. This means that if substantial resources are allocated more to one factor, such as human capital (through educational subsidies, scholarships, training, or a better-quality educational, training or employment system in general), then not enough resources - either private or public - could be allocated to the second factor i.e. to physical capital. This explanation has an implicit assumption within its own words, namely that the economy behaves under full employment and under a resource capacity binding constraint. Relaxing one of these assumptions could have other points of views in conflict with what we have here. However, taking the conservative view for a moment, it is concluded that human capital extracts available resources that could have otherwise been used to buy new assets or engage in productive investments with positive net returns. Turning to the third result, it suggests that human capital has a positive effect on residuals, thus causing a better environment for technological progress and/or at the same time increasing the productivity of current technologies through better quality skills of the labor force. The accumulation of human capital in the economy increases the likelihood of higher productivity, a better chance for constructive ideas and innovations, a healthier work environment, and an increased awareness of social participation. This may ultimately lead to additional savings, more profits, better wages, and to a higher welfare path for the economy. On the other hand, human capital obeys a strictly

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[15] Yet, a more elaborate analysis on this subject is suggested measuring the sensitivity of income responses to exchange rate adjustments using an *AR(2)* or an *ARMA(2,1)* stochastic shock for the real effective exchange rate in a real-business cycle model.

concave return to output, implying a low value-added contribution with sharp diminishing returns as the economy's accumulation of human capital reaches its saturation point. Therefore, a careful welfare scheme for human resource expenditures is needed based on the level of human capital in the economy in addition to the absorptive capacity of the labor force and potential for technical progress. Another important result from the causality analysis for human capital is that the long-run behavior of inflation and exchange-rate adjustments do not have a significant effect on the level of human capital accumulation. Inflation shifts and money supply disturbances therefore do not contribute to the accumulation nor allocation of human capital resources in the economy.

Exogeneity and causality analysis on the generalized ADL growth model for Egypt show, among other things, that there are two weakly exogenous factors to the productive output of the economy: human capital accumulation and exchange rate adjustments, the former being a causal factor to long-run growth while the latter being non-causal in the long-run but with short-run causality. In addition, there are two other causation factors to the long-run growth of the economy, and these are: physical capital accumulation and inflation, as evidenced by the economy's positive attribute of real inflationary growth. The weakly exogenous human capital causation variable includes a positive income response to primary educational attainment and a negative (or mildly counter-cyclical) income response to post-primary educational attainment. The analysis also suggests that, among all variables considered, there were no strongly exogenous variables to the growth path of the economy.

III.6: Co-integration Restrictions and the Co-integrated MRS Model

After testing for weak exogeneity and Granger non-causality, co-integration analysis have been conducted to test whether there are any co-integrating relationships between the significant variables in our ADL growth model. A co-integrating relationship between two variables signifies that a linear combination of them removes the unit root [28,41]. That is, if two variables y_t and x_t are I(1) and a linear combination of them $\{y_t - Kx_t\}$ yields an I(0) process[16], then these two variables are said to be co-integrated [29]. Restriction tests for co-integrating vectors in ADL and *VAR* systems compromise a vast set of literature, with evidence suggesting that most aggregate economic variables are better regarded as integrated in a *VAR* system than as stationary variables [in 3,4,28,29,38,40,41,42,44,45, and 46]. Co-integration restriction tests for our growth model framework resulted in at least one co-integrating vector to be significant (Table 15 and Graph H). The reduced form of the long-run solution imply that a co-integrating relationship between physical capital accumulation and income per working population exists, and that *(Y/KL)* follows a strong correlation with inflation. Analysis on the co-integration vector imply that human capital accumulation is having little valuable significance on long-run growth. The co-integration relationship takes the following form in both the short and long-run, implying a relatively constant marginal rate of substitution between factor inputs in the economy:

$$lnYL = lnK + 13.66\ lnR + 0.66717\ lnH$$

Speeds of adjustments (alpha coefficients) for the variables show relatively high speeds of adjustments towards a long-run balanced growth path, especially for *lnK*:

lnYL	-0.13472	(0.089203)
lnK	-0.47121	(0.097453)
lnR	-0.16664	(0.095164)
lnH	0.15119	(0.042578)

[16] $\{y_t - Kx_t\}$ is I(0) also implies that (y_t,x_t) are jointly weakly stationary. From this, $E[y_t]=KE[x_t]$ and $E[y_t-Kx_t]=0$.

Inflation also shows a relative fast convergence, yet human capital is shown to be diverging away from its equilibrium path (also seen non-converging in Graph K) . With a diminishing marginal product, human capital is seen to be either marginally unproductive to real output or taking a larger share of resources than what it should take at equilibrium, assuming a binding resource capacity constraint. Both explanations could be valid given government's policy of emphasis on human educational attainment in spite of the fact of increasing disguised unemployment in the labor market. This policy stems from a social norm in society whereby low educational attainment is considered inappropriate for work in the labor market even if the job scope does not necessarily require such an attainment. This is only false for low-paid unskilled labor [62,63]. Government subsidies from primary to secondary to higher degrees has produced a high educational attainment that has not been effectively utilized by the private sector thereby depleting scarce resources that would have otherwise been productive in physical capital or technological innovation. On the other hand, human capital is found to be a causal variable to long-run growth with positive returns to long-run output. Thus, a higher educational setting of the Egyptian society *does* in fact lead to a higher welfare status. Good governance with respect to capital budgeting of human resources needs to be addressed and resource-allocation costs weighed for better understanding of the forces of human capital growth to long-run income. Causality of human capital formation to growth is evident but the more important question is: what kind of comparative causality relationship does human capital contribute, and how can the optimal level of human resource allocation be achieved within a binding resource capacity constraint? Unfortunately, these questions need substantial additional research beyond the scope of this paper. The main result, though, is evident: the co-integration relationship signifies that all factor inputs positively contribute to long-run income, with labor, physical capital, and human capital acting as imperfect substitutes in the economy's production process. In addition to the above result, the coefficients of income per labor *and* physical capital accumulation were failed to be rejected to have their values reduced to unity. This has a very significant economic interpretation, namely that there exists a *constant and stable* marginal rate of substitution (MRS) between the two factor inputs, physical capital and labor. This can be seen by re-writing the above relation in power form as:

$$(Y/KL) = H^{0.67} R^{13.7}$$

The above equation signifies a constrained aggregate production function for the economy, with two main binding constraints. First, it suggests that there exists a constant marginal rate of substitution between physical capital and labor, given that human capital and inflation are both held constant over time. This means that the economy's production process is integrated with its own labor and investment supplies and that both factors work as an internal engine for growth of the economy. On the other hand, inflation and the accumulation of human capital provide additional sources for growth on an external level form for the economy's production process. Human capital shifts the substitutability between physical capital and labor on a higher scale giving rise to a more efficient productive system and therefore to a higher level of output. Intuitively, an increase in human capital means better productivity in the workplace and hence a lower amount of labor needed to attain the same level of output. With the same argument, a lower amount of investment is needed to contribute to the same level of output (or conversely, a higher human capital implies that the same investment expenditures will lead to higher returns because of better productivity and therefore to higher output in the economy). Second, the exponent of inflation is strikingly high as compared to the generalized ADL model described above. This is only true because of the imposed constraint of no constant term in the production process. This constraint has the interpretation of restricting the productive resources in the economy to be always needed for any output to be attained. In other words, with no labor nor investments, the economy is assumed to produce zero output. Also included in the exponent of inflation is the residual effects of technology i.e. learning-by-doing effects. The co-integration model therefore acts as an auxiliary model to the generalized ADL growth model, with a binding co-integration vector which implies a constant and stable MRS between physical capital and labor. The co-integrated MRS model also implicitly includes learning-by-doing effects in technology.

Since technological progress has only been implicitly included within the residuals of the ADL and co-integration MRS models, one can safely say that both the ADL model and the co-integration MRS model do not fully account for the growth behavior of the economy, namely because they are missing an important parameter in their structure: learning-by-doing technological effects, or residual technological progress. The growth of the Egyptian economy cannot be fully analyzed without including this important implicit parameter *explicitly* into our system. The next section explores the relevance of other omitted variables on the ADL model with residual technological progress almost surely significant for long-run growth. Learning-by-doing is further explored in the section following the next.

III.7: Lagrange Multiplier Tests for Some Omitted Variables

Lagrange-Multiplier tests [28,40] for short-run effects of omitted variables (on a trend, government's share of income, residual technological progress, real absorption per labor, and real adjusted current account balance) have been tested and found to be:

Lagrange Multiplier test for omitted variables:

Trend Variable (or Year)	F(1, 36) =	1.4308 [0.2395]
Government's Share of Income	F(1, 36) =	3.6656 [0.0635]
Residual Technological Progress	F(1, 36) =	4664.9 [0.0000] **
Real Absorption per Labor	F(1, 36) =	16.334 [0.0003] **
Real Adjusted Current Account Balance	F(1, 36) =	36.194 [0.0000] **

Imposing a trend variable in the generalized ADL model has no statistical significance on model results. The same is true of adding a government expenditure to income ratio (or government consumption to GDP per labor), although the non-significance percentage rate is very low. However, three variables are considered significant to short-run responses of the model:

1. Residual technological progress[f] effects, with a one-lagged operator,
2. Absorption of the economy per unit of working labor population, and
3. Discounted current account balance (using 1990 base year GDP deflator).

The last two variables are expected to have a significant role in short-run responses of income per labor since they are encompassed by it and are therefore subsets of the dependent variable in the ADL model. Finding them insignificant would have been an erroneous result. Being subsets of the dependent variable is by itself a reason for suspecting autocorrelation between them. However, a subcausal relationship has to be tested on the long-run model with additional parameters relevant to international trade imposed, and this is beyond the scope of this paper. Residual technological effects, on the other hand, is a different story. The Lagrange-Multiplier test has failed to reject residual technological progress as a significant omitted variable, implying that technical progress is of importance to long-run responses of the dependent variable and to the growth path of the economy. Technological progress is therefore expected to have a positive causal relation to long-run income growth and is also expected to marginally contribute to future income through learning by doing effects, among other positive externalities to output. Technical progress indirectly contributes to long-run growth through its interaction with other factor inputs in the production process of the economy, and it also acts to increase the efficiency and effectiveness of the transformation of those inputs into real output. Incorporating a residually-adjusted learning-by-doing effect on the above ADL model and testing the significance of its short-run and long-run responses to income is therefore mandatory for explaining the real growth behavior of the Egyptian economy.

III.8: Learning-By-Doing, VAR Nesting, and Model Encompassing

A vector-autoregressive system (*VAR* system) for the incorporation of residual technological progress on long-run growth was estimated based on the generalized ADL model with the co-integration restrictions imposed. Incorporating learning by doing effects on the ADL model using a one-period polynomial lag adjustment for the residuals resulted in the following error-correction mechanism for long-run learning by doing effects (see Table 16 and Graph I):

lnA = -0.349053 + 0.218122 lnYL ;

where *A* represents residual technological progress with a one-period lag adjustment.

In the above analysis, a learning by doing power function for residual technological progress [57,58,43] was assumed to be

$$A = Bf(Z)^{\varphi}$$

where $\boldsymbol{Z}$ represents all endogenous variables, with $f(\mathbf{Z}) = lnYL$, and $\varphi<1$.

φ is assumed to take values less than unity to account for decreasing returns to scale in knowledge production (and therefore in technological progress) on output per worker [57,58]. For the Egyptian economy, learning by doing effects on income per labor have been found to be significant to long-run growth and this provides a *marginal* approach [52,58] in explaining the true long-run path of the economy. Although some arguments for learning by doing effects suggest that they provide a full endogenous model explaining the real sources of technical growth [7,8], these arguments none-the-less do not claim that learning-by-doing *per se* can provide a full explanation of the input factors' contribution to the economy's balanced growth path. Therefore, residual technological progress only marginally explains the growth path of income for the economy. On the other hand, the generalized ADL model is not fully equipped either. It lacks learning-by-doing effects and lacks accounting for substitution between physical capital and labor. However, it does contain all direct factor inputs in addition to the significant inflationary pressure and the (long-run non-significant) exchange-rate adjustments. The ADL growth model will therefore fully explain the true long-run behavior of the Egyptian economy only after it is augmented by the other two models in our system: the co-integration MRS model and the learning-by-doing model for technological progress. When integrating learning-by-doing as the *marginal* model and generalized ADL model as the *conditional* model together for explaining the long-run growth path of the economy, a solvable vector system is achieved. However, this solvable system will not yield an error-correction solution because of the co-integration relationship within its variables. Therefore, the co-integrating relationships between factors inputs have to be added to the vector system in order to arrive at a long-run *VAR* system that can truly explain the behavior of the Egyptian economy's balanced growth path.

Integrating learning by doing effects on the growth-causation ADL model estimated earlier, along with the co-integration MRS model, defines the *VAR* system for the economy. From this, the *VAR* system can now be written in terms of three inter-dependent models:

(1) the *conditional* generalized ADL growth model,
(2) the *co-integrated* model with constant marginal rate of substitution between factor inputs, and
(3) the *marginal* model incorporating residually-adjusted learning by doing effects.

Conditional Model: lnYL = - 0.891866 + 0.434586 lnK + 0.789028 lnR + 0.153911 lnH
Co-integrated Model: lnYL = lnK + 13.66 lnR + 0.66717 lnH
Marginal Model: lnA = - 0.349053 + 0.218122 lnYL

For balanced sustainable growth, the error-correction mechanism[11] approaches zero in the long-run, and solving & testing simultaneously yields the restricted *VAR* ‘nesting’ model of the following form:

$$\boldsymbol{y_t} = \sum_{\boldsymbol{i}=1}^{\boldsymbol{m}} \pi_{1\boldsymbol{i}} \boldsymbol{y_{t-i}} + \sum_{\boldsymbol{j}=0}^{\boldsymbol{r}} \pi_{2\boldsymbol{j}} \boldsymbol{z_{t-j}} + \boldsymbol{v_t} \quad \text{with } \mathbf{v_t} \sim \mathbf{N}(0,\Omega) \text{ and } \pi_1(\boldsymbol{L})\boldsymbol{y_t} = \pi_2(\boldsymbol{L})\boldsymbol{z_t} + \boldsymbol{v_t}.$$

The *VAR* nesting model describes the behavioral long-run balanced growth path for the economy and is characterized by having zero *restricted* standard errors for all the coefficients. This restriction follows the error-correction mechanism whereby the long-run solution is assumed to be an exact solution of the economy's balanced growth path [28,41,42], assuming all economic agents are optimizing and are rational and assuming no persistent aggregate shocks to the economy's business cycle. Applying this approach to our data using the above behavioral equations; it can be seen that the conditional, co-integrated and marginal models converge to the following long-run growth path:

ln(Y/AL) = -0.8783 + 0.4289 lnK + 0.6924 lnR + 0.1369 lnH

Thus, along its balanced growth path, the *VAR* system reduces to the following long-run production function (Graphs J, K, and L, with phase diagrams in Graphs M and N):

$$\frac{\boldsymbol{Y}}{\boldsymbol{AL}} = 0.415(\boldsymbol{K})^{0.43}(\boldsymbol{H})^{0.14}(\boldsymbol{R})^{0.69}$$

This is only true because of the residually adjusted learning by doing effects on long-run income per labor. In other words, the *ECM* residuals have been taken from the conditional model and tested as a dependent variable in the marginal model for analyzing learning by doing effects on income. From this result, one can suspect that the co-integrated model as a restricted form of the conditional model can be relaxed in the *VAR* system with a model reduction test. Therefore, although the co-integrating vector is significant in the conditional model alone, it is found to be insignificant when modeled within the *VAR* system. The economy has behaved with a relatively constant marginal rate of substitution between factor inputs and with production isoquants correlated with inflation, but these behavioral conditions are neither necessary nor sufficient for balanced sustainable growth.

Model reduction tests (Table 17) resulted in the conditional model encompassing the co-integrated model, with the marginal model taken as *exogenous* to the *VAR* system. Encompassing and invariance tests for the conditional and marginal models resulted in rejecting the first model to encompass the second, while also rejecting the second to encompass the first. Both models fail to encompass the *VAR* nested model. Therefore, both models are dominated by and are inferentially redundant relative to the *VAR* nested model. After adjusting for structural macroeconomic fluctuations and incorporating learning by doing effects with polynomial lag operators, the balanced growth model for the economy yielded 42.89% of long-run income growth explained by accumulation of physical capital, and 13.69% explained by human capital formation. Both human and physical capital accumulation therefore contribute to growth, yet the effectiveness of capital markets and the efficiency of financial intermediaries are considered of more importance to growth than a higher educational attainment of the working labor population. A dynamic inflationary pressure of 0.6924 on real income growth have been found to be significant in log-difference form. Residuals account for 43.42% of changes in income per labor including learning-by-doing effects and inflation shifts. After adjusting for inflation, however, effective technological progress have been found to be *1.92%* per year over the past half-century of Egypt’s economic performance.

III.9: A Conclusive Assessment to the Simultaneous VAR System

What does all of this mean? Well, one can say that the behavior of the Egyptian economy during its past half-century of performance has been a relatively passive one with the exception of the last five or six years at which time real steady growth started to appear. Physical capital accumulation has been the main drive for the economy’s growth path with the savings rate appearing to follow a random walk process, a phenomenon that leads to real inflationary growth. Value-added capital and the allocative efficiency of physical capital have been positively utilized and are seen to have significant positive effects on the long-run growth path of the economy. This does not mean, however, that the economy is sustainable and is moving along a balanced steady path in the long-run. Human capital and technology are two important factors that have not been effectively utilized nor efficiently absorbed into the Egyptian socio-economic system. Human capital is seen as a weakly exogenous parameter in the growth path of the economy while technological progress is only seen as marginally significant. Whereas equilibrium convergence has been realized with respect to physical capital, human capital is seen to be diverging away from its equilibrium path. Therefore, one can say that the behavior of the Egyptian economy is not on its optimum track, since balanced sustainable growth can only occur when all factor inputs are on a steady growth path, cyclically fluctuating around it, or converging towards it in the long-run. In the case of Egypt, this is only true for physical capital and inflation but not for the accumulation of human capital. There has been a high educational attainment level in the economy but this was not effectively absorbed by the socio-economic system causing financial leakage away from sustainable growth. Expenditures on human capital could have been utilized more efficiently or allocated elsewhere, but excessive expenditures in education (especially in post-primary education) caused some finances in the education sector to create their own opportunity costs, and in the long-run caused human capital to cyclically diverge from its optimal path. Technological progress has also been weak to grow with time and with income. Technical progress is seen to be mildly significant to the long-run growth path of the economy, yet in addition it lies mostly in the hands of exogenous technologies through learning-by-watching more than learning-by-doing effects, implying that endogenous technological change did not contribute as much to the economy's progress as did borrowed technologies. Also, the dynamic interaction between the different productive inputs in the economy show very little changes through time, especially the interaction between physical capital and labor. This has the advantage of a stable substitution between factor inputs but also has the disadvantage of producing the same output the same way over and over again, causing very little innovation and idea creation, and therefore to a traditional and monotonous production and/or technological technique. Lack of new production techniques and insufficient creativity would obviously bring growth to a halt even when the economy's capital resources are being intensified. Therefore, it is very reasonable to assume that the Egyptian economy's total capital resources have not been fully utilized because of insufficient endogenous technological change. This may be true because of ineffective capital acquisition by local investors on a mass-production scale, or because of market entry barriers to some markets already absorbed by multi-national enterprises of monopolistically-competitive increasing returns to scale, or because of an inefficient risk-averse behavior on the part of Egyptian goods suppliers and investors, or because of ineffective financial intermediation and lack of market regulatory laws, or because of a bureaucratic institutional structure, or because of social norms including a resistance to change attitude, or because of all of the above combined. In any case, the socio-economic system needs a big push in its institutional base and work habits, government and political re-structuring, in addition to regulatory and decentralized policies directly aiming at long-run national welfare. This, for a better prospect of this country's future.

IV: GENERAL CONCLUSIONS

To remind the reader, the objective of this research has been to model and test aggregate production functions on the Egyptian economy and to analyze the effect of physical and human capital formation on the economic growth path of Egypt, using a vector-auto-regressive *(VAR)* structural econometric approach. Economic data from 1950 to 1997 have been tested for unit roots, orders of integration, distributed lags, growth causation, weak exogeneity, strong exogeneity, and co-integration, using a general to specific modeling technique. An error correction model utilizing all growth-causation factors was estimated and tested using a model typology of simple dynamic systems. Factor inputs (labor, physical capital, human capital, and technological progress) and structural macroeconomic factors (inflation shifts and exchange rate adjustments) have been analyzed within an ADL system framework. The conditional ADL model, co-integration restricted model, and marginal model describing learning by doing effects resulted in a nested *VAR* system describing the economy's balanced growth path.

The dynamics of the nested VAR system imply the following general conclusions:

1. the economy behaves as a nested growth system with (1)- a long-run *conditional* distributed lag model, (2)- a *marginal* learning-by-doing model for endogenous technological change, and (3)- a *co-integrated* model with constant short-run marginal rates of substitution between factor inputs
2. the economy shows decreasing returns-to-scale in aggregate production, with quasiconcave output with respect to physical capital accumulation and strict concavity of output with respect to human capital formation
3. human capital acts as a weakly exogenous factor to short-run output
4. the economy exhibits constant complementarity between physical capital and labor in the short-run and with production isoquants correlated with inflation, but these behavioral conditions are neither necessary nor sufficient for balanced sustainable growth
5. the allocative efficiency of physical capital accumulation was shown to be the significant driving force to the growth of real income
6. significant but weak learning-by-doing effects in technology (effective technological progress have been found to be *1.92%* per year over the past half-century of Egypt's economic performance mainly due to exogenous or borrowed technologies)
7. speeds of adjustments towards equilibrium levels show a relatively high speed of adjustment for physical capital with human capital shown to be cyclically divergent from its equilibrium path
8. positive output returns for primary-school educational attainment and negative output returns for post-primary educational attainment
9. the aggregate savings rate follows a random walk process with no drift
10. *VAR* nested model on balanced growth path was estimated to be $\frac{\boldsymbol{Y}}{\boldsymbol{AL}} = 0.415(\boldsymbol{K})^{0.43}(\boldsymbol{H})^{0.14}(\boldsymbol{R})^{0.69}$
11. exchange rate adjustments were found insignificant to long-run income although having a high degree of economic causality to short-run output
12. model reduction tests resulted in the conditional model encompassing the co-integrated model with a parsimonious marginal model, although encompassing and invariance tests for the conditional and marginal models resulted in both models failing to encompass the *VAR* nested model
13. fluctuations of actual to equilibrium values (deviations from balanced growth path) for long-run income were found to have a cyclic effect on physical capital and an increasing effect on human capital
14. all of the above conclusions imply that the country's overall economic performance has been relatively passive, especially within two major areas pertaining to growth: human capital (inefficient human capital utilization) and technology (weak endogenous innovations and weak learning by doing effects)

V. POLICY IMPLICATIONS

The first policy recommendation which comes to mind is due to human capital formation: *insignificant causality of human resource expenditures and weakly exogenous human capital formation to long-run economic growth* (mainly due to excessive government educational subsidies of the post-primary education sector). A major policy-related conclusion from this research is that it is not the quantity of educated human resources that accounts towards a balanced growth path, but it is the *quality* of science and market-based education that can only make this possible. This effect is also inflated due to the strict concavity of output with respect to human capital and the rapid decline of marginal productivity of labor in production. A valid policy target could be to shift some budgetary resources away from post-primary educational subsidies towards more innovative investments and towards a larger stock of physical capital accumulation. Since the economy behaves as an ADL co-integrated model with physical capital accumulation having the largest share of causality to long-run income, one can conclude that physical capital is the driving force to the economy's progress and *a more efficient, less beauraucratic, capital market structure is urgently needed*. An increase in the aggregate savings rate and/or improvements in the efficiency of capital into industrious output is an important target that should be addressed. Moreover, *exchange rate devaluation shocks to the economy drive the already high risk-averse behavior of suppliers into an inefficient short-run response.* Exchange rate shocks of the past have caused short-run disturbances to income with a converging pattern towards its previous trend. A devaluation with austerity may not be the current solution to the economic problems at hand. Incorporation of mass production technologies with significant learning by doing effects and positive externalities to output could be an important policy target instead.

Current production is decreasing returns to scale with a *quasiconcave output function with respect to physical capital accumulation and strict concavity of output with respect to human capital and labor*. However, the *VAR* model suggests that the economy is capable of a more substantial learning effect through better productivity in labor and investments *whenever fit into an efficient balanced growth system*. The current marginal rate of substitution between factors inputs needs to be optimized towards that end. Capitalization of high-tech research and development efforts to positively complement the anticipated learning by doing production technologies is an important policy stimulus for sustainable economic growth. Thus, *the role of the state should mainly be directed towards that of a balanced system controller rather than acting as an economic agent within the system*. A cost-benefit analysis for gains and losses to budgetary re-allocations within a competitive market structure should be thought of as a profit-optimizing objective but within the scope of economic welfare and a long-run homogeneous social structure for the Egyptian socio-economic system at hand. It is evident from the *VAR* nested model that effective technological progress has a positive, yet cyclic, effect on long-run income. Thus, a real business cycle analysis of policy recommendations is preferred, for it could be true that the economy is hungry for physical capital and innovative investments but once assets have been bought and equipment and/or franchises contracted, a recession could be under way due to lack of the institutional structure catching up with the external learning by doing effects, the result of which could be a short-run positive growth divergent from the economy's sustainable balanced growth path, leading to a net long-run recession, i.e. a trap.

Also, it seems evident from the model results that the behavior of the economy seems to be that of 'real inflationary growth'. However, excessive inflation renders this growth as ineffective in the long-run with a counter-cyclical effect on physical capital accumulation. Thus, *a sound economic policy could allocate a fiscally-binding budget gap with targeted inflation keeping prices determined according to the dynamic competitiveness of markets with an effective regulation of monopolies (whether state or private)*. Another policy-related aspect is the recent trend of consumption behavior in the economy with a relative increase in the average propensity to consume. Income distribution policy implications of this trend could be done through distributional inequality indices of welfare within the scope of a capital-intensive technological breakthrough. It has been shown from the balanced growth *VAR* analysis that long-run income per effective worker shows a converging trend with increased technological progress. This could be true due to the fact of 'borrowed technologies'. That is, the residually adjusted technological progress may be evident because of increased production and increased innovative investments from joint-ventures or multinationals crowding-out local innovations. The existence of imported or 'borrowed' technologies may have a positive influence on growth through learning by watching, followed by input market innovations and real local technological progress. However, crowding out effects of local investors could have a negative effect on growth, since local entrepreneurs could be capable of knowledge and idea creation but incapable of market entry due to their decreasing returns to scale in production relative to borrowed increasing returns, or due to market imperfections, consumption demonstration effects of imported goods, or because of locally inefficient capital markets. Policy implications, then, would be *improvement of the capital market infrastructure, improvement in local marketing skills, incentives for export production and promotion, and improvement in financial intermediaries and financial credit systems.* Additional policy recommendations include incorporation of locally-based large-scale production units by innovative entrepreneurs, incentives for increased physical capital accumulation with positive returns to labor, and dispersion of human capital towards current primary school subsidies with post-primary competitiveness. On the monetary-fiscal policy debate, policy implications from the nested *VAR* system developed in this paper as applied to the Egyptian economy are rather strong and unbiased: *a more restrictive monetary policy towards exchange rate stabilization, inflationary-controlled growth with an optimal fiscal-gap binding constraint, and incentives* *for technological breakthroughs which can shift the economy's resource capacity onto a higher production-possibilities frontier.*

Although the analysis done in this paper may seem rather detailed and somewhat comprehensive, there are many policy and distributional factors in the Egyptian economy which were not included in our modeling system. Thus, labeling the nested *VAR* model in this paper as conclusive is very far from the truth. Several extensions are needed. For example, sectoral analysis of the three main sectors of the economy (agriculture, industry, and services) is mandatory for a more efficient description of the economy's dynamics. Moreover, demographic transitions, resource allocations, institutional and external politics, and good governance, are all equally important. Expanding on the last two points may be the most effective in converging the *VAR* model towards a more balanced socio-economic system with a political face. As Roger Owen [53] has pointed out that "just as important… are the ongoing questions of war and peace and of the [political] balance between population and resources" to the economic development and growth in Egypt and in the Middle East as a whole. Thus, *a homogeneous social system with a balanced distribution of income must be a constraint within the optimal allocation of resources and investment activities conducted by government policy*. Regional integration issues and globalization of trade, GATT, and other Western-influenced barriers to autonomous development must be addressed, assessed, and evaluated based on normative national interests. It could turn out that there is a mutual benefit to such impositions, but careful national welfare analysis must be stressed with long-run welfare targets in mind. Austerity and privatization are only *necessary* conditions for achieving long-run growth and welfare, but these conditions may not be *sufficient* for long-run social optimum. With the theory of second-best in perspective, capital-deepening policies may not be as desirable as they seem when further assessed from a social welfare optimum point of view (rather than from a pure capitalistic point of view). *Capital deepening with austerity may transfer the allocation of resources from state-owned to private hands, but the social deadweight loss due to imperfect competition and monopoly in the private sector is sure to persist if adequate regulatory reform is not persevered.* Moreover, excessive capital deepening may increase inequality in the long-run, allowing for contraction of society's middle class and expansion of the lower class, giving rise to a social pyramid structure. Although desirable from an architectural point of view, a pyramid structure may segregate a once homogenous population into two main social classes, leading to a dis-normal distribution of wealth, and if persistent with time, may lead to social unrest, a social trap (via the savings-investment trap), and to a probable social and/or political chaos. Therefore, a multi-objective allocative optimization strategy is recommended for a homogenous Egyptian socio-economic system in the long-run, with two main *strategic objectives* in mind: *(1) maximization of long-run income per working labor population, and (2) minimization of a social welfare loss function exhibiting deviations from the first-best social optimum*. The second objective could be constrained by the first, or the first could be constrained by the second, depending on the structure and parameters of the suggested model. In either case, a second-best solution is likely to be the outcome since a tradeoff is needed in balancing the given objectives, with the optimal solution dependent on the current and expected political objectives of the country. And from here there goes once again the never-ending debate between growth and equity: which one first, and which one least; whereby a multi-objective agenda has to be placed on decision-makers, politicians, (and even journalists), and most importantly the general public who is already well-aware of such trade-offs and who is already seeing a transition to a new socio-economic system, with its real returns not being realized as of yet.

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Table 1: Descriptive Statistics for K, L, Y, YL, and H

	K	**L**	**Y**	**YL**	**H**
Sample size	48	48	48	48	48
Mean μ	79.749042	10.312606	29.405241	2.510994	24.502886
Std Deviation σ	55.334431	3.446413	20.195053	1.050888	13.966657
Skewness	0.236808	0.431368	0.539373	0.017481	0.990741
Excess Kurtosis	-1.392794	-0.980319	-1.089707	-1.253231	-0.229596
Minimum	1.660081	5.534430	3.996960	0.722199	9.616200
Maximum	180.666784	17.264685	69.735095	4.050236	58.361287
Normality χ^2	10.851	7.7072	14.678	5.354	25.683
Probability of H_0 **: Normal**	[0.0044] **	[0.0212] *	[0.0006] **	[0.0688]	[0.0000] **

* 5% significance, ** 1% significance

Skewness $= \frac{m_3}{m_2^{3/2}}$, Excess Kurtosis $= \frac{m_4}{m_2^2} - 3$, with $m_i = \frac{1}{T}\sum_{t=1}^{T}(x_t - \bar{x})^i$

Normal Distribution of a random variable x is defined as the Gaussian density function:

$$f_x(x|\mu_x, \sigma_x^2) = (2\pi\sigma_x^2)^{-1/2} \exp\left[-\frac{(x-\mu_x)^2}{2\sigma_x^2}\right]$$

Table 2: Correlation matrix

	K	**L**	**Y**	**YL**	**H**
K	1.0000				
L	0.98177	1.0000			
Y	0.98255	0.99272	1.0000		
YL	0.98541	0.96923	0.97192	1.0000	
H	0.93952	0.97678	0.97952	0.91061	1.0000

The correlation coefficient is defined by

$$\rho = \frac{\sum_{t=1}^{T}(x_t - \bar{x})(y_t - \bar{y})}{\sqrt{\sum_{t=1}^{T}(x_t - \bar{x})^2 \sum_{t=1}^{T}(y_t - \bar{y})^2}} = \frac{\sigma_{xy}}{\sigma_x \sigma_y}$$

Table 3: Unit root tests for K, L, Y, YL and H

	t-adf	beta Y_1	\sigma	lag	t-DY_lag	t-prob	F-prob
K	-2.6971	0.78242	4.1034	5	1.1467	0.2595	
K	-2.4578	0.80967	4.1218	4	0.29522	0.7696	0.2595
K	-2.5265	0.81697	4.0692	3	1.4242	0.1630	0.5029
K	-2.1923	0.84507	4.1253	2	0.79498	0.4317	0.3497
K	-2.0661	0.85975	4.1053	1	2.2339	0.0314	0.4164
K	-1.6020	0.88780	4.3102	0			0.1380
L	0.21160	1.0067	0.041149	5	-0.28766	0.7754	
L	0.11839	1.0035	0.040606	4	-0.30659	0.7610	0.7754
L	-0.0047753	0.99987	0.040092	3	0.097955	0.9225	0.9168
L	0.12703	1.0020	0.039552	2	1.5810	0.1224	0.9799
L	0.80027	1.0116	0.040325	1	0.043728	0.9653	0.6492
L	0.86918	1.0118	0.039805	0			0.7748
Y	-1.0520	0.96156	0.93490	5	-0.20176	0.8413	
Y	-1.1177	0.96031	0.92200	4	-1.2872	0.2065	0.8413
Y	-1.3054	0.95371	0.93038	3	0.068176	0.9460	0.4463
Y	-1.3257	0.95403	0.91778	2	-0.30356	0.7632	0.6501
Y	-1.3955	0.95262	0.90675	1	3.4354	0.0014	0.7813
Y	-1.1293	0.95670	1.0247	0			0.0447
YL	-2.8215	0.65602	0.086060	5	0.80168	0.4283	
YL	-2.7768	0.70102	0.085620	4	0.64214	0.5250	0.4283
YL	-2.8509	0.73509	0.084918	3	1.4680	0.1508	0.5960
YL	-2.4127	0.79795	0.086233	2	0.66205	0.5120	0.3832
YL	-2.3765	0.82199	0.085593	1	3.0386	0.0043	0.4764
YL	-1.3693	0.89271	0.094196	0			0.0464
H	0.65443	1.0317	0.64339	5	3.4487	0.0015	
H	1.8006	1.0930	0.73674	4	-1.2437	0.2219	0.0015
H	1.2951	1.0465	0.74232	3	-0.14639	0.8844	0.0029
H	1.5044	1.0434	0.73243	2	-0.17488	0.8621	0.0079
H	1.5765	1.0415	0.72303	1	-2.5935	0.0134	0.0170
H	0.75122	1.0201	0.77429	0			0.0030

Critical t-adf values: 5%=-2.932 1%=-3.593; Constant included

Table 4: ADL tests for lnK, lnL, lnY, lnYL, lnH, lnE, and lnR

Variable	*Constant*	*Lag 1*	R^2	*F-test*	*F-prob*[a]
lnK					
Coeff.[b]	0.4887	0.9012			
Std.Err[b]	0.03649	0.008919	0.995612	F(1,45)= 10210.2	[0.0000] **
lnL					
Coeff.	0.02294	1.001			
Std.Err	0.002847	0.001244	0.99993	F(1,45) = 646936	[0.0000] **
lnY					
Coeff.	0.1459	0.9723			
Std.Err	0.02078	0.00655	0.997962	F(1,45)= 22032.1	[0.0000] **
lnYL					
Coeff.	0.07538	0.9517			
Std.Err	0.01024	0.01092	0.994111	F(1,45)= 7596	[0.0000]**
lnH					
Coeff.	-0.009771	1.016			
Std.Err	0.01668	0.005427	0.998717	F(1,45) = 35041.5	[0.0000] **
lnE					
Coeff.	0.06175	1.027			
Std.Err	0.02695	0.03046	0.961952	F(1,45) = 1137.72	[0.0000] **
lnR					
Coeff.	0.01803	0.7848			
Std.Err	0.009566	0.09093	0.628651	F(1,44) = 74.4868	[0.0000] **

a: F-prob of $H_O : \beta = 0$ in $y_t = \alpha + \beta y_{t-1} + v_t$, Rejecting H_0 implies an AR(1) process for the variable tested.

b: applicable only to the coefficient and standard error estimates of the constant term and lagged term (first two columns).

Table 5: Testing for Neoclassical production functions[a]: Y=AL, Y=AK, and Y=AF(K,L)

Y=AL						
Modelling lnY by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	0.054505	0.13126	0.415	0.6800	0.0040	0.09
lnY_1[a]	0.92545	0.043226	21.410	**0.0000**	0.9142	0.11
lnL	-1.2804	2.0105	-0.637	0.5276	0.0093	0.10
lnL_1	1.3978	1.9829	0.705	0.4847	0.0114	0.10
R^2 = 0.998062 F(3,43) = 7382.5 [0.0000] \sigma = 0.0361721 DW = 1.61						
RSS = 0.05626223211 for 4 variables and 47 observations						
Instability tests, variance: 0.12964 joint: 1.09432						
Information Criteria: SC = -6.40021; HQ = -6.49841; FPE = 0.00141978						
Solved Static Long Run equation						
lnY =	+0.7312		+1.575 lnL			
(SE)	(2.15)		(0.5308)			
Y=AK						
Modelling lnY by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	0.032005	0.051018	0.627	0.5338	0.0091	0.09
lnY_1	0.92058	0.035830	25.693	**0.0000**	0.9388	0.12
lnK	0.26899	0.11193	2.403	**0.0206**	0.1184	0.11
lnK_1	-0.20662	0.084345	-2.450	**0.0184**	0.1225	0.11
R^2 = 0.998211 F(3,43) = 7999.3 [0.0000] \sigma = 0.0347523 **DW = 1.75**						
RSS = 0.05193194149 for 4 variables and 47 observations						
Instability tests, variance: 0.23616 joint: 0.803551						
Information Criteria: SC = -6.4803; HQ = -6.5785; FPE = 0.0013105						
Solved Static Long Run equation						
lnY =	+0.403		+0.7853 lnK			
(SE)	(0.7616)		(0.1286)			
ECM = lnY - 0.402977 - 0.785317*lnK						
WALD test Chi^2(1) = 37.31 **[0.0000] ****						
Y=AF(K,L)						
Modelling lnY by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	-0.23957	0.20491	-1.169	0.2491	0.0323	0.08
lnY_1	0.75821	0.10715	7.076	**0.0000**	0.5498	0.10
lnL	-0.31696	2.0276	-0.156	0.8765	0.0006	0.09
lnL_1	0.58573	1.9600	0.299	0.7666	0.0022	0.09
lnK	0.28651	0.11079	2.586	**0.0134**	0.1402	0.10
lnK_1	-0.18179	0.084019	-2.164	**0.0364**	0.1025	0.10
R^2 = 0.998354 F(5,41) = 4974.2 [0.0000] \sigma = 0.0341391 DW = 1.61						
RSS = 0.04778463696 for 6 variables and 47 observations						
Instability tests, variance: 0.155707 joint: 1.17609						
Information Criteria: SC = -6.39969; HQ = -6.547; FPE = 0.00131426						
Solved Static Long Run equation						
lnY =	-0.9908		+1.112 lnL		+0.4331 lnK	
(SE)	(0.4578)		(0.2746)		(0.1073)	

a: variables in *italic* are significant variables to long-run income, with corresponding t-prob in **bold**.

Table 6: ADL model: modeling lnYL using significant lag ADL specification

The present sample is: 3 to 48						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	-0.23387	0.11402	-2.051	0.0468	0.0952	0.07
lnYL_1	0.74487	0.10534	7.071	0.0000	0.5555	0.12
lnK	0.33599	0.11839	2.838	0.0071	0.1676	0.09
lnK_1	-0.21838	0.10179	-2.145	0.0380	0.1032	0.09
lnH	-0.13627	0.28606	-0.476	0.6364	0.0056	0.06
lnH_1	0.17159	0.28431	0.604	0.5495	0.0090	0.06
R^2 = 0.994665 F(5,40) = 1491.6 [0.0000] \sigma = 0.034487 DW = 1.65						
RSS = 0.04757402522 for 6 variables and 46 observations						
Instability tests, variance: 0.159621 joint: 1.30595						
Information Criteria: SC = -6.37472; HQ = -6.52389; FPE = 0.00134448						
Solved Static Long Run equation						
lnYL = -0.9167		**+0.461 lnK**			**+0.1384 lnH**	
(SE) (0.3147)		**(0.05613)**			**(0.1715)**	
ECM = lnYL + 0.916655 - 0.460984*lnK - 0.138438*lnH						
WALD test Chi^2(2) = 142.9 [0.0000] **						
Tests on the significance of each variable						
Variable	F-test	Value	Probability		Unit-root t-test	
lnYL	F(1, 40) =	49.996	[0.0000] **		-2.4219	
Constant	F(1, 40) =	4.2074	[0.0468] *			
lnK	F(2, 40) =	4.7022	[0.0147] *		2.4811	
lnH	F(2, 40) =	0.39879	[0.6738]		0.69079	
Tests on the significance of each lag						
Lag	F-test	Value	Probability			
1	F(3, 40) =	17.654	[0.0000] **			

Table 7: Static regression with no lags

Modelling lnYL by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	-0.72069	0.076986	-9.361	0.0000	0.6708	0.13
lnK	0.42210	0.012776	33.038	0.0000	0.9621	0.16
lnSCH	0.28290	0.054856	5.157	0.0000	0.3821	0.12
R^2 = 0.987602 F(2,43) = 1712.7 [0.0000] \sigma = 0.0507077 DW =0.595						
RSS = 0.1105645031 for 3 variables and 46 observations						
Solved Static Long Run equation						
lnYL = -0.7207		+0.4221 lnK			+0.2829 lnSCH	
(SE) (0.07699)		(0.01278)			(0.05486)	
WALD test Chi^2(2) = 3425.3 [0.0000] **						

Table 8: Generalized ADL model with human capital and structural macroeconomic factors of inflation and exchange rate adjustments

Modelling lnYL by OLS						
The present sample is: 3 to 48						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	-0.38463	0.16304	-2.359	0.0237	0.1308	0.07
lnYL_1	0.65647	0.12047	5.449	0.0000	0.4452	0.08
lnK	0.39603	0.12648	3.131	0.0034	0.2095	0.07
lnK_1	-0.25477	0.10557	-2.413	0.0209	0.1360	0.07
lnH	-0.43921	0.28510	-1.541	0.1319	0.0603	0.07
lnH_1	0.47063	0.28501	1.651	0.1071	0.0686	0.07
lnR	0.30576	0.11837	2.583	0.0139	0.1528	0.11
DlnE	0.039265	0.039264	1.000	0.3238	0.0263	0.16
DlnE_1	-0.049623	0.039744	-1.249	0.2197	0.0404	0.06
R^2 = 0.995621 F(8,37) = 1051.6 [0.0000] \sigma = 0.0324877 DW = 1.84						
RSS = 0.03905171106 for 9 variables and 46 observations						
Instability tests, variance: 0.151405 joint: 1.90339						
Information Criteria: SC = -6.32243; HQ = -6.54618; FPE = 0.00126195						
Solved Static Long Run equation						
lnYL =	**-1.12**	**+0.4112 lnK**	**+0.09147 lnH**			
(SE)	**(0.1488)**	**(0.05394)**	**(0.07635)**			
	+0.8901 lnR	**-0.03015 DlnE**				
	(0.4071)	**(0.1425)**				
ECM = lnYL + 1.11965 - 0.411207*lnK - 0.0914728*lnH - 0.890055*lnR						
+ 0.0301534*DlnE						
WALD test Chi^2(4) = 304.86 [0.0000] **						
Tests on the significance of each variable						
Variable	F-test	Value	Probability	Unit-root t-test		
lnYL	F(1, 37) =	29.692	[0.0000] **	-2.8514		
Constant	F(1, 37) =	5.5656	[0.0237] *			
lnK	F(2, 37) =	5.6513	[0.0072] **	2.8146		
lnH	F(2, 37) =	1.7722	[0.1841]	0.99011		
lnR	F(1, 37) =	6.6719	[0.0139] *	2.583		
DlnE	F(2, 37) =	1.0029	[0.3765]	-0.21976		
Tests on the significance of each lag						
Lag	F-test	Value	Probability			
1	F(4, 37) =	9.0982	[0.0000] **			

Table 9: Testing for Weak exogeneity of K, H, R, and E on long-run lnYL using a Wald test for general restrictions on the generalized ADL model

Variable in Generalized ADL model	$\chi^2(n)$	*Wald test*	*Wald F-prob of weak exogeneity*
K	$\chi^2(2)$	11.303	[0.0035] **
H	$\chi^2(2)$	3.5443	[0.1700]
R	$\chi^2(1)$	6.6719	[0.0098] **
E	$\chi^2(2)$	2.0059	[0.3668]

Table 10: Granger non-causality testing, strong exogeneity tests, and causality analysis on the Generalized ADL model

PHYSICAL CAPITAL K						
Modelling lnK by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
lnYL_1	2.3512	0.099767	23.567	0.0000	0.9313	0.19
Constant	2.9936	0.19271	15.534	0.0000	0.8548	0.17
DlnE_1	-0.32525	0.10924	-2.977	0.0049	0.1778	0.09
lnH_1	-0.25359	0.086043	-2.947	0.0053	0.1748	0.17
lnR_1	-0.63801	0.36573	-1.745	0.0886	0.0691	0.26
R^2 = 0.987847 F(4,41) = 833.15 [0.0000] \sigma = 0.107603 DW = 0.820						
RSS = 0.4747159805 for 5 variables and 46 observations						
Instability tests, variance: 0.0723793 joint: 0.892956						
Information Criteria: SC = -4.15752; HQ = -4.28183; FPE = 0.012837						
Solved Static Long Run equation						
lnK =	+2.351 lnYL	+2.994	-0.3253 DlnE			
(SE)	(0.09977)	(0.1927)	(0.1092)			
	-0.2536 lnH	-0.638 lnR				
	(0.08604)	(0.3657)				
WALD test Chi^2(4) = 3332.6 [0.0000] **						
INFLATION R						
Modelling lnR by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	0.092139	0.18172	0.507	0.6149	0.0062	0.27
DlnE_1	0.092293	0.048444	1.905	0.0638	0.0813	0.15
lnH_1	-0.020475	0.041761	-0.490	0.6265	0.0058	0.28
lnK_1	-0.026016	0.052091	-0.499	0.6201	0.0060	0.32
lnYL_1	0.18109	0.14092	1.285	0.2060	0.0387	0.36
R^2 = 0.620233 F(4,41) = 16.74 [0.0000] \sigma = 0.0451955 DW = 0.993						
RSS = 0.08374798304 for 5 variables and 46 observations						
Instability tests, variance: 0.0849507 joint: 2.30193**						
Information Criteria: SC = -5.89243; HQ = -6.01673; FPE = 0.00226466						
Solved Static Long Run equation						
lnR =	+0.09214	+0.09229 DlnE	-0.02048 lnH			
(SE)	(0.1817)	(0.04844)	(0.04176)			
	-0.02602 lnK	+0.1811 lnYL				
	(0.05209)	(0.1409)				
WALD test Chi^2(4) = 66.961 [0.0000] **						
EXCHANGE RATE ADJUSTMENTS DlnE						
(Wald test for general restrictions on short-run and long-run effects)						
Long-run growth effect: WALD test Chi^2(1) = 2.4365 [0.1185]						
Short-run effect on income: WALD test Chi^2(1) = 4.1822 [0.0409]*						
HUMAN CAPITAL H						
Modelling lnH by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
lnYL_1	2.5332	0.41353	6.126	0.0000	0.4779	1.10**
lnK_1	-0.67639	0.17582	-3.847	0.0004	0.2652	0.89**
DlnE_1	-0.17982	0.17816	-1.009	0.3187	0.0242	0.43
lnR_1	-0.14261	0.59912	-0.238	0.8130	0.0014	0.66*
Constant	3.7240	0.39227	9.493	0.0000	0.6873	0.72*
R^2 = 0.906456 F(4,41) = 99.324 [0.0000] \sigma = 0.16801 DW = 0.354						
RSS = 1.157317095 for 5 variables and 46 observations						
Instability tests, variance: 0.354378 joint: 3.21957**						

Information Criteria: SC = -3.26638; HQ = -3.39069; FPE = 0.0312954			
Solved Static Long Run equation			
lnH =	+2.533 lnYL	-0.6764 lnK	-0.1798 DlnE
(SE)	(0.4135)	(0.1758)	(0.1782)
	-0.1426 lnR	+3.724	
	(0.5991)	(0.3923)	
WALD test Chi^2(4) = 397.3 [0.0000] **			

Comments on Granger non-causality and strong exogeneity

Physical capital accumulation is a causation variable to growth. Long-run solution yields a positive effect of income per labor and residuals on physical capital (procyclical in an RBC model), while suggesting that a devaluation or excessive inflation would lower the effective physical capital stock, and thus in the long-run cause a relative decline in income per labor.

Inflation shifts are considered a causation variable to growth, implying 'real inflationary growth'. Long-run solution suggests that inflationary growth has a positive effect on income per labor but a negative (counter-cyclical) effect on physical capital. There are therefore two conflicting forces acting on long-run response of income per labor. The first is due to high inflationary pressure on assets and investments tending to decline their real value through time, causing a relative decline in physical capital accumulation and thus a relative decline in long-run output and income. The second, however, implied by this result, is that inflation shifts tend to have a positive effect on income per labor as a 'spill-over' effect to inflation shocks in the economy. It is evident that these two forces work in opposite directions , but it is also evident from the ADL model estimated earlier that the economy behaves with 'real inflationary growth' with spill-over effects dominating the direct effect on physical capital or investments.

Exchange rate adjustments are non-casual to long-run growth but do affect short-run income responses to their respective adjustments. A more elaborate analysis is suggested measuring the sensitivity of income responses to exchange rate adjustments using an AR(2) or an ARMA(2,1) stochastic shock for the real effective exchange rate in a real-business cycle model.

Human capital, although a weakly exogeneous variable in the ADL model, is failed to be rejected as a causal variable to long-run growth. Human capital is therefore weakly but not strongly exogeneous to the ADL model. Long-run solution suggests three possible effects:

1. a positive effect on output (and real income per labor)
2. a negative effect on physical capital accumulation, and
3. a positive effect on the residuals

The first result is a consequence of human capital as an effective factor in the production process, with an increasing return to output, yet with a diminishing marginal product. The second result politely suggests that human and physical capital are considered substitutes in the production process of the economy, and that if resources are allocated more to one factor such as human capital, then not enough resources - either private or public - could be allocated to the second factor (i.e. to physical capital). Turning to the third result, it suggests that human capital has a positive effect on residuals, thus causing a better environment for technological progress and/or at the same time increasing the productivity of current technologies through better quality skills of the labor force.

Weakly exogeneous variables: E, H.
Causality variables to long-run growth: K, R, H.
Non-causality variables to long-run growth: E, with short-run causality.
Strongly exogeneous variables to growth: none.

Table 11: Growth-causation adjusted ADL model

Modelling lnYL by OLS

The present sample is: 3 to 48

Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	-0.31852	0.11333	-2.811	0.0077	0.1684	0.06
lnYL_1	0.64286	0.10818	5.942	0.0000	0.4752	0.07
lnK	0.42904	0.11836	3.625	0.0008	0.2520	0.06
lnK_1	-0.27384	0.098900	-2.769	0.0086	0.1643	0.06
lnH	-0.26107	0.27523	-0.949	0.3487	0.0226	0.05
lnH_1	0.31604	0.27527	1.148	0.2579	0.0327	0.05
lnR	0.28180	0.11703	2.408	0.0209	0.1294	0.10

R^2 = 0.995356 F(6,39) = 1393.1 [0.0000] \sigma = 0.0325879 DW = 1.68

RSS = 0.04141682848 for 7 variables and 46 observations

Instability tests, variance: 0.145839 joint: 1.63901

Information Criteria: SC = -6.43009; HQ = -6.60412; FPE = 0.00122357

Solved Static Long Run equation

lnYL =	**-0.8919**	**+0.4346 lnK**	**+0.1539 lnH**
(SE)	**(0.2115)**	**(0.03774)**	**(0.1142)**
	+0.789 lnR		
	(0.3212)		

ECM = lnYL + 0.891866 - 0.434586*lnK - 0.153911*lnH - 0.789028*lnR

WALD test Chi^2(3) = 325.3 [0.0000] **

Tests on the significance of each variable

Variable	F-test	Value	Probability	Unit-root t-test
lnYL	F(1, 39) =	35.31	[0.0000] **	-3.3013
Constant	F(1, 39) =	7.8996	[0.0077] **	
lnK	F(2, 39) =	7.6147	[0.0016] **	3.272
lnH	F(2, 39) =	1.1822	[0.3173]	1.1218
lnR	F(1, 39) =	5.7979	[0.0209] *	2.4079

Tests on the significance of each lag

Lag	F-test	Value	Probability
1	F(3, 39) =	14.513	[0.0000] **

AR 1- 2	F(2, 38) =	1.3244	[0.2780]
ARCH 1	F(1, 38) =	0.22439	[0.6384]
Normality	Chi^2(2)=	17.981	[0.0001] **
Xi^2	F(12, 27) =	0.66439	[0.7690]
Xi*Xj	F(27, 12) =	0.7371	[0.7542]
RESET	F(1, 39) =	0.031826	[0.8593]

Table 12: Model Typology: alternative specifications, restrictions, reparameterizations, and data transformations on the generalized ADL model

Alternative Models, Data Transformations and Reparameterizations	*Type of Restrictions on ADL Model*	**Test Statistic**	*Test Result*	***Significance***
AR(1)	linear: Rb=r	F(4,40)	2.4468	[0.0619]
Traditional Static Model	general	χ^2(4)	169.24	[0.0000] **
Leading Indicator Model				
Physical capital	linear: Rb=r	F(3,40)	17.654	[0.0000] **
Human capital	general	χ^2(4)	2547.7	[0.0000] **
Both factors	general	χ^2(2)	8.0994	[0.0174] *
Partial Adjustment Mechanism (PAM)				
Physical capital	general	χ^2(1)	4.603	[0.0319] *
Human capital	general	χ^2(1)	0.36428	[0.5461]
Both factors	general	χ^2(2)	4.6966	[0.0955]
Adaptive Expectations	general	χ^2(1)	49.996	[0.0000] **
Dead Start Model				
Physical capital	general	χ^2(1)	8.0537	[0.0045] **
Human capital	general	χ^2(1)	0.22695	[0.6338]
Both factors	general	χ^2(2)	8.0994	[0.0174] *
Testing the significance of lagged income in levels.	general	χ^2(1)	5.8655	[0.0154] *
Growth Rate Model				
isomorphic transformation ***for physical capital***	general	χ^2(1)	6.156	[0.0131] *
isomorphic transformation for human capital	general	χ^2(1)	0.47719	[0.4897]
Testing whether entire ADL model be estimated in first differences without a constant term	general	χ^2(2)	6.3359	[0.0421] *
Testing the validity of applying Growth Rate Model to entire data	general	χ^2(4)	13.194	[0.0104] *
Testing for first-order serial autocorrelation.	RALS estimation on $\hat{\boldsymbol{v}}_{t-1}$	t-prob	0.5180	-----

Comment on Model Typology

The following models were tested and rejected to be the true long-run models of real income growth for the Egyptian economy: traditional static model, leading indicator model, partial adjustment mechanism for physical capital, adaptive expectations, dead start model for physical capital, dead start model for joint factors, isomorphic transformation of physical capital, isomorphic transformation for joint factors, and the common factor restriction model. The Wald test for linear restrictions rejects a linearly homogeneous production function, and rejects the hypothesis that physical capital's share of long-run income per labor could be one-third. Also, Wald test rejects independency of real income growth on physical capital accumulation based on an AR(1) model.

The Wald test *failed* to reject the following models based on a 5% significance level: partial adjustment mechanism for human capital, partial adjustment mechanism for joint factors, dead start model for human capital, and isomorphic transformation of human capital.

Table 13: RALS Estimation (Recursive Autoregressive Least Squares)

Modelling lnYL by RALS				
Variable	Coefficient	Std.Error	t-value	t-prob
Constant	-0.40136	0.18988	-2.114	0.0412
lnYL_1	0.54976	0.22750	2.417	0.0206
lnK	0.49902	0.15738	3.171	0.0030
lnK_1	-0.30321	0.12749	-2.378	0.0225
lnH	-0.17902	0.24725	-0.724	0.4735
lnH_1	0.25841	0.23988	1.077	0.2882
lnR	0.31894	0.17033	1.873	0.0688
$\hat{u}$_1	0.24469	0.28423	0.861	**0.3947**
\Sum y(t)^2 = 8.91801 σ = 0.0323965				
ϕ = 0.03988223953 for 7 variables and 46 observations (8 parameters)				
Root of the Error Polynomial = 0.2447				
χ^2 Tests of autoregressive parameters: AR1(OLS)= 1.4347, p value=0.23099				
ARCH 1 F(1, 37) = 0.21562 [0.6451]				
Normality Chi^2(2)= 16.691 [0.0002] **				
Xi^2 F(12, 26) = 0.64612 [0.7841]				
Xi*Xj F(27, 11) = 0.60235 [0.8623]				
RESET F(1, 38) = 0.29321 [0.5913]				
AR 1- 2 F(2, 37) = 1.1868 [0.3165]				

Table 14: ARCH Model

Testing for ARCH from lags 1 to 5						
χ^2(5) = 2.1323 [0.8305] and F-form(5,29) = 0.3182 [0.8980]						
ARCH Coefficients:						
	Constant	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5
Coeff.	0.001054	-0.05876	-0.02775	-0.09336	0.1596	-0.08096
Std.Err	0.0006282	0.1853	0.1834	0.1827	0.1832	0.1852
RSS = 0.000249787 σ = 0.00293485						
Testing for Heteroscedastic errors (squares)						
χ^2(12) = 10.567 [0.5664] and F-form(12,26) = 0.64612 [0.7841]						
V01=lnYL_1, V02=lnK, V03=lnK_1, V04=lnH, V05=lnH_1, V06=lnR						
Heteroscedasticity Coefficients:						
	Constant	***V01***	***V02***	***V03***	***V04***	***V05***
Coeff.	-0.05498	-0.01374	0.07279	-0.04457	0.02209	-0.01659
t-value	-0.9426	-0.4643	1.028	-0.9907	0.427	-0.3332
	V06	***V01^2***	***V02^2***	***V03^2***	***V04^2***	***V05^2***
Coeff.	-0.01656	0.001555	-0.005826	0.00302	0.03803	-0.03677
t-value	-0.5704	0.1006	-0.7162	0.5627	0.4872	-0.5108
	V06^2					
Coeff.	0.1308					
t-value	0.9539					
Testing for Heteroscedastic errors (squares and cross-products)						
χ^2(27) = 27.44 [0.4402] and F-form(27,11) = 0.60235 [0.8623]						
V01=lnYL_1, V02=lnK, V03=lnK_1, V04=lnH, V05=lnH_1, V06=lnR						
Heteroscedasticity Coefficients:						
	Constant	***V01***	***V02***	***V03***	***V04***	***V05***
Coeff.	0.4448	0.418	-0.09318	-0.1741	-0.5195	0.7792
t-value	0.8071	0.5903	-0.1277	-0.3122	-0.2788	0.3809
	V06	***V01^2***	***V02^2***	***V03^2***	***V04^2***	***V05^2***
Coeff.	1.115	0.2563	0.1274	0.01307	1.003	1.106

t-value	1.21	0.5878	0.3398	0.05079	0.5805	0.6668
	V06^2	***V02*V01***	***V03*V01***	***V03*V02***	***V04*V01***	***V04*V02***
Coeff.	0.2077	-0.3594	0.1175	-0.08132	-0.711	-0.9604
t-value	0.405	-0.6945	0.3321	-0.1322	-0.5717	-0.317
	V04*V03	***V05*V01***	***V05*V02***	***V05*V03***	***V05*V04***	***V06*V01***
Coeff.	1.253	0.524	1.326	-1.617	-2.043	0.5694
t-value	0.3933	0.4692	0.4366	-0.4995	-0.6374	1.177
	V06*V02	***V06*V03***	***V06*V04***	***V06*V05***		
Coeff.	-0.7873	0.4256	-0.07197	0.2404		
t-value	-1.205	0.8181	-0.02584	0.08725		

Table 15: Cointegration analysis (significant restriction on constant marginal rate of substitution between production factors K and L)

eigenvalue μ_i	*loglik for rank*					
	556.497	0				
0.699337	581.734	1				
0.368537	591.388	2				
0.186358	595.719	3				
0.00693946	595.865	4				
Ho:rank=p	*-Tlog(1-\mu)*	*using T-nm*	*95%*	*-T\Sum log(.)*	*using T-nm*	*95%*
p == 0	50.47**	45.67**	27.1	78.74**	71.24**	47.2
p <= 1	19.31	17.47	21.0	28.26	25.57	29.7
p <= 2	8.662	7.837	14.1	8.954	8.102	15.4
p <= 3	0.2925	0.2646	3.8	0.2925	0.2646	3.8
long-run matrix Po=$\alpha\beta'$						
	lnYL	lnK	lnR	lnH		
lnYL	-0.37516	0.12881	0.33854	0.066479		
lnK	0.070127	-0.087904	-0.018031	0.015649		
lnR	-0.0055568	0.049666	-0.49270	-0.066670		
lnH	0.097078	-0.032870	0.042082	-0.021468		
β'						
lnYL	lnK	lnR	lnH			
-0.053107	0.053107	0.72578	0.035431			
α						
lnYL	-0.13472					
lnK	-0.47121					
lnR	-0.16664					
lnH	0.15119					
Standard errors of α						
lnYL	0.089203					
lnK	0.097453					
lnR	0.095164					
lnH	0.042578					
Restricted long-run matrix Po=$\alpha\beta'$						
	lnYL	lnK	lnR	lnH		
lnYL	0.0071547	-0.0071547	-0.097779	-0.0047734		
lnK	0.025025	-0.025025	-0.34200	-0.016696		
lnR	0.0088499	-0.0088499	-0.12095	-0.0059043		
lnH	-0.0080292	0.0080292	0.10973	0.0053568		
Reduced form β'						
	lnK	**lnR**	**lnH**			
lnYL	**1.0000**	**13.666**	**0.66717**			

*Co-integrating relationship: lnYL= lnK + 13.66*lnR + 0.66717*lnH*				
Standard errors of long-run matrix				
lnYL	0.0047373	0.0047373	0.064742	0.0031606
lnK	0.0051755	0.0051755	0.070730	0.0034529
lnR	0.0050539	0.0050539	0.069069	0.0033718
lnH	0.0022612	0.0022612	0.030902	0.0015086
Moving average impact matrix				
lnYL	-1.0344	-0.72012	-0.035074	0.24735
lnK	-2.5465	0.85398	-0.25039	0.032101
lnR	0.067250	-0.11723	0.015081	-0.032407
lnH	0.88888	0.041984	0.013813	0.98645
loglik = 581.72603 -log| Ω | = 27.701239 unrestr. loglik = 581.73384				
LR-test, rank=1: χ^2(1) = 0.015617 [**0.9005**]				

Table 16: Modeling Learning by Doing Effects

Modelling lnA by OLS						
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2	Instab
Constant	-0.070351	0.013677	-5.144	**0.0000**	0.3981	0.15
lnA_1	0.79845	0.096867	8.243	**0.0000**	0.6294	0.21
lnYL	0.91068	0.12655	7.196	**0.0000**	0.5642	0.16
lnYL_1	-0.86672	0.12060	-7.187	**0.0000**	0.5635	0.16
R^2 = 0.682005 F(3,40) = 28.596 [0.0000] \sigma = 0.0279415 DW = **1.61**						
RSS = 0.03122906427 for 4 variables and 44 observations						
Instability tests, variance: 0.0779754 joint: 0.64383						
Information Criteria: SC = -6.90658; HQ = -7.00863; FPE=0.000851702						
Solved Static Long Run equation						
lnA =	*-0.3491*	*+0.2181 lnYL*				
(SE)	*(0.2013)*	*(0.1362)*				
WALD test χ^2(1) = 2.5654 [**0.1092**]						

Table 17: Model Encompassing and Model Reduction Testing

Model 1: Conditional Growth-causation ADL model						
Model 2: Learning by Doing Marginal Model, adjusted with lnYL as the dependent variable						
Joint Model: VAR system						
dep.var	T	k	df	RSS	σ	Schwarz
2: lnYL OLS	46	4	42	0.024733	0.0242669	-7.19533
1: lnYL OLS	47	7	40	0.0418162	0.0323327	-6.45119
Encompassing test statistics						
σ [M1] = 0.0325879 σ [M2] = 0.0242669 σ [Joint VAR] = 1.38578e-008						

Model 1 v Model 2	Form	Test	Form	Model 2 v Model 1
-38.5846	N(0,1)	Cox	N(0,1)	-6.43344
24.2127	N(0,1)	Ericsson IV	N(0,1)	5.3289
39	Chi^2(2)	Sargan	Chi^2(5)	42
1.07835e+014	F(2,37)	Joint Model	F(5,37)	2.57584e+013
[**0.0000**]				[**0.0000**]