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Full Length Research Paper

The endogenous growth theory and innovation in Egypt

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In today's economy and society, performance analyses of the government attract more and more attention. This paper presents an evaluation of the Egyptian government of using R&D expenditure from (1996 to 2008) using data envelopment analysis (DEA). Special emphasis was placed on how to present the DEA results to government to provide more guidance to it on what to manage and how to accomplish the changes.

Key words: Endogenous growth theory, DEA, innovation, R&D.

INTRODUCTION

Innovation does not come from organizations, but from individuals. Innovation will take place whatever the circumstances because people need to survive and hence will always strive to improve their lot. Governments can either discourage innovation with excessive bureaucratic procedures or restricted access to certain data, services or products, or they can encourage and facilitate it (Cooper, 2009). A theoretical link between innovation and economic growth has been contemplated, since at least as early as Adam Smith (1776). Not only did he articulate the productivity gains from specialization through the division of labor as well as from technological improvements to capital equipment and processes, he even recognized an early version of technology transfer from suppliers to users and the role of a distinct R&D function operating in the economy (Hasan, 2007). But as admitted by Solow in his 1987 Nobel lecture, the development of a new growth model was, at that time, a reaction against the incompleteness of the Harrod-Domar-Hicks tradition model. Along with taxes, regulations, tariffs, quotas and licenses, public investment represents yet another instrument which governments may apply to secure their policy goals and to manage economic activity. A government invests in R&D in order to realize economic, social, environmental and cultural benefits for the community it represents. As such, the justification for public investment in R&D should be subject to scrutiny and review, as with all other areas of public decision making. Evaluation of this investment aims to determine both the costs and benefits of publicly financed projects in R&D and can be used to justify public investment in R&D and improve the efficiency and effectiveness of that investment. First, important endo-genous growth theory models and their implications are presented, followed by economic growth and innovation in Egypt. Finally, the paper presents an evaluation of Egyptian government, using R&D expenditure from (1996 to 2008) using data envelopment analysis (DEA).

MATERIALS AND METHODS

The new endogenous growth theory

Much of the recent economic literature distinguishes between exogenous and endogenous growth models. The important difference between them is that, the steady-state growth rate is determined exogenously in exogenous growth model, e.g., technical change is determined exogenously, but it is determined endogenously in the endogenous growth models. One of the main reasons economists have grown interested in endogenous growth is the empirical puzzle surrounding it: the exogenous models predict that, countries with low per-capita incomes grow faster than those with high-capita incomes, so that over time per-capita incomes converge. On the other hand, the empirical studies have found that poor countries were not converging (lckes, 1996). There are two main branches in the new endogenous growth theory: 1) models featuring technological advances that endogenously generate externality effects. Here the production function presents increasing returns to scale (IRS) due to the presence of spillover effects coming from

Abbreviations: DEA, Data envelopment analysis; **DMU**, decision making unit; **R&D**, research and development .

knowledge generation and/or education; 2) models using the AK-technology, where constant returns to scale (CRS), due to the accumulation of all types of capital are present (Augusto and Sena, 2000).

The first branch is known as the Romer-Lucas model, which Romer (1986) and Lucas (1988) models are examples of but the second branch is known as the AK-Technology model, which the model of Rebelo (1991) model is an example. Beyond these models there are at least two extensions that should be mentioned, mainly when economic policy is concerned: 1) Growth-cum-government as in Barro (1990) and 2) Growth-cum-Trade as in Grossman and Helpman (1990, 1991). These models will be presented and growth policy for developing countries derived.

The Romer-Lucas model

According to this model, firms engage in R&D because they expect it will be profitable. In other words, firms allocate funds to R&D as long as the expected payoff (return on investment, or "ROI") from R&D at the margin is higher than for any other allocation of those resources (Robert and Lucas, 1988). This investment in R&D results in the creation of two types of knowledge, that which is appropriable (internal effect) and that which is not (external effect). Appropriable knowledge refers to knowledge the firm can utilize itself, exclude others from using it, and generate profits from it. Knowledge that is not appropriable has the properties of a public good; it is non-rival (used by one firm and does not preclude use by another) and non-excludable (it is difficult to prevent others from using). This model is based on the assumption that, profit-seeking firms will engage in R&D for selfish reasons, since they can appropriate some of the value from the knowledge they create. Most economists argue that, a role also exists for the public funding of some types of R&D, particularly basic research that is often very hard for any single firm to appropriate, since the resulting know-ledge spillovers are valuable to the overall economy and would otherwise suffer from under-investment (Hasan, 2007). Policy implications coming from this model are related to the potential for externalities, spillovers coming from the stock of knowledge and/or labor force skills. Economies, which have availability in those factors, can grow faster than the ones constrained by shortage of them. So, we find that this model implies divergence among the growth rates of different economies, which means that, if for example, there are two activities, one that generates high skills/learning/knowledge and another generating low skills/learning/knowledge, countries that specialize in the former will grow sustainably faster than the ones that specialize in the latter (Romer, 1986).

The AK-technology model

According to this model, the more patient a country is the larger is its saving rate and thus, its long-run growth rate, which means that the more willing a country is to substitute temporally, the higher its long-run savings and growth rates. Therefore, differently from Romer-Lucas model, policies that have impact on savings are crucial for long-run growth. For example, if Israel is pricing present consumption at a very high level and/or discounting future con-sumption at a very low rate (both causing higher savings), relative to Egypt, then the long-run growth rates of the former will be greater than those of the latter. This can be extended to various developing countries that grow at different stages and are different with savings. According to this model, increasing savings is key to foster sustained economic growth. So, we find that, the AK-technology model implies divergence among the growth rates of economies, as in the Romer-Lucas model, so we can conclude that, the two models have different structures of analysis and different policy implications.

The extensions of endogenous growth model

The extensions of endogenous growth model concerning the role of government and trade should be considered in terms of their impact on the growth process. The two extensions point to certain con-ditions under which government action and trade engagement can improve the growth possibilities of an economy. A brief summary of two possibilities of economic policy implementation - fiscal policy and trade policy - presented. Regarding fiscal policy, Barro (1990) examines the role of government expenditures in services that enhance productivity in the private sector and concludes that, these expenditures may increase the growth rate of the economy. However, if the government revenues are used to finance government services that have no effects on productivity, or are wasted by bureaucrats, then growth will decrease (William and Serigo, 1993). On the other hand, the role of taxation depends on how it alters the choices that economic agents face. For instance, if the engine of growth is capital accumulation, income taxes that include taxation of interest income will decrease a capitalist's incentives to accumulate capital, and consequently, growth will be negatively affected, since the owners of capital will obtain only a fraction of the future benefits due to the tax.

Thus, regarding developing countries, government intervention as a provider of infrastructure cannot be disconnected from the role of the government as a tax imposer, and if the tax burden is excessive, the developing country can face growth restrictions. Grossman and Helpman (1990) also explored the role of comparative advantage in the determination of trade patterns and growth performances of different countries in the world economy. In this model, if technological spillovers are global, such that innovative firms have access to a common pool of knowledge, then, eventually, relative factor endowments will determine the speciali-zation of a certain country. According to the endogenous growth theory models presented, the Egyptian government should focus on education and labor skills improvement, in order to obtain potential positive externalities spillovers, savings by pricing present con-sumption at a very high level and/or discounting future consumption at a very low rate to get sustained long-run growth rates. It should know the importance of both government intervention and international trade as promoters of growth.

Economic growth and innovation in Egypt

Using Box Jenkins Methodology [1] and economic growth rate and R&D expenditure / GDP data[2], I found that both follow the same model [ARIMA (1, 1, 1)] [3] which means that they are related, so, I can use them as input and output for a decision making unit (DMU) for simplicity. Governments invest in R&D expenditure because they know the ROR (rate of return) from it. Many of the most impor-tant outcomes of R&D investment, e.g. new knowledge, skills and experience, are intangible and unquantifiable, their benefits may not be realized for some years and their impact may be felt in entirely unrelated areas, so we can assume that the government as any producer uses inputs to get output, but, in this case the inputs and outputs are different. The inputs as R&D expenditure/GDP, the outputs as growth rate, high technology exports/ manufactured exports[4].

Most empirical studies focus on endogenous growth theories obtaining the relation between these outputs and inputs by

[1] In details in Appendix 1 , and the results in Appendix 2 , 3

[2] Data of world development indicators at http://data.worldbank.org/indicator

[3] I use Minitab program for getting the results

[4] I use these inputs and output for simplicity

regression analysis, this paper on the other hand is interested in measuring the government efficiency using past inputs and outputs using "Data Envelopment Analysis"(DEA) that will be explained subsequently.

The "Data Envelopment Analysis"(DEA)

Economic efficiency refers to the maximum output attainable from using several inputs. It has two components, 'the purely technical or physical component' refers to the ability to avoid waste by producing as much output as input usage allows (output-oriented measure), or by using as little input as output production requires (input- oriented measure). 'The allocative or price component' refers to the ability to combine inputs and outputs in optimal proportions in light of prevailing prices (Abou-Ali and Kheir-El-Din, 2010).

There are two questions we can answer, respectively, the first one: by how much can output quantities be proportionally expanded without altering the input quantities used? (Output oriented approach), the second: by how much can input quantities be reduced without changing the output quantities produced? (Input oriented approach). The choice of one or the other set of measures depends on whether the decision making unit has more control over inputs or outputs. In the case of the Egyptian government, the inputs oriented measures are more appropriate. The paper rely on DEA for measuring the purely technical efficiency with output-oriented measure using one input (R&D expenditure /GDP), two outputs (GDP growth rate, high technology exports/ manufactured exports)[5], in other words this paper tries to answer the following question, by how much can output quantities be proportionally expanded without altering the input quantities used ?.

DEA was originally introduced by Charnes et al. (1978) as a nonlinear programming model to measure the relative efficiency of decision making units (DMUs). The model has been applied to banks, insurance companies, schools, universities, hospitals and governments (Charnes et al., 1978). Occasionally called frontier analysis, DEA is a performance measurement technique which can be used for analyzing the relative efficiency of productive units, having the same multiple inputs and multiple outputs. It is a non-parametric analytic technique which allows us to compare the relative efficiency of units as benchmark and by measuring the inefficiencies in input combinations in other units relative to the benchmark (Aysan and Ceyhan, 2007). DEA is an alternative analytic technique to regression analysis. Regression analysis approach is characterized as a central tendency approach and it evaluates DMUs (decision making units) relative to an average. In contrast, DEA is an extreme point method and compares each DMU with the only best DMU. DEA identifies relative efficient DMUs (which are used as reference points) which define the efficiency frontier and evaluates the inefficiency of other DMUs which lie below that frontier (Chansarn, 2008).

The main advantage of DEA is that, unlike regression analysis, it does not require an assumption of a functional form relating inputs to outputs. Instead, it constructs the best production function solely on the basis of observed data; hence, statistical tests for significance of the parameters are not necessary. Another advantage is the possibility of measuring the efficiency of one unit (government) over time or many units in on point of time, and it can be applied to non-profit making organizations (William et al., 2006).

DEA methodology

Here we present a brief non technical discussion of DEA as a non-parametric mathematical programming approach to frontier estimation. The DEA measure the technical efficiency assuming constant return to scale (CRS) by the following mathematical problem

$$\min_{\theta,\lambda} \theta$$

$$subject\ to\quad -y_i + Y\lambda \geq 0,$$

$$\theta x_i - X\lambda \geq 0,$$

$$\lambda \geq 0$$

Where θ is a scalar, λ is an Nx1 vector of constant, X is a K x N input matrix, Y a M x N output matrix. For the i^th decision making unit (DMU) inputs and outputs are represented by the vectors x_i and y_i, respectively. Moreover, K represents the number of inputs; M is the number of outputs and N the number of years, in our case K equals to one input, M is represented by two outputs. The linear programming problem is solved N times, once for each year. The value of obtained θ will be the technical efficiency score for every year. It satisfies θ ≤ 1. A DMU is termed efficient, if and only if the optimal value θ is equal to 1 and all the slack variables are zero.

RESULTS AND DISCUSSION

The paper uses data from world development indicators [6](time series from 1996 to 2008) on R&D expenditure /GDP, GDP growth rate and high technology exports/ manufactured exports (Table 1).The degree of correlation between inputs and outputs is an important issue, that has great impact on the robustness of the DEA model. Thus, a correlation analysis is imperative to establish appropriate inputs and outputs. On the one hand, if very high correlations are found between an input variable and any other input variable (or between an output variable and any of the other output variables), this input or output variable may be regarded as a proxy of the other variables. Therefore, this input (or output) could be excluded from the model. On the other hand, if an input variable has very low correlation with all the output variables (or an output variable has very low correlation with all the input variables), it may indicate that this variable does not fit the model. Correlation analyses were done for each pair of variables and Table 2 presents the details (Yang, 2009).

I did not find any evidence of very high correlation between any one input variable and any other (nor between output variables) and any one input variable having very low correlation with any of the output variables (nor between output and input variables) in Table 2.

[5] I assume that the output of R&D exists in The same year for simplicity, but in real life the output of R&D may exist in the future.

[6] At http://data.worldbank.org/indicator

Table 1. Descriptive statistic.

Variable	# of years	Mean	Std. Dev	Min	Max
GDP growth rate	13	4.98	1.53	2.37	7.15
high technology exports/ manufactured exports	13	0.475	0.262	0.163	0.89
R&D expenditure /GDP	13	0.217	0.301	0.186	0.27

Table 2. Correlation matrix of input and outputs.

	GDP growth rate	High technology exports/ manufactured exports	R&D expenditure /GDP
GDP growth rate	1	-0.2888	0.573
high technology exports/ manufactured exports	-0.2888	1	0.1201
R&D expenditure /GDP	0.573	0.1201	1

Table 3. DEA model results.

Years	TE (technical analysis)	% of output that can be proportionally expanded without altering the input quantities used
1996	0.833	16.7
1997	0.849	15.1
1998	0.622	37.8
1999	0.622	37.8
2000	0.622	37.8
2001	0.886	11.4
2002	1.000	0
2003	0.838	16.2
2004	0.705	29.5
2005	0.637	36.3
2006	0.895	10.5
2007	0.941	5.9
2008	1.000	0
mean	0.833	16.7

This is a reasonable validation of my DEA models. Table 3 indicates the results of DEA analysis[7]. So, I find that the average of estimated technical efficiency is 83.3% which means that on average, government can expand 16.7% of their output without altering the input quantities used. So, government should use R&D expenditure in efficient fields that yield the optimal outputs. There are some shortages of using the DEA, one of them is that, the results could be more realistic if I use different countries, in this case, the efficient unit that I will compare others with will be more realistic because DEA measure the relative efficiency, which means that changeable results with changeable sample size.

[7]The paper use DEAP2.1 (Data Envelopment Analysis Program) for solving the DEA model

Conclusion

The paper concludes that, the Egyptian government should focus on education and labor skills improvements to get potential positive externalities spillovers, saving more by pricing present consumption at a very high level and/or discounting future consumption at a very low rate to get sustained long-run growth rates. It should focus on the importance of both government intervention and international trade as promoters of growth. It could try to use R&D expenditure in efficient fields that yield optimal outputs.

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APPENDIX 1: BOX JENKINS METHODOLOGY USING MINITAB PROGRAM

Step 1: Estimate the parameter d

The parameter d can be estimated by checking the stationary of the series via constructing time plot and ACF of the series. If the series is stationary in the mean then, d=0. If the series is not stationary in the mean, find the differences and plot the differences and obtain ACF. If the differences are stationary then d = 1. If the difference is not stationary in the mean find the differences of differences and plot the new differences and ACF. The maximum value for d in practice is 2.

Step 2: Estimate the model orders p and q

The AR order (p) and MA order (q) can be estimated as follows

ACF	PACF	The identified model
Decays	cuts off after 1 lag	AR(1) _ ARMA(1,0) _ ARIMA(1,d,0)
Decays	cuts off after 2 lag	AR(2) _ ARMA(2,0) _ ARIMA(2,d,0)
Decays	cuts off after P lag	AR(p) _ ARMA(p,0) _ ARIMA(p,d,0)
cuts off after 1 lag	Decays	MA(1) _ ARMA(0,1) _ ARIMA(0,d,1)
cuts off after 2 lag	Decays	MA(2) _ ARMA(0,2) _ ARIMA(0,d,2)
cuts off after q lag	Decays	MA(q) _ ARMA(0,q) _ ARIMA(0,d,q)

Step 3: Does the model include a constant term?

A test of whether the model includes a constant term or not can be done using Minitab as follows: stat → Basic statistics→ 1 Sample t→ Variables (Original data or the differences) → OK If the C.I contains zero, then no constant term is needed but if zero is outside the C.I, then a constant term is needed.

Step 4: Estimate the identified model

The identified model ARIMA (p, d, q) can be estimated using Minitab as follows:

Stat→ Time Series→ ARIMA→ Series (original data not the differences)

Autoregressive (p), Difference (d), Moving Average (q) choose include constant term in model, if the model includes a constant and vice versa →Ok.

Step 5: Diagnostic checks

The identified model can be checked using Box Pierce Test Box Pierce Test, test whether the errors are white noise or not P-value of Box Pierce test is given for different lags in the estimation output. When P-value is greater than significance level α, we accept H0: The errors are white noise (or the model is appropriate) when P-value is less than significance level α, we reject H0: The errors are white noise (or the model is not appropriate) and should be modified.

APPENDIX 2: ARIMA MODEL FOR GDP GROWTH

Step 1: Estimate the parameter d

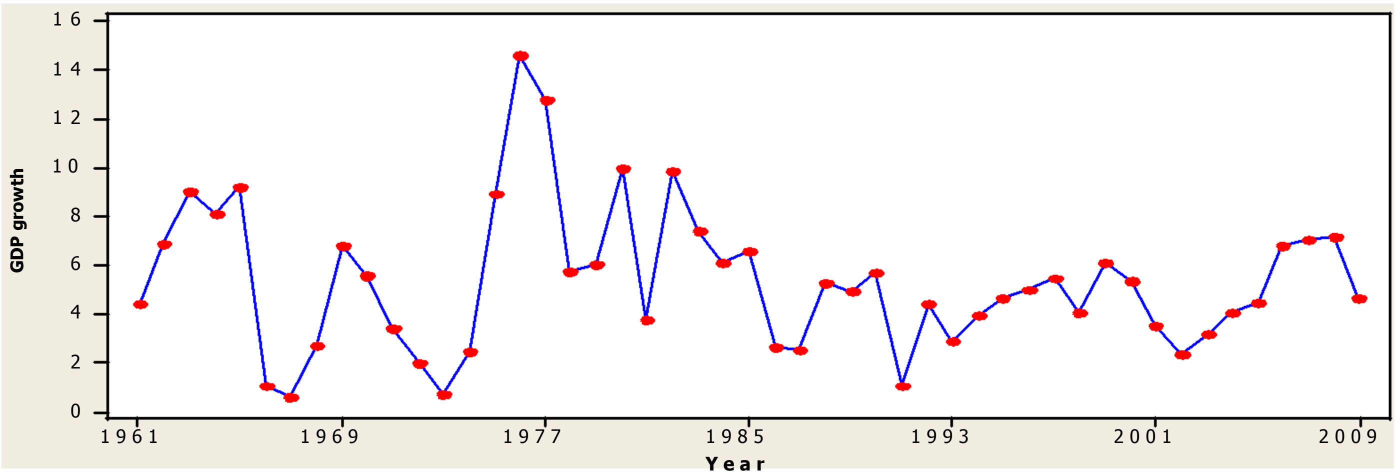

Figure 1. Time series plot of GDP growth.

Step 2: Estimate the model orders p and q

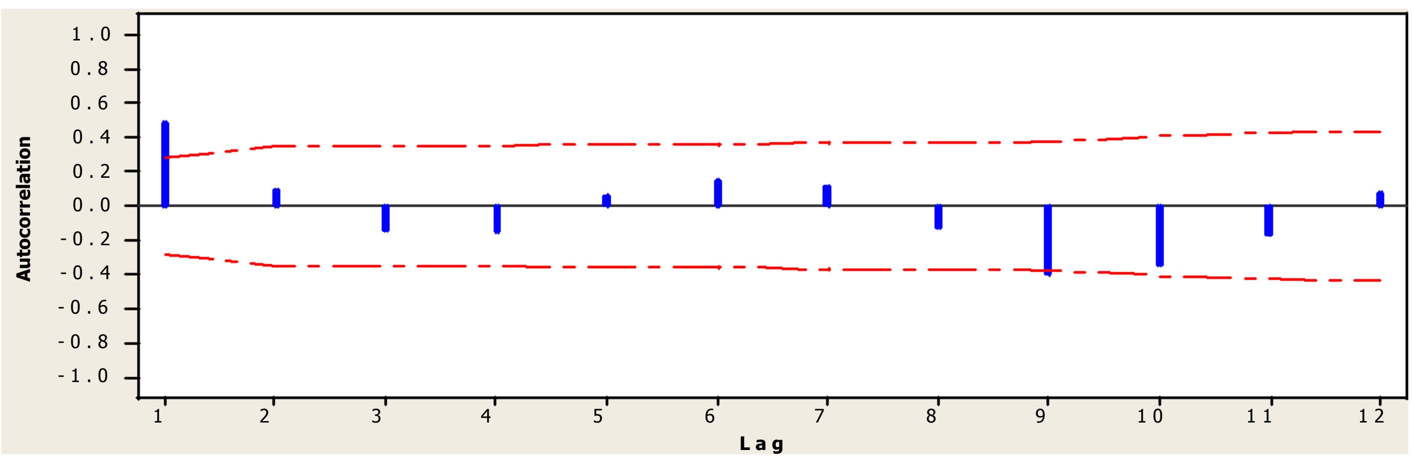

Figure 2. Autocorrelation function for GDP growth (with 5% significance limits for the autocorrelations).

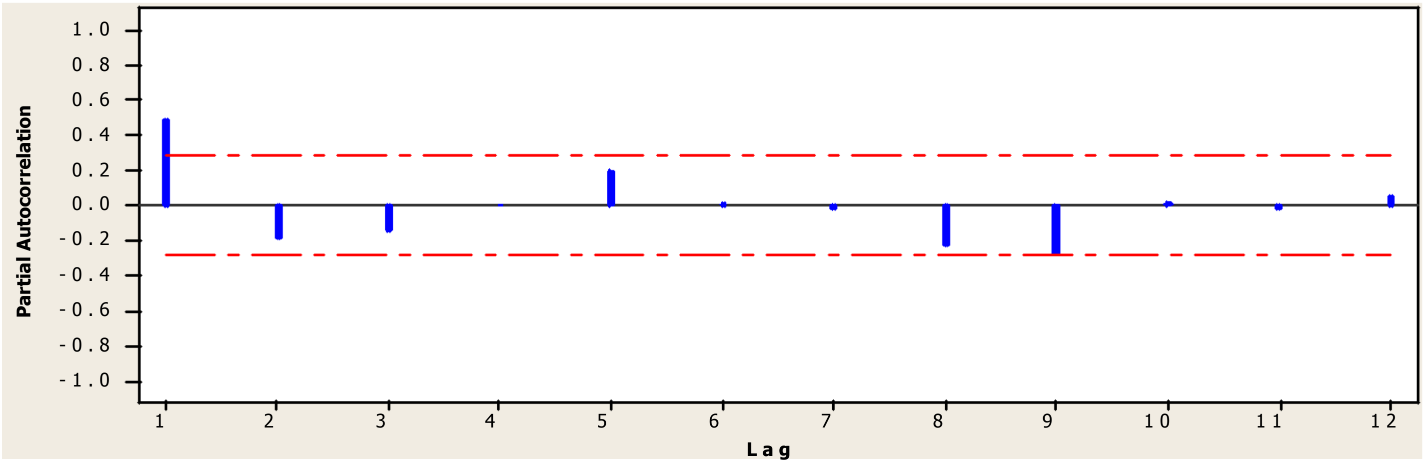

Figure 3. Partial autocorrelation function for GDP growth (with 5% significance limits for the partial autocorrelations).

Step 3: Does the model include a constant term?

One-sample T: GDP growth.

Variable	N	Mean	S.D	SE Mean	95% CI
GDP growth	49	5.36136	2.93927	0.41990	(4.51710; 6.20561)

Step 4: Estimate the identified model

Final estimates of parameters.

Type	Coef	SE Coef	T	P
AR 1	0.4739	0.1613	2.94	0.005
MA 1	0.9627	0.1149	8.38	0.000
Constant	-0.01120	0.03399	-0.33	0.743

Differencing: 1 regular difference, number of observations: original series 49, after differencing 48, residuals:SS = 326.006 (backforecasts excluded), MS = 7.245 DF = 45

Step 5: Diagnostic checks

Modified Box-Pierce (Ljung-Box) Chi-Square statistic.

Lag	12	24	36	48
Chi-Square	20.3	26.9	31.6	*
DF	9	21	33	*
P-Value	0.016	0.174	0.536	*

Appendix 3: ARIMA model for R&D expenditure / GDP

Step 1. Estimate the parameter d.

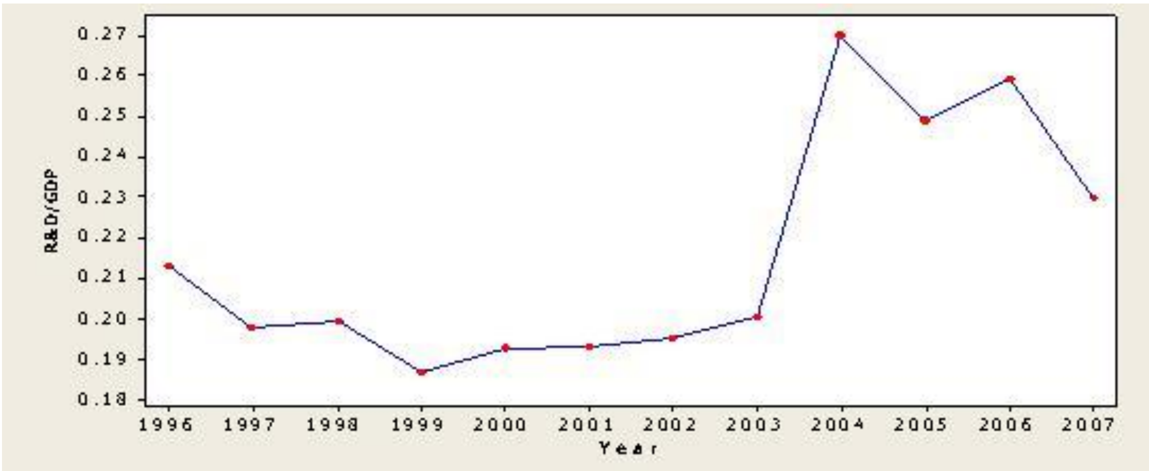

Figure 4. Time series plot of R&D/GDP.

Step 2: Estimate the model orders p and q

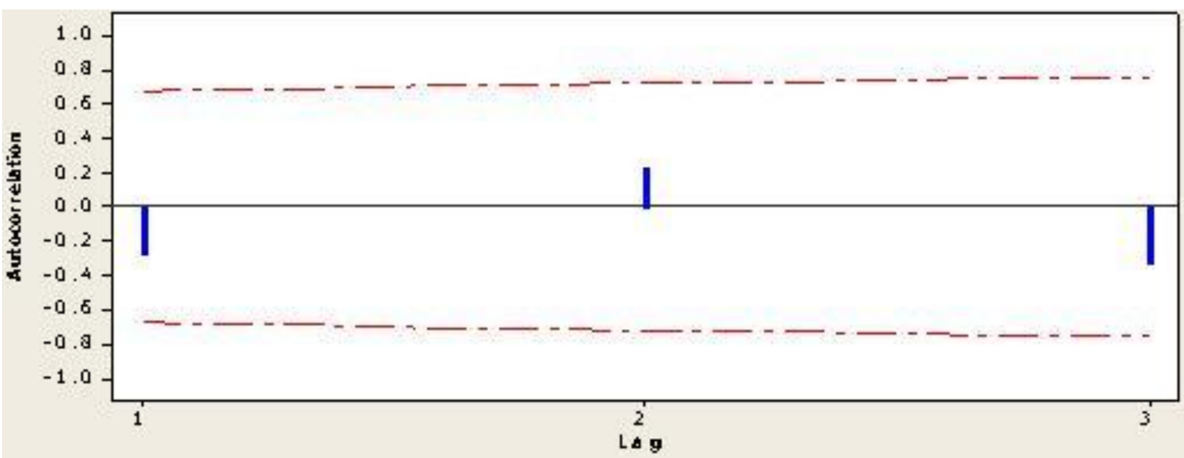

Figure 5. Autocorrelation function for R&D/GDP (with 5% significance limits for the autocorrelations).

Step 3: Does the model include a constant term?

One-Sample T: R&D/GDP.

Variable	N	Mean	St. Dev.	SE Mean	95% CI
R&D/GDP	12	0.215316	0.029091	0.008398	(0.196832; 0.233799)

Step 4: Estimate the identified model

Final estimates of parameters.

Type	Coef	SE Coef	T	P
AR 1	-0.9996	0.0587	-17.04	0.000

Step 4 cont.

MA 1	-0.8920	0.3026	-2.95	0.018
Constant	0.00509	0.01403	0.36	0.726

Differencing: 1 regular difference; Number of observations: Original series 50, after differencing 49; Residuals: SS = 251288 (backforecasts excluded); MS = 5463; DF = 46.

Step 5: Diagnostic checks

I know that the residual is white noise from the ACF of the residual

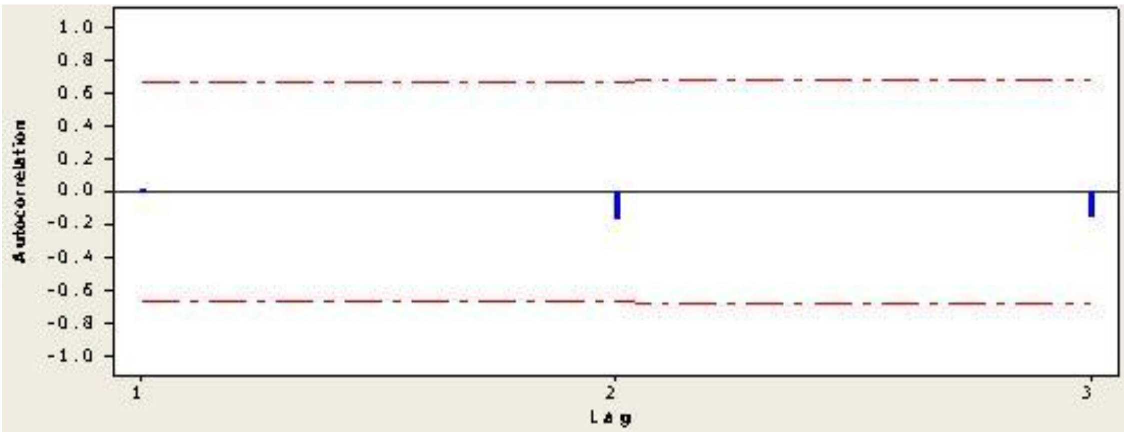

Figure 6. ACF of residuals for R&D/GDP (with 5% significance limits for the autocorrelations).

Appendix 4: Results from data envelopment analysis program (DEAP)

Results from DEAP Version 2.1
Instruction file = INS.txt
Data file = DTA.txt
Output orientated DEA
Scale assumption: CRS
Slacks calculated using multi-stage method

Efficiency summary.

Years	TE (technical analysis)
1	0.833
2	0.849
3	0.622
4	1.000
5	0.886
6	1.000
7	0.838
8	0.705
9	0.637
10	0.617
11	0.895
12	0.941
13	1.000
mean	0.833