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Source of Growth in Libya: Is MRW Model Still Applicable for an Oil Based Economy?

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Abstract Growth and fluctuations in the Libyan GDP depend on oil prices and oil revenues. With data on oil revenues, GDP, capital and labour inputs spanning more than five decades we find that labour has been the most important source of growth of the per-capita income in Libya over this period. While the role of capital accumulation has been less important but positive, the contributions of TFP to growth are negative more often. Based on our analysis we conclude that the Mankiw, Romer and Weil model of economic growth **[1]** is not applicable to Libya, which is one of the oil-based economies in the Arab World.

Keywords Sustainable Growth, Oil, Libya

JEL Classification: O1, O2, O3, O4 and O5

1. Introduction

The major objective of this paper is to determine the source of growth in Libyan economy and to understand if there are any sources other than oil affecting the growth in Libya. For Libyan economy, the oil revenues provide an opportunity for both growth and development. Throughout five decades of oil abundance, there was almost no other sector than oil that contributed to GDP in Libya **[2].**

The main question is what are the shares of labour and capital in the Libyan GDP? Are they similar to those in other oil-based economies? Is MRW model applicable to Libya? These questions will be answered in this paper by estimating the output function for Libyan economy up to 2014. Results illustrate to the relative significance of each source of economic growth. Based on our analysis we conclude that the Mankiw, Romer and Weil model of economic growth **[1]** is not applicable to Libya, which is one of the oil-based economies in the Arab World.

2. Theoretical Framework

Mankiw, Romer, and Weil suggested a model based on Solow model **[3]** They examined whether this model is consistent with international variation in the standard of living, and they argued that an augmented Solow model with human capital as well as physical capital provides an excellent description of cross-country data **[1].** Jones enriched this topic in his empirical study emphasising on human capital measuring **[4]**. **[5]** applied Cobb-Douglas and CES production functions for basic and extended Solow model for 98 countries. **[6]** investigated the source of growth among 88 countries; results mainly toggled capital accumulation. For emerging East Asian economies, **[7]** find that 90 percent of the growth in output per worker is attributed to total factor productivity TFP.

While **[8]** found TFP likely to play the main role in growth in the developing economies, the capital accumulation was more important in emerging and advanced countries **[9].** In essence, the TFP and capital accumulations are the main drivers of economic growth in the long run and short run respectively **[10].** On the other hand, the results vary between TFP and physical capital accumulation as an accounted source of economic growth, depending on the type of production function in use **[11].**

[12] showed that in the high growth years the TFP seemed to be the main contributor, while the labour is the main one in the slow growth periods, and capital is a more important source for the modest.

For oil-based economies; **[13]** investigated the source of growth in 10 MENA countries which for the period 1960-1998 under neutral technological progress, and found that capital accumulation is the lead driver of the growth and more contributor rather than labour on it. Also, others found that TFP contribution is negligible, and even negatively in all countries without exception **[13], [14]. [10]** found that economic growth stems from capital accumulation rather than from TFP. Their study included some non-oil economies such as Israel, Turkey, Morocco and Egypt. For Israel and Saudi Arabia, the situation was

reversed, TFP is more important than capital.

[15] concluded that oil has the main impact on real GDP among all other inputs in both the short and the long run for Saudi Arabia's economy. Given above, the objective of this study is to determine the sources of growth in the Libyan economy applying MRW model as this issue has not been tracked to the best of our knowledge.

3. The Structure of Libyan Economy and Input Factors

Libyan economy was subject to many economic plans in the sixties when funds became available for investing and turned into one of the rentier economies in few years **[16].** Since then, Libya witnessed improvements. However, it experienced negative growth in many years. The growth in non-oil GDP was greater than in the GDP of the oil sector. Nevertheless, it was highly related to the oil shocks rather than to economic effects **[17].** In other words, in spite of remarkable economic growth during the studied period, this growth was uncertain and hardly sustained during the oil shocks, as most of the economic growth was attributed to oil [**18].**

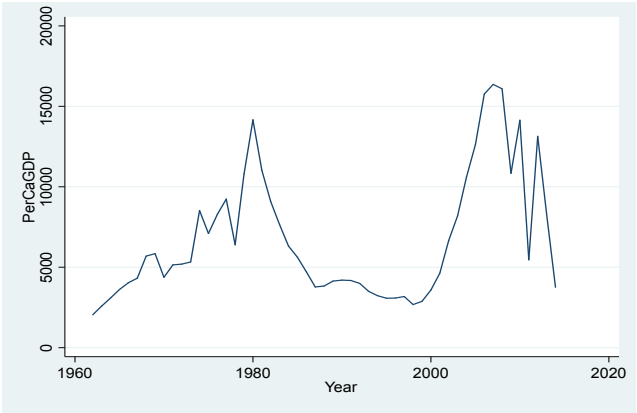


Figure 1. Real per capita GDP over the period (1962-2015) in 2010 Dinars

As shown in the table (1) the average growth rate of physical capital over the period in real values was 6.9%, and for labour force was 4.24%, both grew greater than GDP per worker, which grew by just 4.20%. Per worker GDP and per worker physical capital both show a similar trend, in which they both were affected by the growth of output and population.

Table 1. Growth rates in input factors per five-year periods in Libya (1970-2014)

Period	Physical Capital*	Human capital**	Labour Force*	Population*
1970-1974	23.63	7.21	7.97	4.05
1975-1979	22.52	11.62	5.43	3.98
1980-1984	16.97	11.61	4.23	4.09
1985-1989	4.62	9.14	1.47	2.86
1990-1994	3.80	7.32	2.94	2.27
1995-1999	3.77	9.53	3.79	1.82
2000-2004	6.77	7.81	2.80	1.53
2005-2009	15.93	6.56	4.62	2.39
2010-2014	3.67	NA	4.96	2.18

Source: * Author work, ** Barro and Lee **[19].**

Influence of oil shocks is clear as shown in Figures 2A to 2D, and it is true for both physical and human capital, Figures 2B and 2C respectively. Physical capital per worker grew following the oil revenues in most years. And because of the huge gap in the basic infrastructure [1] required, decreasing in oil revenues mirrored reduction in physical capital accumulation. This may explain the continuous decline in real physical capital per worker between 1983 and 2000 when the investments dedicated mostly to the social needs **[20]**, and the investment-output ratio witnessed a long-run down-ward trend.

Human capital also witnessed many fluctuations related to the oil shocks and showed a reversed trend with the physical capital. It reveals the allocation problem in the Libyan economy. This makes the role of capital in the economic growth more doubtful.

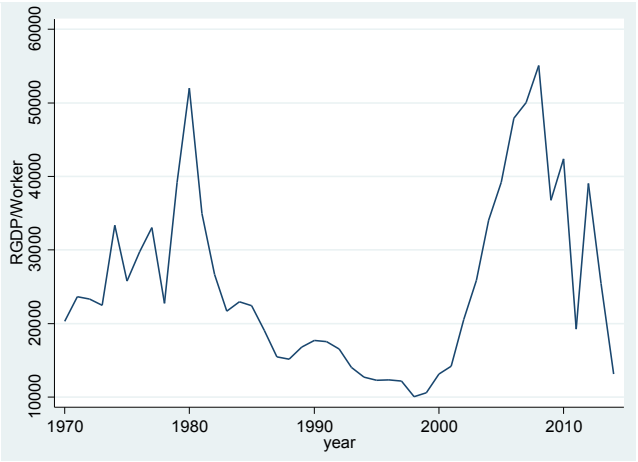


Figure 2A. Log of real GDP per worker GDP/L in Libya

[1] In the seventies, the government adapted a plan funding highways, housing, high voltage electricity net and alike in the whole country. These investments were relatively large. However, they were theoretically part of physical capital, and many of them are out of usage or unreliable due to the way they located in such large country.

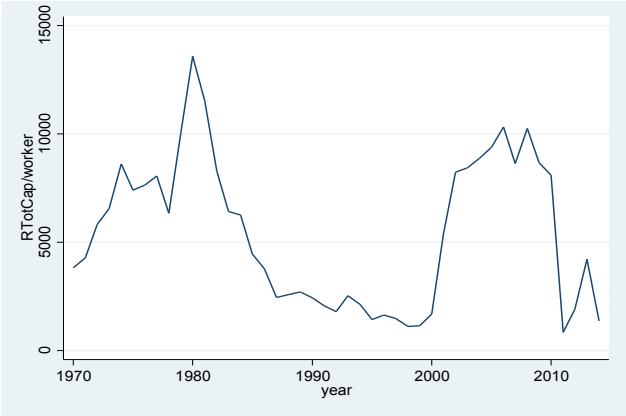


Figure 2B. Log of real physical capital per worker K/L in Libya

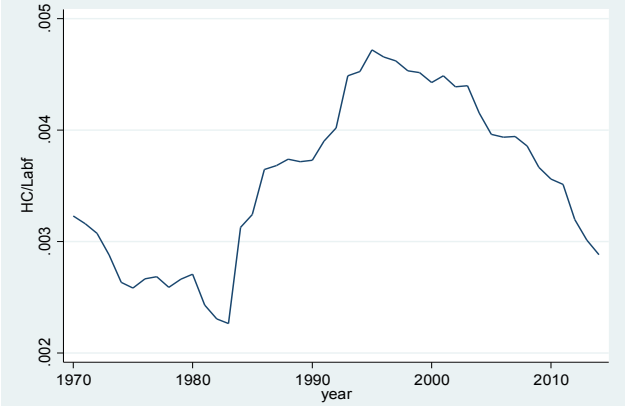
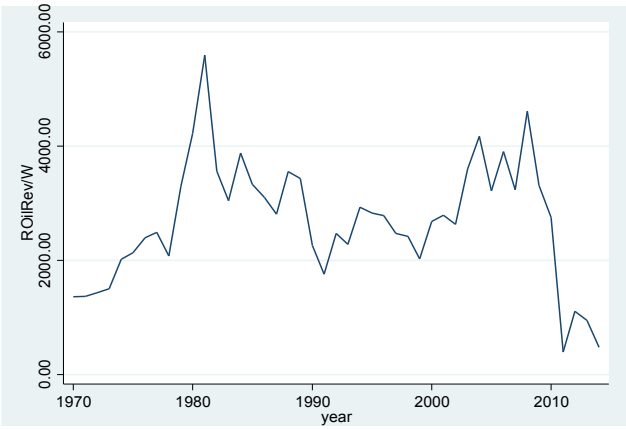


Figure 2C. Log of human capital per worker H/L in Libya

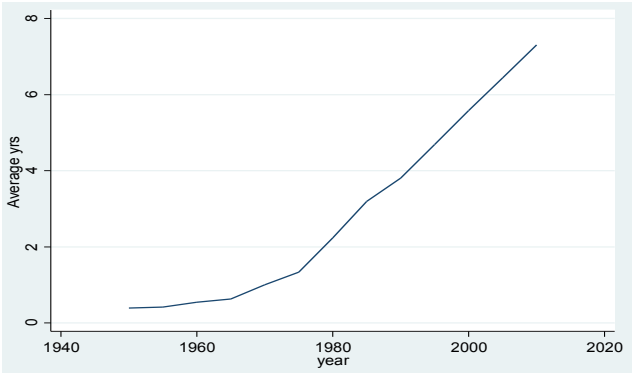


Note: All values are in Libyan currency and real values. Data were taken from the World Bank.
Human capital per worker calculated by multiplying human capital index by population then dividing by the number of the labour force

Figure (2D). Log of oil revenues per worker R/L in Libya

On the other hand, expansion in the rate of youth due to high population growth rate led to more demand for jobs, and put more pressure on the available physical capital with declining ratio per-worker ratio; the authority tried to tackle the employment by including more graduated in non-productive jobs **[21]**. It dealt with employment at the expense of the productivity, which dropped over time **[22].**

Regards to human capital: However, **[23]** arrived at an augmented Solow model where the human capital consists of more than knowledge capital. Others argued that the role of human capital in developing countries, and in oil-based ones, in particular, is still reasonably doubtable. **[6], [24], [25]** and **[26].**



Source: Barro. http://www.barrolee.com/data/dataexp.htm

Figure 3. Average years of schooling in Libya (1950-2010)

For Libya: Figure (3) shows the trend of the most used proxy of human capital over the studied period. It demonstrates a remarkable progress at least in quantities.

4. Basics of Growth Models and Variables for Empirical Analysis

This topic has been studied empirically upon two approaches: the national accounting approach and the regression approach **[27].** The first approach calculates the labour share from national accounts data assuming that capital and labour are partners in output yielding. The later estimates the TFP share from the given data. This study will follow the second approach, and apply MRW model due to two reasons: one is related to national accounts data availability, and the second because this approach has been widely used in the literature since Solow model has enough substance to apply **[28]** Also, the assumption of Hicks-neutral technical change is employed with constant returns to scale (CRS). This method exposes more importance for the factors accumulation, which in turn reveals the role of institutions in the society in the growth process, **[29]** and may able to explain most of the variation in per capita income **[30].**

The suggested technique is quite similar to the basic Solow and tries to address the criticisms which face the original model, and in fact touches the influences of magnitudes of saving to GDP ratio, and population growth on income **[5, 14, 31, 32, and 33]**. They simply augmented the model by including human capital along with physical one as an input factor; findings revealed that adding this variable improved the predictions and enhanced the magnitude of physical capital so that it gave the model more robustness to explain the relationship already

suggested in **[1]**. They employ Cobb-Douglas production function[2].

4.1. Basic Solow Model

Consider a Solow model with Cobb-Douglas production function,[3] and two input, capital and labour. Then assume that population and technology growth is exogenously determined under CRS assumption:

$$Y_t = K_t^{\propto}(A_t L_t)^{(\beta)} e^{ut} \quad (1)$$

Where Y_t stands for annual output represented in GDP in year *t* as usual.

K and L are the input factors, capital and labour respectively.

$\propto$ is the share of capital in output while (β) is the share of labour input, and both of them is $0 < \propto, \beta < 1$ condition of constant returns to scale being exposed here so the sum of them is equal to one, $\propto + \beta = 1$. (A), denotes the level of technology used in the economy. e^{ut} , is the error term.

Mankiw, Romer and Weil [1] considered the growth rate of saving, population growth, and technological progress as exogenous variables, therefore, output at any time can be defined by:

$$Y_t = (K_t^{\propto})(A_t L_t)^{1-\propto} \quad (2)$$

Here it is needless to mention that labour (L), and technology (A), both assumed to grow exogenously at η and λ respectively, therefore, both are related to time rather than to endogenous variables, thus they grow at:

$$L_t = L_0\, e^{\eta t}$$

and

$$A_t = A_0 e^{\lambda t}$$

Both equations define labour supply and available level of technology respectively at any time.

Firstly, assuming competitiveness, input factors are both paid their marginal productivity, and according to Euler exhaustion theorem these payments are equal to output **[36]**, thus to simplify:

$$rK + wL = Y$$

Dividing by Y,

$$\frac{rK}{Y} + \frac{wL}{Y} = 1$$

Giving that $\propto = \frac{rK}{Y}$, $\beta = \frac{wL}{Y}$ therefore, $\propto = \frac{\propto AK^{\propto-1}L^{\beta}.K}{Y}$ and $\beta = \frac{\beta AK^{\beta}L^{\beta-1}.K}{Y}$

Given the assumption that labour and technology both are exogenous **[1],** it implies that only capital will be under consideration in this model. Thus net capital stock is often defined as the investment resulted in saving accumulation (S) after reduced by annual depreciation (δ). As per neoclassical model, capital plays substantial role in the process of economic growth, as this is the case, output Y_t depends along with other factors- on how the corresponding society could accumulate capital, **[4]**. Savings is the main channel to accumulate capital continuously, and it is just the output remaining after consumption, therefore it will be[4]:

$$S_t = sY_t$$

$$0 < s < 1$$

Here, (S) is saving to GDP ratio; it must be greater than the sum of the two opposite factors denoted by depreciation δ and population growth rate n.

Therefore:

$$S = sY_t > (n + \delta + \lambda)K_t \quad (3)$$

Growth in the capital is equal to:

$$\dot{k} = \widehat{sy} - (n + \delta + \lambda)k_t \quad (4)$$

Equation (4) known as fundamental equation of growth in neoclassical model, and $\dot{k}$ is the growth rate of capital with respect to time, equal to dk/dt, $\widehat{sy}$ is per capita saving ratio.

Positive or negative changes in capital must reflect in per capita capital up to steady-state level when it becomes zero:

$$\frac{dk/dt}{k_t} = \frac{\dot{k}}{k_t} = 0$$

Per capita output:

$$\tilde{y} = \left(\frac{sA}{(n+\delta)}\right)^{\frac{\alpha}{1-\alpha}} \quad (5)$$

The required market clearance condition is obtained from equating the income-yielding to the income spending as follows:

$$Y_t = C_t + S_t = I_t + C_t \quad (6)$$

Therefore, investment must equal saving to obtain equilibrium on macro-level.

$$I_t = S_t$$

$$dk = I = sY - \delta K \quad (7)$$

Replacing Y by its expression:

[2] - There are many formulas in which we can be applied to estimate the trend of growth for any economy; however, it is common to use the Cobb-Douglas formula to estimate such economies see for example: Barro and Lee **[34]**.

[3] Derivation of the model can be reviewed in, Jones **[35]** or in: Bhattarai **[9]** .

[4] See Bhattarai, K., Further Economic Analysis, unpublished lecturers, University of Hull, 2012.

$$dk = I = sAK^{\propto}L^{\beta} - \delta K \quad (8)$$

Given capital at any given period and adding this to previously accumulated stock gives capital stock at the time (t):

$$K_t = K_{t-1} - \delta K + sAK^{\propto}L^{\beta} \quad (9)$$

$$K_t = (K_{t-1} - \delta K_{t-1}) + I_t \quad (10)$$

This formula has often been employed for this task, especially for developing economies **[25], [37]** and can be defined as follows:

Capital stock affected annually by the rate of depreciation as well as by growth of population (η), and deterioration in technology used (λ), this means that growth in per worker capital (k) can be defined as follows:

$$\frac{dk}{k} = \frac{dK}{K} - \frac{dL}{L} - \frac{dA}{A} \quad (11)$$

Therefore:

$$\frac{dk}{k} = \left[\frac{sY}{K} - \frac{\delta K}{K}\right] - \eta - \lambda \quad (12)$$

$$\dot{k} = sy_t - (\eta + \delta + \lambda)\, k_t \quad (13)$$

(s) is the fraction of disposable income dedicated to investment through saving process.

This defining equation is the core stone in Solow model for growth. Solow considers the fraction saved of the income as a policy variable, as the capital per worker - and so capital stock- converges to a steady-state level over time as follow:

Investment is the unique source for capital formation as in equation (7), even it would be influenced by the terms (η, δ, λ) negatively.

In the steady state level, there will be no changes in capital, (in mathematical language, the FOC equal to zero):

$$\frac{\partial k}{\partial t} = s - (\eta + \delta + \lambda) = 0 \quad (14)$$

Therefore, the above equation can be written as follows:

$$S = (\eta + \delta + \lambda) \quad (15)$$

This results that as the saving rate is equal to the sum of growth in population, depreciation rate and improvement in technology, capital stock will not change. Otherwise, the growth path goes in positive or negative depends on whether RSH of the equation (15) is less or greater that LRH respectively.

The amount of capital, which fulfills the steady-state condition, k^* is defined as:

$$k^* = \left[\frac{sA}{(\eta+\delta+\lambda)}\right]^{\frac{1}{1-\alpha}} \quad (16)$$

For simplifying purposes, output per effective worker is preferred over the output one, therefore, by dividing the whole function by (AL), we can obtain a simple formula to estimate the model parameters as follows:

$$y = \frac{Y}{AL} = \frac{AK^{\propto}l^{\beta}}{Al} = K^{\propto}L^{\beta-1}$$

$$= \left[\frac{K}{L}\right]^{\propto} = \left[\frac{sA}{(\eta+\delta+\lambda)}\right]^{\frac{\propto}{1-\alpha}} \quad (17)$$

Substituting steady-state level of capital (k^*) equation (16) in equation (2), and with some arrangements, and taking natural logarithms of the terms, we can obtain the steady-state income per capita as follow:

$$ln\left(\frac{Y_t}{L_t}\right) = ln\, A_0 + \lambda_t + \frac{\alpha}{1-\alpha} ln(s) -$$

$$- \frac{\alpha}{1-\alpha} \ln\, (\eta + \delta + \lambda) \quad (18)$$

Later, this equation will be pointed as an extended model.

Equation (18) will be tested first to find out whether it will give robust results. Then production function will be decomposed into effective inputs which include capital accumulation K, labour efforts L and H human capital **[38]** as shown below.

4.2. Solow Model with Human Capital

When researchers turned to investigate the role of human capital in the economic growth, **[39]** estimates reveal that U. S. human capital stock in 1969 was more than 50% of the total capital stock. **[1]** enriched above growth model by adding human capital as an independent variable in it.

Their empirical results revealed that adding human capital to the Solow model substantially improved its performance not only on a significance level of coefficients but also by raising the magnitudes of R-squared and altering the results of physical capital to a predicted direction **[1].**

In this context, the formula of the model will be extended to conclude one more variable (H) which is human capital[5]:

Start with augmented C.D. production function:

$$Y_t = A_t K_t^{\propto} H_t^{\gamma} (A_t L_t)^{\beta} \quad (19)$$

Moreover, two types of capital instead of one determine the evolution of the economy, (e. i physical and human capital), and the steady-state levels of both are defined as follows:

$$\dot{k} = sy_t - (\eta + \delta + \lambda)\, k_t \quad (20)$$

[5] Human capital is defined as "*the stock of productive skills, talents, health and expertise of the labour force*" in *Human Capital* by Goldin **[40]** from Department of Economics Harvard University and National Bureau of Economic Research. In Oxford English Dictionary, it is defined as "*the skills the labour force possesses and is regarded as a resource or asset*."

$$\dot{h} = hy_t - (\eta + \delta + \lambda)\, h_t \quad (21)$$

While other variables are as before following similar to the process previously, production function with human capital will be as follows:

$$ln\left(\frac{Y_t}{L_t}\right) = \ln A_0 + \lambda_t + \frac{\alpha+\beta}{1-\alpha-\beta}\ln(s_t) - \frac{\alpha}{1-\alpha} ln\ (\eta + \delta + \lambda) + \frac{\beta}{1-\alpha-\beta}\ln(h_t) \quad (22)$$

Where, s_t denotes saving to GDP ratio however, it is often defined as a proxy of physical capital, and h_t denotes accumulation of human capital. To deal with this equation, it will be pointed as model (2).

At this point, some explanation should be given. There are many proxies for physical and human capital accumulation as MRW have stated in their empirical study **[1].** They suggested two ways to deal with this variable: one is to estimate a reduced form of equation (22), in which the rate of human capital accumulation will represent the variable, and the other way is to estimate the equation (22) directly where h_t represented by the stock of human capital **[41, 42, 43, 44, 45].**

The second problem with this variable is what data is better for estimation; this is related to the availability of data and its quality. MRW constructed their data for this variable, which put more conditions on this issue. In this context, regards to the limitation of data on human capital for most of under developing countries, four indicators have been considered and tested as proxies for human capital; namely, human capital index HCI, average years of schooling, literacy rate for people over 15, and expected years of living.

Before estimation, it is necessary to provide some definitions, to clarify concepts and introduce the variables to be used henceforth.

Firstly: Definitions used are not different from those that are well known in the literature, in addition, the followings will be used:

- Non-oil production: Output out of oil sector.
- Aggregate yearly GDP in real values.

The remaining variables are yet to be cleared. All variables will be in the real values in Libyan currency (Dinar) unless stated.

Dependent and independent variables are illustrated in the table below:

Table 2. Dependent and independent variables used for estimation

Variables	Definition
Dependent variable	
Log of GDP per worker in local currency	*Ln(GDP/W)*
Log of GDP per-capita in local currency	*Ln(GDP/Pop*
Log of GDP per worker in Us Dollars	*Ln(GDP$/W)*
Independent Variables	
Log of investment-output ratio	$Ln(I/Y)$
Log of saving output ratio	$Ln(S/Y)$
Log of capital stock per worker	$Ln(Stck/W)$
Log of (population growth+ depreciation rate +{technology as in MRW model})*	$Ln(n + g + \delta)Ro$
Log of (population growth+ time trend + depreciation rate)	$Ln(n + t_t + \delta)$

* MRW assumed that the rate of growth in A which is g is equal to 0.02, and there is no reason to assume a different amount for each country. Here, the letters Ro denotes to the same assumption of Romer.

5. Estimation and Results

5.1. Data Description and Pre-estimation Tests

According to MRW model, OLS is relevant to estimate parameter, which will be unbiased depending on the specification **[1].** Meanwhile, Prais-Winsten method has been applied since it is an appropriate method to deal with time series problem (i. e. serial correlation) however, OLS is employed wherever good results can be obtained.

Moreover, in MRW model $(\boldsymbol{g})$ is assumed equal to 0.02, $(\boldsymbol{\delta})$ is equal to 0.03[6], both are added to population growth for each country **[39]**. This term is labelled here $\boldsymbol{ln(n + g + \delta)Ro}$**.** In addition, we made a little change by using the time trend instead of MRW assumption ($\boldsymbol{g}$**= 0.02),** and is labelled, $\boldsymbol{ln(n + g_t + \delta)}$**.**

Calculated annual depreciation rate of capital stock in Libya averaged 0.039, while a previous study estimated it by 0.059 **[46]**. Therefore, we use both (calculated one along with that assumed by MRW alternatively)**.**

Before estimation, variables have been tested for stationarity, through ADF and Philips-Perron tests. Dependent variables all are stationary at first difference, except $\boldsymbol{ln(n + g + \delta)Ro}$ and ***ln (stck/w)*** are stationary at level at 5% and 10% respectively, as showed in the following table:

[6] They assumed that technological change and depreciation rate are similar across the countries.

Table 3. Stationarity test

Variables	ADF		PP		Intercept & Trend
	I(0)	I(1)	I(0)	I(1)	
ln(GDP/W)		-7.96***		-7.95***	Yes
ln(GDP$/W)	-2.86*	-8.19***	-2.90*	-8.15***	Yes
ln(GDP/Pop)		-80.3***		-8.02***	Yes
ln(s/y)		-9.47***	-4.58***		Yes
ln(stck/W)		-5.29***		-5.37***	Yes
ln(I/y)	-4.11***		-4.04***		Yes
$ln(n+g+\delta)Ro$	-2.89*	-7.22***	-2.92**	-7.22***	Yes
$ln(n+g_t+\delta)$	-10.28***		-7.83***		Yes

5.2. Results

Stata SE 14 program is used to estimate parameters. Within all estimated formulas there were output -aggregate GDP per worker, per-capita, or non-oil GDP per worker- as a dependent variable, while independent variables represented by one of three proxies: saving to GDP ratio, investment to GDP ratio, and capital stock per worker. Then the best-estimated parameters, which have the best criterions has been chosen.[7]

5.2.1. Basic Solow Model (Aggregate GDP)

In this section, the basic Solow model as derived earlier in equation (18) is applied in three steps. First: for the whole period (1962-2014). Secondly, it is for sub-periods, to avoid any misspecification, such as policies changes. Thirdly, the same model is applied for the non-oil output to capture any different parameters.

For prolonged period 1962-2014, the term $\boldsymbol{ln(n+g+\delta)Ro}$ gave insignificant parameter when regressed against two different dependent variables -per worker GDP and per-capita GDP- (models 1 and 2 Table 4). Saving ratio also shows insignificance. To deal with this, we considered two essential features of Libyan the economy. First: due to nature of oil-sourced GDP, because role of oil revenues, which account for 66% in average of total government revenues (in some years accounted for 90%), to avoid the effect of the exchange rate, we re-estimate models using GDP in US dollars. Since all other variables are just ratios, one can assume that this action will not affect the results. Second: we ignored the period of conflicts from 2011 and after, which definitely influenced all macroeconomic variables

The two actions enhanced the results separately so that parameter of $\boldsymbol{ln(n+g+\delta)Ro}$ become significant and singes turned as predicted, (models 3, 4 and 5 Table 4), all parameters become greater in magnitude and more significant, and the constant term now remarkably higher. Parameters of $\boldsymbol{ln(s/y)}$ and $\boldsymbol{ln(n+g+\delta)Ro}$ become opposite in signs and almost equal in magnitude as predicted by the model.

Capital stock per worker gave insignificant results, and investment to GDP ratio gave better results, however; MRW did not employ it in their empirical study.

Statically, $\mathbf{R^2}$ shows that this model can explain 73 to 79 percent of changes in per-worker income, and when the last four (2011-2014) years are excluded, R^2 becomes higher up to 0.87%.

For robustness, the whole period is divided into sub-periods according to different economic policies implemented to capture as much as possible more significant parameters; these periods are divided as follows:

1. 1962-1980, in this period, oil was dominant, and liberal policies were implemented.
2. 1981-1990, this stage was characterised by governmental control on an economic level, decline in oil prices and oil revenues[8], which affected strongly all economic activities.
3. From 1991 up to now, witnessed returning to an open-door policy, and expansion in government spending.

Similarly, to what has been done for the prolonged period, we estimated many forms and results are shown in the table (4) below.

Parameter $\boldsymbol{ln\frac{s}{y}}$ is the only significant independent variable with predicted sign in all sub-periods compared with $\boldsymbol{ln(stck/w)}$, and $\boldsymbol{ln\frac{I}{y}}$. The period 1962-1980 gave better results with three proxies of the dependent variable (GDP per worker, GDP per capita and GDP per worker in US dollar), while the periods after did not.

[7] In MRW model two different proxies have been applied, saving to GDP ratio, and capital stock per worker.

[8] - This decline was due to two reasons: implemented policies during late seventies and eighties by decreasing oil production to extend the oil life-span, and external causes related to OPEC commitments, see **[20]**.

Table 4. Basic Solow model estimates for Libyan economy (1962-2014)

Model No.	1	2	3	4	5
Dependent variable	**GDP/W**	**GDP/Pop**	**GDP$/W**	**GDP$/W**	**GDP/W**
Period	**1962-2014**	**1962-2014**	**1962-2014**	**1962-2014**	**1962-2010**
Constant	9.91*** (36.7)	8.6*** (31)	20.1*** (40)	20.2*** (42)	20.4*** (45)
$ln^{S}/_{y}$			0.32*** (2.17)		0.53*** (3.78)
$ln^{I}/_{y}$	0.26*** (3.5)	0.26*** (3.66)		0.53*** (3.54)	
$ln(n+g+\delta)Ro$	-0.15 (-1.47)	-0.20* (-1.93)	-0.34* (-1.85)	-0.51*** (-2.75)	-0.39*** (-2.54)
Implied α	0.21	0.21	0.24	0.35	0.35
N	53	53	53	53	49
R^2	0.79	0.73	0.74	0.78	0.87
F	99	70	76	94	162
D-W	1.69	1.73	1.68	1.65	1.61
Serial Correlation Correction Method	Prais Winsten	Prais Winsten	Prais Winsten	Prais Winsten	Prais Winsten

Note: T-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5. Basic Solow model estimates for Libyan economy (Sub-periods 1962-2014)

Model No.	1	2	3	4
Dependent Variable	**GDP/W**	**GDP$/W**	**GDP/Pop**	**GDP$/W**
Period	**1962-1980**	**1962-1980**	**1962-1980**	**1980-2010**
Constant	9.96*** (62)	20.04*** (43.7)	8.46*** (42.6)	26.3*** (10.8)
$ln^{S}/_{y}$	0.30*** (-2.78)	0.59*** (2.12)	0.25** (2)	0.59*** (3.24)
$ln(n+g+\delta)Ro$	-0.24*** (-4.2)	-0.71*** (-4.1)	-0.27*** (-3.69)	
$ln(n+g_t+\delta)$				-1.33* (-1.93)
Implied α	0.23	0.37	0.20	0.37
N	19	19	19	31
R^2	0.66	0.80	0.76	0.96
F	18	38	29	398
D-W	1.36	1.21	1.29	1.16
Serial correlation Correction Method	Prais Winsten	Prais Winsten	Prais Winsten	Prais Winsten

Note: T-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.2.2. Basic Solow Model (Non-oil GDP)

Mankiw, Romer and Weil, excluded oil-based economies from their empirical study. It is crucial to clarify weather this model can answer this issue or not. Therefore, we tried to shed lights on this question specifically.

For this purpose, non-oil GDP is employed instead of aggregate GDP, and a similar process has been done as in 5.2.1. and 5.2.2. Results are illustrated in Table (6). They show that $ln(stck/w)$ becomes more significant than $ln^{I}/_{y}$ and $ln^{S}/_{y}$. Moreover, the term $ln(n+g+d)Ro$ becomes insignificance, therefore it is replaced with $ln\,(n+g_t+\delta)$ which enhanced the results for both prolonged and sub-periods (1, 3 and 4) in Table 6. R^2 becomes higher however, it still less than its levels for aggregate GDP estimations.

Table 6. Basic Solow Model estimates for Non-oil GDP (1962-2014)

Model No.	1	2	3	4
Dependent variable	**Non-oil GDP/W**	**Non-oil GDP/W**	**Non-oil GDP/W**	**Non-oil GDP/W**
Period	**1962-2014**	**1980-2010**	**1980-2010**	**1981-2014**
Constant	-6.0*** (-3.5)	2.33*** (9.5)	-5.3*** (-2.7)	-3.1 (--1.46)
$ln(stck/w)$ $\ln(I/Y)$ $ln(n+g+\delta)Ro$	0.85*** (4.65)	0.32*** (-2.43) -0.18*** (-2.43)	0.82*** (5.1)	0.61*** (3.32)
$ln(n+g_t+\delta)$	-0.26*** (-2.77)		-0.33* (-1.7)	-0.37* (-1.9)
Implied α	0.46	0.24	0.45	0.38
N	53	49	31	34
R^2	0.30	0.17	0.88	0.66
F	12.22	5.8	107	33
D-W	1.83	2.07	1.08	1.45
Serial Correlation Correction Method	Prais Winsten	Prais Winsten	Prais Winsten	OLS

Note: T-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.2.3. Extended Solow Model:

Perfecting to the analysis above, extended Solow model -equation (22) - as suggested by MRW has been applied for the same period, and a similar process has been done. No outcomes can be accepted neither due to statistical criterion or economically. Some of the estimated forms gave a negative sing for saving to output ratios and for the term $\frac{\beta}{1-\alpha-\beta} ln(h_t)$, which contradicts with the assumptions and the theory. In this context it is worth to mention that plenty of studies have recorded similar results in which explanatory power of human capital in economic growth depends on the proxy used **[4]**, and the growth rate of this variable often enters regressions negatively or very little explanatory power, **[32], [45]** and **[47].** In some cases, there were insignificant parameters, which could not pass the essential tests.

The next step is to calculate the share of each input factor, according to Harrod-neutral assumption, as well as TPF contribution to economic growth as follows:

Growth in GDP can be broken down into the contribution of the K, L and total factor productivity.

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \propto \frac{\dot{K}}{K} + (1- \propto)\left(\frac{\dot{L}}{L}\right) \quad (18)$$

Where: $(1- \propto) = \beta$

Then:

$$(T\dot{F}P/TFP) = \dot{Y}/Y - [\alpha(\dot{K}/K) + \beta(\dot{L}/L)] \quad (19)$$

Variables with a dot are differentials with respect to time as usual in economics parlance.

$(T\dot{F}P/TFP)$, or $\frac{\dot{A}}{A}$ denote the growth rate in TFP and referred to as the *Solow Residuals*.

Table (7) below illustrates calculated contributions of each factor for of five years periods in percentage. Relatively, there is no high volatility in contributions of input factors. The capital share was equal to (34.47) in average compared with (64.02) for labour. This contrasts with available results of previous studies on some of oil-based MENA economies. When capital grows faster than labour, this leads to a negative correlation between contributions of the two factors, K & TFP. In our case, real physical capital grew by 6.9% on average over the period, while labour force, labour supply and population, all grew at an average of 4.25%, 5.06% and 2.7% respectively over the period, which explains the low contribution of capital due to the law of diminishing returns. Also, the impact of closed economy policy between 1980 -2000 appears in contributions of all factors as seen in figure (4). Furthermore, the contribution to output growth due to TFP depends reversely on (α) (share of physical capital) **[37],** this can be observed in table (7), once the contribution of capital grows, the TFP falls down, and vis-versa.

Table 7. Contributions of TFP and each input factor to economic Growth in Libya (1964-2014)

Year	GDP Growth	TFP	Physical Capital	Labour	A/A
1964	23.98	-1.37	8.87	16.48	-24.5
contribution of each factor in %		*(-5.70)*	*(37.0)*	*(68.71)*	
1969	6.80	0.19	2.31	4.30	100.8
contribution of each factor in %		*(2.75)*	*(34.04)*	*(63.21)*	
1974	66.48	0.76	23.0	42.72	-5199.9
contribution of each factor in %		*(1.14)*	*(34.06)*	*(64.26)*	
1979	75.58	1.50	25.92	48.15	335.7
contribution of each factor in %		*(1.99)*	*(34.30)*	*(63.71)*	
1984	-14.23	0.38	-5.11	-9.50	-43.8
contribution of each factor in %		*(-2.66)*	*(35.93)*	*(66.73)*	
1989	10.59	-0.08	3.73	6.93	-67.8
contribution of each factor in %		*(-0.71)*	*(35.25)*	*(65.46)*	
1994	-5.73	-0.92	-1.69	-3.13	99.6
contribution of each factor in %		*(15.98)*	*(29.41)*	*(54.61)*	
1999	9.37	-1.02	3.63	6.75	-10.1
contribution of each factor in %		*(-10.89)*	*(38.81)*	*(72.08)*	
2004	31.41	0.15	10.94	20.32	-130.7
contribution of each factor in %		*(0.47)*	*(34.83)*	*(64.69)*	
2009	-32.69	0.37	-11.57	-21.48	-75.5
contribution of each factor in %		*(-1.12)*	*(35.39)*	*(65.73)*	
2014	-47.23	-0.87	-16.22	-30.13	-911.3
contribution of each factor in %		*(1.85)*	*(34.35)*	*(63.80)*	
Averages %		**-0.34**	**34.47**	**64.02**	**-**

A/A is calculated time trend of TFP following Solow method (Solow 1957)

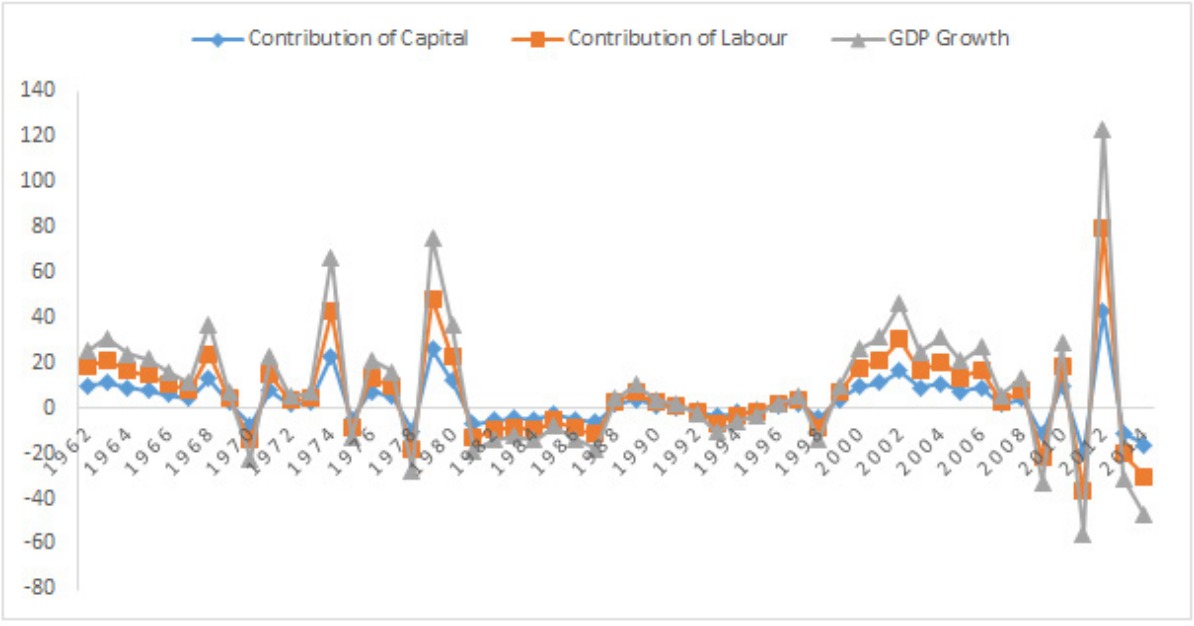


Figure 4. GDP growth and contribution of each factor

To understand these outcomes: we ought to remember that MRW have excluded oil-based countries from their empirical study. They noticed that one should not expect a standard growth model to explain the economic process for the extraction process. The fundamentals of economic growth require a clear relationship between input factors and the output, this relationship does not exist in the oil extraction procedure or at least does not work properly. The question here is that, why the MRW model works well in the basic form and does not with the extended form, results are not reliable. This is not different from previous outcomes of many studies not only for Libyan economy but also for oil-based countries **[46]**. Some explanation is that the role of human capital is still unclear or insignificant in developing countries, either due to the quality of data or because the increase in human capital stock in the long-run is usually greater than technological progress which leads to diminishing returns **[41].** In this regard, World Bank has warned that natural recourse may hinder the process of human capital accumulation in which the base of long-run economic growth **[47]** Also, this may due to the low impact of education on economic growth in these countries. Low importance of human capital compared to that of physical capital in oil-based economies, the causality between output and human capital is still unclear and may be opposite to that in the developed countries **[7, 48, 49, 50, 51, 52, 53, 55 and 56]**. This feature does not appear when employing only physical capital **[57]**. In the meanwhile, some studies have shown a significant negative impact of the oil export on human capital **[58]**.

6. Conclusions

Three aspects support basic Solow model in explaining the changes in per-worker GDP. First, the coefficients on saving ratio and population growth are almost equal in magnitudes and opposite in sings (models 2, 3, 4 Table 4 and model 3 Table 5). Secondly, both of them are significant, and they can explain changes in output-per-worker. Thirdly, the capital stock is significant in both short and long run while investment to GDP ratio is significant only in the short-run. Elasticities of input factors were calculated using time-series on capital stock and labour force. The sum of the coefficients is not equal to one due to the lack of equality of remuneration to the marginal productivity of capital and labour.

On the other hand, according to national accounts, capital share in income in Libya is higher than that in oil-rich countries. It was between 0.61 and 0.80 over the studied period. Therefore, one can expect that elasticity of income with respect to capital is about two-thirds of GDP. Implied $\propto$ in all regressions is much lower than expected. This result contradicts with prediction, and even with MRW empirical out comes, in which they obtained a higher value for $\propto$ than they expected. From 1980 and beyond the model became unable to explain changes in income, when Libyan economy became more depended on oil. This also explains why MRW excluded oil-based economies from their empirical studies.

For non-oil GDP, capital stock per-worker is more important over investment ratio. This is because the labour productivity in this sector is higher, while in the oil sector, the productivity is pre-determined, and labour has less impact on output. The elasticity of output with respect to capital for non-oil GDP is slightly higher than that in aggregate GDP. Thus capital is more important than labour in the oil sector. The term $ln(n + g + \delta)$ used by Romer is less significant than $ln(n + g_t + \delta)$ term used in our analysis. This means that time trend in technical growth g_t plays more important role than constant technological growth (g) assumed by MRW. Increasing oil revenues plays as an engine for economic growth rather than technological progress and these revenues have a time trend. Therefore, it can be claimed that basic Solow model as suggested by MRW is relevant even for Libya as a case of oil-based economies.

In regards to the extended model with human capital, results are not reliable. This is consistent with conclusions in previous studies for other oil-based countries. In fact, the oil revenues help remarkably less in progress of education and health sectors and end up in creating less human capital in oil-rich countries such as Libya.

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