International Economic Studies
Vol. 39, No. 2 (New Issue), Autumn & Winter 2011-2012
pp. 17-34
Received: 15-09-2011 **Accepted:** 30-01-2012

Oil Shocks and Macroeconomic Adjustment: a DSGE modeling approach for the Case of Libya, 1970–2007

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Abstract:
Libya experienced a substantial increase in oil revenue as a result of increased oil prices during the period of the late 1970s and early 1980s, and again after 2000. Recent increases in oil production and the price of oil, and their positive and negative macroeconomic impacts upon key macroeconomic variables, are of considerable contemporary importance to an oil dependent economy such as that of Libya. In this paper a dynamic macroeconomic model is developed for Libya to evaluate the effects of additional oil revenue, arising from positive oil production and oil price shocks, upon key macroeconomic variables, including the real exchange rate. It takes into consideration the impact of oil revenue upon the non-oil trade balance, foreign asset stock, physical capital stock, human capital stock, imported capital stock and non-oil production. Model simulation results indicate that additional oil revenue brings about: an increase in government revenue, increased government spending in the domestic economy, increased foreign asset stocks, increased output and wages in the non oil sector. However, increased oil revenue may also produce adverse consequences, particularly upon the non-oil trade balance, arising from a loss of competitiveness of non-oil tradable goods induced by an appreciation of the real exchange rate and increased imports stimulated by increased real income. Model simulation results also suggest that investment stimulating policy measures by government produce the most substantive benefits for the economy.

Keywords: Oil related shocks, Libya, dynamic macroeconomic model, simulation analysis, policy implications.

JEL Classification: E27, E60, Q33, Q43, Q48.

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1. Introduction

The Libyan economy is a small developing economy that has been heavily dependent on the oil sector since the early 1960s. Oil revenue has had both direct and indirect effects on factors leading to development of the economy. The significance of the oil sector in the economy stems from its role as a major source of government revenue, exports and foreign exchange. Also, a major share of national income is derived from the oil sector. The economy has experienced increased domestic oil production as well as substantially increased oil prices during the period of the late 1970s and early 1980s, and again after 2000. The macroeconomic impact of these developments is of considerable contemporary importance to an oil dependent economy such as Libya. Recent developments in the oil sector have brought about: an increase in government revenue, increased government spending in the domestic economy which has contributed to economic development, and increased employment and wages in the oil and oil related sectors. However, these developments may also have produced adverse consequences on the non-oil sector by reducing employment in the relatively more labour intensive non-oil sector, a loss of competitiveness of non-oil tradable goods arising from an appreciation of the real exchange rate, increased imports arising from increased real income, and, accordingly, a deterioration of the non-oil trade balance.

Identifying the positive and negative impact of the oil sector boom upon key macroeconomic variables for Libya requires a detailed analysis of the structure of the economy under study. To do so, we develop a dynamic macroeconomic model that evaluates the effects of additional oil revenue upon key macroeconomic variables, including the real exchange rate. It takes into consideration the impact of increased oil revenue upon the non-oil trade balance, foreign asset stocks, physical capital stock, human capital stock, imported capital stock and non-oil production.

The paper proceeds as follows: section two discusses the theoretical framework utilized in this paper, with emphasis placed upon a fixed exchange rate combined with control over capital mobility. Section three presents the results of simulation scenarios, and section four provides conclusions and policy implications.

2. Theoretical framework: the model

The oil related macroeconomic model developed in the current study of the Libyan economy has its foundation in the models of Buiter and Miller (1981), Eastwood and Venables (1982), Buiter and Purvis (1982), Neary and Van Wijnbergen (1984), Harvie and Gower (1993), Harvie and Thaha (1993), and, more recently and importantly, Cox and Harvie (C-H henceforth) (2010), for the case of a flexible exchange rate and advanced resource-abundant economy. The latter contribution is a general equilibrium model focusing on the dynamic long run nature of the adjustment process. These models represent extensions to the basic Dornbusch model (1976), incorporating features particularly arising from the existence of an oil sector and its related economic effects. In these models a deterministic framework is adopted in which economic agents are assumed to possess rational or forward looking expectations. This is equivalent to the case of perfect foresight. Non-financial markets are subject to sticky prices and in some models, such as Harvie and Gower (1993), Harvie and Thaha (1993) and Cox and Harvie (2010), sticky quantity adjustment, resulting in disequilibrium throughout the adjustment process. On the other hand, financial markets are assumed to be in continual equilibrium. Thus, the effects arising from oil related shocks are initially transmitted primarily through the financial market, and then to the product and labour markets.

However, in order for these models, specifically the C-H model, to be more applicable for an oil-developing economy such as that of Libya, a number of amendments have to be made. These are as follows:

The majority of oil production and its revenue is produced and generated by government owned entities; hence oil production and revenue is under government control. Therefore, the way in which government spends the oil revenue will have a significant impact upon the future development of the economy.

Government allocates the oil revenue between two types of expenditure. First is consumption expenditure which stimulates the demand for domestic non-oil output. The second is development (or investment) expenditure, which is divided into three parts; government development spending on physical capital, government development spending on human capital and that devoted to imported capital. The first type of government expenditure induces non-oil output demand, while the second induces non-oil output demand and supply.

It is assumed that the oil sector, during its production and boom periods, will have a long run sustainable impact on non-oil output. The oil boom generates both physical capital stock accumulation in the non-oil sector and human capital stock accumulation induced by government capital expenditure (spending effect), foreign asset stock accumulation via developments in the current account (current account effect), acquisition of technology through capital imports (technology effect), and budgetary implications via tax revenues generated from oil production (revenue effect). These contribute to permanently boosting the productivity capacity of non-oil output in the post oil boom period in particular.

The model developed assumes that the nominal exchange rate is fixed, since it has remained noticeably unchanged over most of the period of study in Libya, and international capital mobility is highly controlled by the government.

In the C-H model there is assumed to be four financial assets available in the economy. These are domestic money, domestic bonds, foreign bonds and equities. The equities represent claims to ownership of the physical capital stock used in the non-oil sector. In the case of Libya there is assumed to be only one financial asset available in the economy, which is a money asset. This assumption is due to the immaturity of financial assets in the economy, and lack of data available for other financial assets.

The equations of the model are presented in Table 1. All variables are in log form except that of the domestic and world interest rates, and the parameter in front of each variable indicates its elasticity. The definitions of endogenous and exogenous variables are presented in Table 2. Equilibrium in the model depends upon equilibrium in the product market, assets market and foreign trade sector. The product market is discussed first.

The product market consists of eighteen equations, represented by Equations 1–18. Equation 1 describes the total demand, or spending, on non-oil output (No^d). It is a log linear approximation of total spending in the form of private consumption spending, private investment spending, government spending and the non-oil trade balance consisting of non-oil exports (x^n) and non-oil imports (m^n). The parameters (β_i) represent the elasticities of spending in each category.

In line with the C-H model, private consumption expenditure is given by Equation 2. It depends positively upon non-oil output supply and private sector wealth. The production of non-oil output represents income generated by the public and private sectors, although most non-oil output is produced by the public sector in Libya[1].

Equation 3 describes private sector gross investment, which equals the change in the stock of private capital and is based on the partial adjustment hypothesis. This partial adjustment arises from costs of adjusting the actual physical capital stock (k^p) to the desired capital stock (k^{p*}). The increase in capital from the end of the previous period to the end of the current period is some fraction γ of the divergence between the desired and actual stock of capital. The desired capital stock is assumed to depend upon non-oil output[2] (see Equation 4 in table 1).

Total government spending (g) is identified by Equation 5. It depends positively on two components of expenditure; government consumption spending (c^g), which is assumed to be dependent upon oil revenue as shown in Equation 6, and government development expenditure. Government development spending is divided into three parts; government development spending on physical capital (for example, infrastructure) (i^g), government development spending on human capital (for example, education and health care) (i^h) and that devoted to imported capital (for example, imported foreign technology) (i^{cap}). The Libyan government plays an important role in providing infrastructure and free education and healthcare necessary to build human capital[3]

[1] Non-oil output can be considered as a good which can be either consumed domestically or exported, and is an imperfect substitute for the foreign non-oil imported good.

[2] In the C-H model the change in the stock of private capital is determined by Tobin's q ratio, which is the ratio of the marginal market valuation of capital relative to the replacement cost of the capital.

[3] In this context, Libya has achieved essential improvements in terms of primary, secondary, and tertiary school enrolments. For example, secondary school enrolment substantially increased from 21 percent in 1970 to 95 percent in 2002. Also, tertiary enrolment recorded a significant increase from 3 percent to 53 percent in the same period. However, there are concerns about the quality of the content and actual access to up-to-date knowledge and expertise. These concerns are attributed mainly to Libya's isolation for more than a decade due to the embargo and the sanctions imposed upon the country by the US and UN, and the ban on foreign languages from the curricula. Regarding the health sector, life

(World Bank, 2006), as well as acquiring imported technology.

Equations 7, 8, and 9 describe government investment spending on the physical, human and imported capital stocks, respectively, which arises from a gradual adjustment of the actual public capital stock to their policy determined levels. The policy determined levels are determined by oil revenue, as given by Equations 10, 11 and 12. This is another major difference between this model and that of the C-H model.

Equation 13 identifies the budgetary stance, which is government expenditure (g) less tax revenues (t). The budget deficit can be financed in three ways; through money accommodation (sales of government bills and securities to the Central Bank of Libya (CBL)), by borrowing domestically from the private sector, or by borrowing from abroad. In Libya the government issues bonds to the central bank only, and does not issue bonds to the public. The public are not able to buy treasury bills and bonds due to the lack of financial institutions in the economy. Also, the Libyan government has not, as yet, borrowed from abroad. Therefore, Equation 13 shows that any excess of real total expenditure (g) over real total tax revenue (t^x) must be financed by borrowing domestically from the CBL. Tax revenues are generated from two sources, oil production and non-oil production (Equation 14).

The non-oil trade balance is disaggregated further into non-oil exports less non-oil imports as shown in Equation 15 and identity Equation 30. Equation 15 specifies non-oil exports (x^n), which depends positively upon the real exchange rate ($e + p* — p$) and world real income ($y*$). Non-oil imports is also disaggregated into non-oil consumption imports (m^{con}) and non-oil capital imports (i^{cap}). Equation 16 identifies non-oil consumption imports, which depends negatively upon the real exchange rate and positively on domestic real income (y). Equation 9 identifies non-oil capital imports which are assumed to be endogenously determined, arising from a gradual adjustment of actual imported capital spending to its policy determined level. Libyan non-oil capital imports, which comprise capital goods and raw material goods, increased rapidly during the oil boom periods. This is attributed to the highly ambitious development programme conducted by government during the oil boom periods. Thus, a large share of oil revenue is being used directly for the purchase of imports, in particular capital imports, containing advanced technology. This is another departure from the C-H model, and in addition is considered as one of the main contributions of this model.

Real and permanent income (y^p) definitions, first used by Buiter and Purvis (1982), are given by Equations 17 and 18 as in the C-H model. Real income, as identified in Equation 17, depends upon non-oil output (No^s), oil production (o^a) that is assumed to be exogenous, the world price of oil (po), that is also exogenous, the real exchange rate as emphasized here and the exogenously determined price of non-oil imported goods ($p*$). However, in the C-H model such income goes to the private sector, whereas in this model only non-oil income, generated from non-oil output, accrues directly to the private sector, and oil income generated from oil production goes directly to government. This is another major departure from the C-H model. Real oil output directly affects government income and, in turn, spending, as in Equations 5, 6, 7, 8 and 9. It will also affect non-oil output supply as in Equation 24 through imported capital, human and physical capital accumulation, and the allocation of oil production as in Equation 26. Non-oil output will directly influence private sector consumption and the money market, as in Equations 2 and 19.

Equation 18 is the same as in the C-H model. It represents permanent income, which is a function of exogenous permanent non-oil output (No^{sp}), exogenous permanent oil output (o^p), the world price of oil, the real exchange rate and price of non-oil imported goods (see also Harvie, 1994). It is assumed that v , which is the share of non-oil production in total value added, does not change as a result of oil production, is treated as being the same in real and permanent income, and is constant through time. If the share of oil production in domestic real income $(1-v)$ is larger than its share in domestic consumption (μ_2), then the economy will be an oil exporter during its period of production. An assumption maintained throughout the remainder of this paper.

expectancy has increased from 52 years in 1970 to 72 years in 2002 as a result of improvement in health care services (for more detail, see World Bank, 2006, p.7 & 8).

Asset market equations are given by Equations 19–21[1]. Unlike the C-H model and other long run models (see for example Harvie and Gower, 1993; and Harvie and Thaha, 1993), there is only one financial asset (money) in this model. According to conventional money market equilibrium the demand for real money balances depends upon real income, and the nominal interest rate as the opportunity cost of holding real balances. However, the special characteristics of Libya, like most other developing countries, should be considered when specifying the functional form of money demand. Libyan financial markets are immature and still in the process of being liberalised, and capital is restricted due to the constant nominal interest rate. Thus, there is a limited range of alternative financial assets. Furthermore, the interest rate does not reflect the increase in price levels. As a consequence the interest rate does not accurately reflect the opportunity cost of holding money in Libya. In addition, since the interest rate is subject to regulation by policymakers it is no longer a good proxy for the cost of holding money, but, rather, tends to show the restrictiveness of monetary policy. Therefore, the rate of inflation will be utilised as a proxy variable for the opportunity cost of holding money[2].

For this reason the alternative specification of money market equilibrium, as given by Equation 19, incorporates real non-oil income and the rate of inflation as an alternative explanatory variable in place of the interest rate. The nominal money supply is assumed to be endogenous as the nominal exchange rate is fixed. The demand for real money balances (the nominal money stock *m* deflated by the consumer price level *p*) depends positively upon real non-oil income (No^s), representing a transactions demand, and negatively upon the inflation rate (representing an asset demand for money). It is assumed that the money market always clears, so this equation always holds.

Domestic private sector real wealth (w^p) is given by Equation 20 as in the C-H model, except that real bond holdings by the private sector are excluded from Equation 20. This is because of the fact that the Libyan government does not issue bonds to the public. Domestic private sector real wealth consists of three components. The first major component is the private capital stock which is assumed to be owned entirely by the private sector. The private capital stock is produced from private investment. The second major component is real money balances, which consists of cash, deposits, and savings of the private sector. The final component is permanent non-oil income equivalent to that of permanent non-oil output[3]. Equation 21 shows the money growth equation. It indicates the assumption of a fixed exchange rate combined with imperfect capital mobility[4]. Since a fixed exchange rate is assumed for the case of Libya, the money supply and its growth is endogenously determined. It depends upon exogenously determined changes in domestic credit expansion ($d\dot{c}e$) and the accumulation of foreign exchange reserves through balance of payments surpluses/deficits ($f\dot{e}s$) (see Harvie, 1993, and Harvie and Thaha, 1994), as shown in Equation 21*:

$$\dot{m} = d\dot{c}e + f\dot{e}s \qquad (21^*)$$

$d\dot{c}e$ is exogenously determined by government and is assumed for simplicity to be equal to zero. Changes in foreign exchange reserves arise from developments in the current account ($\dot{f}$) and from capital flows due to differences in the domestic and foreign nominal interest rate $(r - r^*)$, as shown in Equation 21**, where τ indicates the interest rate sensitivity of international capital flows[5].

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[1] Tobin's q and the real return on private capital services are omitted from this model due to the lack of data and adequate information.

[2] In this respect many researchers have used alternative variables to that of the interest rate in the demand for money equation in developing countries. For instance, Usui (1996) used the rate of inflation as a proxy for the opportunity cost of holding money in his money demand equation for the Indonesian economy. He found that the inflation rate is significant and negatively related to money demand, better reflecting the opportunity cost of holding money, while the interest rate is not significantly related to money demand.

[3] This is a proxy for the present value of the future income stream for the private sector.

[4] This assumption means that there is a discrepancy between the return on domestic financial assets and foreign financial assets, which can continue for a prolonged period of time. A fixed nominal exchange rate, which is unable to adjust in order to achieve the equalization between expected returns on domestic financial assets and foreign financial assets, and differences in the returns on domestic and foreign financial assets results in persistent capital flows with money supply implications.

[5] The value of parameter τ can range from zero to infinity. If τ is equal to zero then there is completely imperfect international capital mobility, whereas if τ is equal to infinity there is perfect international capital mobility.

$$f\dot{e}s = \tau(r - r^*) + \dot{f} \qquad (21^{**})$$

By substituting Equation 21^{**} into Equation 21^{*}, Equation 21 is obtained.

Equations 22–24 define the price level and aggregate non-oil output supply. Price and inflationary expectations developments are given by Equations 22, 23, and 24. Equation 22 defines the consumer price level, which is a weighted average of nominal wages, the domestic cost of oil and the domestic cost of the world non-oil imported good. The last one is represented by the imported goods price index in foreign currency multiplied by the exchange rate.

Adjustment of nominal wages is generated by an expectations augmented Phillips curve, as given by Equation 23. Two possible adjustment sources are considered. These being excess demand for non-oil goods relative to its available supply $(No^d - No^s)$, and core inflation (π). Core Inflation depends upon developments in the monetary growth rate (Equation 21 in table 1).

Aggregate non-oil output supply is endogenously determined, as given by Equation 24. It depends positively on the public capital stock[1], human capital stock, private capital stock, imported capital stock and employment. Government investment is divided into three parts; capital that affects non-oil output through physical capital stock accumulation, capital that affects non-oil output through human capital formation and capital imports.

Inclusion of the public capital stock is attributed to the assumption that it is complementary to that of the private capital stock in nature. For example, Aschauer (1989a; 1989b) argues that public capital spending, especially on infrastructure, such as highways, streets, water and sewerage system and airports operates as a complement to private sector inputs, and "crowds in" private capital accumulation and enhances its efficiency. In addition, Morrison and Schwartz (1996) examine the relationship between public capital and costs of private production. Their results indicate the importance of public infrastructure investment to the private sector's productivity. They find that public infrastructure investment reduces the cost of private production, and can lead to increased productivity. Hence it has a potentially positive and significant effect on non-oil aggregate supply. Furthermore, like other typical oil-exporting countries in the Middle East and North African regions, Libya is dependent on imports of industrial inputs, in the form of physical capital and technology, from developed countries. Importation of capital goods and raw materials, which contribute more than 65% of total imports (Annual report, CBL, 2005), are crucial for the production of non-oil output, hence they play an important role in the economic development process. Thus, unlike the C-H model and other long run models, the stock of capital imports (k^{cap}) is vital for the supply of goods and services and are also included in Equation 24.

The external sector consists of the current account and the oil trade balance. Developments in the current account are given by Equation 25a (see for example Harvie and Gower (1993) and Harvie (1994)).

$$\dot{f} + e - p = \alpha_1 T + \alpha_2(r^* f + e - p) + \alpha_3(o^x + po + e - p) \qquad (25a)$$

where (o^x) represents net exports of oil. Re-arranging Equation 25a and expressing this in terms of changes in foreign exchange reserves, Equation 25 is obtained. This shows that changes in foreign exchange reserves, as reflected in the current account balance ($\dot{f}$), depends positively upon the non-oil trade balance (as given by Equation 29), foreign interest income ($r^* f$), net oil exports and on the real exchange rate ($e - p$). In long run steady state the current account balance must be zero, otherwise further wealth effects will arise requiring further macroeconomic adjustment. Equation 25 is as in the C-H model.

Equation 26 indicates that net oil exports are exogenously determined, being dependent upon government policy towards the domestic usage or export of oil production.

Finally, Equations 27–30 define four variables which are used extensively throughout this study. Equation 27 defines the real exchange rate as used in this study, Equation 28 defines real money balances, Equation 29 defines the non-oil trade balance, and Equation 30 defines non-oil imports.

3. Simulation results arising from an oil production and oil price shock

The simulation analysis conducted emphasises the dynamic adjustment process and the long-run steady state properties of a number of key macroeconomic variables arising from oil related shocks. These variables are real income, government real oil revenue, non-oil output, private capital stock, public capital stock,

[1] The reason for including government development expenditure is to capture the effects of government-led development strategies. In particular, during the oil boom periods.

human capital stock, imported capital stock, foreign asset stock, non-oil trade balance, real exchange rate, domestic price level and private sector real wealth[1]. These variables were chosen since changes in them, arising from an increase in oil production or oil price, have an important influence upon the development of other key variables and for the domestic economy as a whole. A simulation analysis is conducted using a dynamic stochastic general equilibrium model (DSGE), which is solved by Dynare (see Adjemian, *et al.* 2011), suitable for a small open oil-exporting economy such as that of Libya. The parameter values utilised to conduct the numerical simulation scenarios are shown in Table 3. These parameters were obtained from: 1) estimation of the behavioural equations of the model using the ARDL cointegration technique, 2) those calculated from available data, 3) those set as adjustment coefficients, 4) those obtained from other studies, and 5) those imposed due to data limitation or in order to ensure model stability.

Two simulations scenarios arising from oil related shocks, and their impact upon twelve macroeconomic variables, are implemented:

A) An instantaneous, unanticipated and permanent 15% increase in oil production.

B) An instantaneous, unanticipated and permanent 15% increase in oil price.

A summary of the long run steady state properties of the Libyan macroeconomic model, focussing upon the more important macroeconomic variables mentioned earlier, for both scenarios, is summarised in Table 4. Both scenarios assume an immediate and permanent increase in oil production and oil price by 15%. The numbers in Table 4 display the long run deviations in the steady state values of the aforementioned macroeconomic variables, in percentage terms, from their presumed initial base values. Also, the impact of each shock upon the adjustment path of key macroeconomic variables of interest is contained in Figures 1–12. The horizontal axis measures time periods, whilst the vertical axis for each diagram measures the percentage deviation of each variable from its initial or base value. These figures indicate that the adjustment period arising from oil related shock lasts 40 periods, by which this time all variables have reached their long-run steady state equilibrium. Each figure contains the two cases; Case A represents an oil production shock, and Case B symbolizes an oil price shock. A detailed analysis of the simulation results arising from an oil production and oil price shock is discussed in detail below.

The results presented in Table 4 show that the direction of change of the macroeconomic variables of interest arising from two oil related shocks is analogous. However, the magnitude of the deviations is not the same, although they are comparable for most of the variables. The similarities and differences arising from both shocks for the variables of interest are now discussed.

Figure 1 shows developments in foreign asset stocks arising from both shocks. An increase in either oil production or oil price by 15 percent initially leads to an accumulation of foreign asset stocks, arising from current account surpluses (current account effect) during the adjustment path, but the initial accumulation is larger in Case B. This arises from an immediate increase in oil exports and surplus in the oil trade balance and higher foreign interest income (see Equations 25 and 26 in table 1). An initial accumulation of foreign exchange reserves leads to a temporary increase in the money stock so as to maintain the fixed nominal exchange rate policy, leading to an increase in the domestic price level in the short term. Foreign asset stocks increase continuously throughout the adjustment process towards long run steady state in both cases, signifying current account surpluses, accumulating by 7 percent in long run steady state for Case A, and by 12.3 percent for Case B. This is despite a deficit in the non-oil trade balance arising from increased non-oil imports and decreased non-oil exports[2]. This can be explained by the fact that the non-oil trade balance deficit is entirely offset by continual surpluses in the oil trade balance, with the latter being brought about by either an increase in oil export volumes or an increase in the price of oil, as well as from an increase in foreign interest income.

Total government revenue initially increases during the adjustment process, as can be observed from Figure 2. However, this increase

[1] The adjustment of a number of macroeconomic variables can be obtained from the simulation analysis. However to keep the discussion tractable, focus is placed on only a few key variables as emphasised here.

[2] Increased non-oil imports, in particular non-oil capital imports deteriorate the non-oil trade balance and reduce the accumulation of foreign asset stocks. However, imported capital has a positive impact upon non-oil output.

is greater in Case A than in Case B, as a result of a smaller increase in the price level in the former case during the early stage of adjustment (see Figure 3). That is, an increase in the oil price leads to a higher initial consumer price level in Case B (see Equation 22 in table 1). Government income, therefore, increases immediately in the early stage of adjustment in both cases, implying larger government capital spending upon public capital, human capital formation and imported capital and larger potential benefits for the private sector. Consequently, this stimulates development in the non-oil sector[1]. Real government income slightly declines thereafter to a level where it is higher than its base value by 1.62 percent, in both Cases A and B.

Developments in government revenue (revenue effect) affects total real income directly since government spending increases, and indirectly via expansions in non-oil output supply as can be observed from Equation 24. The indirect effect is induced, as mentioned above, by public capital stock, human capital stock and imported capital stock accumulation, which also benefits the private capital stock and non-oil output supply. Also, increased government real income arising from oil related shocks will have a significant impact upon the real exchange rate. During oil boom periods the government increases its spending to maintain its balanced budget policy, resulting in increased demand for both non-oil as well as imported goods (see Equation 1 in table 1). Consequently, the increased demand for non-oil output (spending effect) will lead to a higher domestic price level during the short run and an appreciation of the real exchange rate (see Figure 4). An appreciation of the real exchange rate (exchange rate effect) will have a significant influence upon the adjustment of a number of key macroeconomic variables, particularly non-oil exports, non-oil imports, and non-oil trade balance, and consequently upon the domestic economy as whole.

The non-oil trade balance initially deteriorates during the adjustment process for both cases, with a noticeably larger deterioration for Case B, as can be seen from Figure 5. The primary reason for the deterioration in the non-oil trade balance is a combination of increasing non-oil imports and declining non-oil exports throughout the adjustment path. Increased non-oil imports are stimulated by an appreciation of the real exchange, an increase in real domestic income and government spending on capital imports. However, the adjustment of non-oil exports is strongly influenced by the initial sizeable appreciation of the real exchange rate, particularly in Case B. Dutch disease consequences are, therefore, likely to occur in terms of deterioration in the non-oil trade balance during the early stage of the adjustment process toward long run steady state. As the real exchange rate appreciates this results in a loss of competitiveness for non-oil exports (exchange rate effect), and higher domestic demand stimulated by an increase in real income increases the demand for non-oil imports.

During the medium run to long run steady state the non-oil trade balance experiences a slight improvement as a result of an improvement in non-oil exports and decline in non-oil imports. This arises from a subsequent depreciation of the real exchange rate, as can be observed from Figure 4. The non-oil trade balance declines by almost 3.5 percent in long run steady state for the case of increased oil production, and deteriorates by 2.5 percent for an oil price increase (see Table 4).

The simulation results for private sector real wealth indicate that it increases continuously throughout the adjustment process toward its long run steady state for either an increase in oil production or oil price (see Figure 6). It accumulates by almost 8 percent in Case A and 7 percent in Case B, as can be observed in Table 4 and Figure 5. Increased private sector real wealth in both cases arises due to an accumulation in private capital stock (see Figure 7), an increase in permanent income and an increase in real money balances. The increased private capital stock is induced by increased non-oil output supply (see Equations 3 and 4 in table 1), which in turn is induced by government investment spending on physical, human and imported capital (technology effect) and is of further benefit to the private sector. This is due to the fact that public capital spending on infrastructure, human capital formation and technological acquisition through imported capital raises the productivity of private factors of production, stimulating both the aggregate supply of non-oil output and aggregate demand for non-oil output.

[1] This explains the continual increase in non-oil output supply in the early stage of adjustment (see Figure 10)

Figure 8 indicates that for either an increase in oil production or oil price, real income increases continuously throughout the adjustment process (income effect). It is noticeably larger for Case A, with most of the increase in real income occurring very early in the adjustment process. It is induced directly by the 15 percent increase in either oil production or oil price and also by subsequent changes in non-oil output (see Equation 17 in table 1). In long run steady state for Case A real income is approximately 7 percent higher than its base value, while it is 5 percent above its base value in Case B, as indicated in Table 4. On the demand side an increase in real income stimulates non-oil imports, which in turn contributes to a deterioration of the non-oil trade balance. However, an increase in non-oil capital imports enhances non-oil output supply, which in turn contributes positively to non-oil output supply and in turn to real income.

Non-oil output supply improves continuously throughout the adjustment process to its long run steady state for either the case of an oil production increase or oil price increase (see Figure 9). The major contributory factors to this development throughout the adjustment process include: a continuous increase in private capital stock, public capital stock (that is, infrastructure), human capital stock (education and training), and imported capital stock (technological acquisition) (see Figures 7, 10, 11, and 12). An increase in overall public capital stock is stimulated directly by government development spending (spending effect). An increase in non-oil output supply stimulates demand via private consumption and private investment. Also, an increase in non-oil output supply increases the nation's real income and induces imports to rise, thereby possibly leading to a trade balance deficit. Thus, the positive effects of an increase in non-oil output supply are offset partially by deterioration in the non-oil trade balance.

The Dutch disease effect upon non-oil output is not likely to occur during the early stage of the adjustment process toward long run steady state from the above results. The windfall revenue arising from the oil sector brings about increased domestic demand for non-oil output, while a real exchange rate appreciation reduces the demand for non-oil output (spending effect and an exchange rate effect). The latter contributes to a loss of competitiveness of the non-oil tradeables sector. In this model the former effect dominates the latter effect and non-oil output demand increases overall. On the non-oil output supply side a Dutch disease effect during the early periods of adjustment is also not observed, due to the gradual accumulation in physical, human and imported capital stocks[1] (see Figures 10, 11, and 12 below, and Equation 24).

In long run steady state non-oil output supply is found to be higher than its base value by 5.2 percent in Case A, and 5 percent in Case B (see Table 4). This is again due to the accumulation of public, human and imported capital stock as well as private capital stock in long run steady state.

The adjustment process from the short-run to the long-run steady state indicates an important result, particularly for the non-oil sector in the case of Libya. The incorporation of human capital stock and imported capital stock accumulation in addition to that of the public capital stock upon non-oil output supply, stimulates the development of the economy over the short and long run. Also, incorporation of foreign asset stock accumulation, via developments in the current account, and the budgetary financing requirement significantly extends the period of time over which the new steady state equilibrium is achieved.

4. Conclusions and policy implications

The main focus of this paper has been to analyse the dynamic adjustment process and the long run steady state properties arising from two oil related shocks. The simulation analysis takes into account the impact of additional oil revenue upon key macroeconomic variables. The major conclusion derived from this paper is that a permanent increase in oil production and oil price by 15 percent will potentially result in an increase in private capital stock, hence private sector wealth, real income, domestic physical capital stock, human capital stock, imported capital stock and non-oil supply (and demand). However, the oil sector boom also has the potential to deteriorate the non-oil trade balance through a loss of competitiveness from a real

[1] A possible explanation for this result is that the real wage is not included in Equation 24 due to technical difficulties in its estimation. When the real wage was included in the simulation procedure, an initial decline in non-oil output supply was observed. Therefore the absence of this variable from Equation 24 appears to mitigate the Dutch disease effect upon non-oil output supply.

exchange rate appreciation. Moreover, the benefits for the non-oil sector arising from public capital stock, human capital stock, and imported capital stock accumulation induced by the boom in the oil sector could be of substantial importance in terms of employment and growth generation. An increase in non-oil output will possibly lead to an increase in the demand for labour, and hence reduce unemployment.

The model presented incorporated and demonstrated the importance of a number of channels through which oil production, and changes in the price of oil, impact the macro-economy, namely a(n): revenue effect, income effect, spending or wealth effect, exchange rate effect, current account effect, and technology effect. A major innovation of this paper has been in highlighting the importance of the technology effect, traditionally ignored in the literature, which is likely to be of importance for developing, oil exporting but technologically backward economies such as that of Libya.

Regarding Dutch Disease consequences, in the context of the Libyan economy, this is likely to be confined to the non-oil trade balance during the adjustment process toward long run steady state. A real exchange rate appreciation will result in a loss of competitiveness for non-oil exportable goods while an increase in real income will increase non-oil imports, and therefore there will be deterioration in the overall non-oil trade balance. However, despite the loss of competitiveness of the non-oil tradable sector, non-oil output supply increases throughout the early periods of adjustment. This is attributable to the fact that the Dutch disease effect upon non-oil output is offset by government development spending on physical, human and imported capital stocks. In the context of the Libyan economy, this confirms the crucial role that the government, which owns the oil sector, must play in enhancing the positive consequences and/or minimising the adverse effects of the oil sector boom. The government could improve productivity and increase the availability and type of capital available for the non-oil tradable sector, such as that for the manufacturing and agricultural sectors, by increasing or changing the composition of government investment in infrastructure, human capital formation and technology acquisition in these sectors. This will eventually improve the competitiveness of these sectors. It will be the responsibility of policymakers to identify where such development spending is best directed, which will require more detailed analysis of key bottlenecks and capacity constraints facing the non-oil sector. A major novelty of this paper is its explicit recognition of the importance of human capital stock accumulation (through education and training) and technology acquisition (through imports) in offsetting the impact of the Dutch disease on non-oil output and improving overall economic development outcomes.

The model presented in this paper can also be modified with the aim of conducting equivalent simulations under alternative exchange rate policies, combined with different degrees of international capital mobility. A change in the nominal exchange rate from a fixed to flexible exchange rate regime could affect the development of the overseas sector; therefore the government may further minimise the adverse effects of the oil boom upon the non-oil trade balance by moving to a more flexible exchange rate system. Under a flexible exchange rate regime the exchange rate is capable of adjusting so that either capital inflows or outflows will have no effect upon foreign exchange reserves. As a consequence, growth of the money stock is exogenous and policy determined and the nominal exchange rate is endogenous. This could contribute to insulation of the domestic economy from inflationary factors such as growth of the money stock which occurs in the case of a fixed exchange rate. This is left here for further research.

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Table 1: The macroeconomic model

Product market	**Equation number**
$No^d = \beta_1 c^p + \beta_2 i^p + \beta_3 g + \beta_4 (x^n - m^n)$	(1)
$c^p = \beta_6 No^s + \beta_7 w^p$	(2)
$i^p = \dot{k}^p = \gamma(k^{p*} - k^p)$	(3)
$k^{p*} = \delta No^s$	(4)
$g = \beta_8 c^g + \beta_9 i^s + \beta_{10} i^h + \beta_{11} i^{cap}$	(5)
$c^g = (1 - \theta_1 - \theta_2 - \theta_3)(o^a + po + e - p)$	(6)
$i^g = \dot{k}^g = \varphi(k^{g^*} - k^g)$	(7)
$i^h = \dot{k}^h = \sigma(k^{h^*} - k^h)$	(8)
$i^{cap} = \dot{k}^{cap} = \lambda(k^{cap^*} - k^{cap})$	(9)
$k^{g^*} = \theta_1(o^a + po + e - p)$	(10)
$k^{h^*} = \theta_2(o^a + po + e - p)$	(11)
$k^{cap^*} = \theta_3(o^a + po + e - p)$	(12)
$bd = g - t^x = \beta_{12}(\dot{m} - \dot{p})$	(13)
$t^x = \beta_{13}(o^a + po + e - p) + (1 - \beta_{13}) No^s$	(14)
$x^n = \beta_{14}(e + p^* - p) + \beta_{15} y^*$	(15)
$m^{con} = \beta_{16} y - \beta_{17}(e + p^* - p)$	(16)
$y = vNo^s + (1-v)o^a + (1 - v - \mu_2) po + (\mu_1 - v)(e - w) - (1 - \mu_1 - \mu_2) p^*$	(17)
$y^p = vNo^{sp} + (1-v)o^p + (1 - v - \mu_2) po + (\mu_1 - v)(e - w) - (1 - \mu_1 - \mu_2) p^*$	(18)
Asset market	
$m - p = \varepsilon_1 No^s - \varepsilon_2 \pi - \varepsilon_3 r$	(19)
$w^p = \varepsilon_5 k^p + \varepsilon_6 (m - p) + \varepsilon_7 y^p$	(20)
$\dot{m} = d\dot{c}e + \tau(r - r^* + \dot{f})$	(21)
Aggregate supply and prices	
$p = \mu_1 w + \mu_2 (e + po) + (1 - \mu_1 - \mu_2)(e + p^*)$	(22)
$\dot{w} = \psi_1 (No^d - No^s) + \psi_2 \dot{m}$	(23)
$No^s = \phi_1 k^p + \phi_2 k^g + \phi_3 k^h + \phi_4 k^{cap} + \phi_5 em$	(24)
External sector	
$\dot{f} = \alpha_1 (x^n - m^n) + \alpha_2 r^* f + \alpha_3 (o^x + po) - (1 - \alpha_2 - \alpha_3)(e - p)$	(25)
$o^x = (1 - \zeta) o^a$	(26)
Definitions	
$c = e - w$	(27)
$l = m - w$	(28)
$T = x^n - m^n$	(29)
$m^n = m^{con} + i^{cap}$	(30)

Note: A dot (.) above a variable signifies its rate of change.
Source: Authors

Table 2: Explanation of symbols used in the model

Symbol	Explanation
Endogenous variables	
No^d	Aggregate demand for non-oil output
c^p	Private consumption
i^p	Private investment
k^{p*}	Desired private capital stock
g	Total government spending
c^g	Government consumption expenditure
x^n	Non-oil exports##
m^n	Non-oil imports##
T	Non-oil trade balance
No^s	Aggregate supply of non-oil output
w^p	Real private sector wealth
k^p	Private capital stock
k^{cap}	Imported capital stock
k^s	Actual public capital stock
k^h	Human capital stock#
k^{s*}	Desired government physical capital stock
k^{h*}	Desired human capital stock#
k^{cap*}	Desired imported capital stock#
i^g	Government investment spending on physical capital
i^h	Government investment spending on human capital#
i^{cap}	Government investment spending on imported capital
t^x	Total tax revenue
m	Nominal money supply[1]
π	Inflation rate**
p	Consumer price level
w	Domestic nominal wage
m^{con}	Consumption of non-oil imports#
y	Total real income[3]
y^p	Permanent real income
f	Foreign asset stocks
o^x	Oil exports
c	Real exchange rate
l	Real money balance
Exogenous variables	
e	Nominal exchange rate[4]
o^a	Oil production
po	World oil price (in foreign currency)
$p*$	Price of non-oil imported goods
$y*$	World real income
No^{sp}	Permanent non-oil income
o^p	Permanent oil-income
$r*$	World nominal interest rate
r	Domestic nominal interest rate
em	Employment

Notes:

[1]Exogenous if the nominal exchange rate is flexible.

[2] This is equivalent to that of the nominal wage (w) used in the C-H model.

[3]This is equivalent to total real domestic production.

[4]Endogenous if the nominal exchange rate is flexible.

#Not included in the C-H model. ## (x^n less m^n) used to represent non-oil trade balance T .

**Used as a proxy for the nominal interest rate in the base model.

Source: Authors

Table 3: Parameters values

β_1 ***	1.0	θ_1 **	0.3	ε_7 ***	1.0
β_2 ***	1.0	θ_2 **	0.2	τ ***	0.2
β_3 ***	1.0	θ_3 **	0.2	μ_1 ***	0.6
β_4 ***	0.75	β_{12} **	1.0	μ_2 ***	0.1
β_6 *	0.6	β_{13} *	0.7	ψ_1 *	0.65
β_7 *	0.3	β_{14} *	0.45	ψ_2 *	0.4
γ ***	0.5	β_{15} *	0.5	ϕ_1 *	0.1
δ *	0.8	β_{16} *	0.75	ϕ_2 *	0.5
β_8 **	0.4	β_{17} *	0.25	ϕ_3 *	0.4
β_9 **	0.3	v **	0.7	ϕ_4 *	0.3
β_{10} **	0.15	ε_1 *	0.4	ϕ_5 *	0.2
β_{11} **	0.15	ε_2 *	0.35	α_1 *	0.15
φ ***	0.5	ε_3 *	0.1	α_2 *	0.5
σ ***	0.5	ε_5 ***	1.0	α_3 *	0.35
λ ***	0.5	ε_6 ***	1.0	ζ ***	0.70
rs ***	0.05				

Sources:
***** Estimated coefficients obtained using the ARDL model.
****** Calculated by the authors based on available data.
***: Cox & Harvie (2010), and Harvie & Thaha (1994).

Table 4: Steady state properties of the model for the base case

Variable/ shock	f	T	g	c	w^p	y	No^s	k^g	k^h	k^{cap}	k^p	p
15% oil production	7.0	-3.5	1.62	0.0	8.0	7.1	5.2	4.5	3.0	3.0	5.8	0
15% oil price	12.3	-2.5	1.62	0.0	7.0	5.0	5.0	4.5	3.0	3.0	4.0	0

Note: The numbers indicate percentage deviation from baseline.
Source: Authors

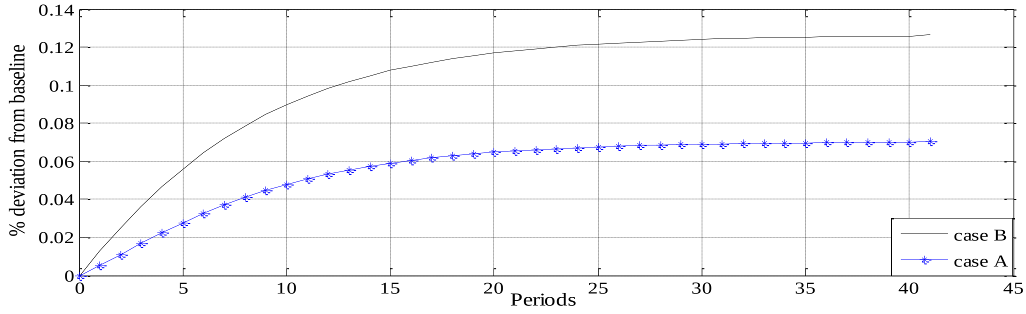

Figure 1: Foreign asset stocks

Source: Authors

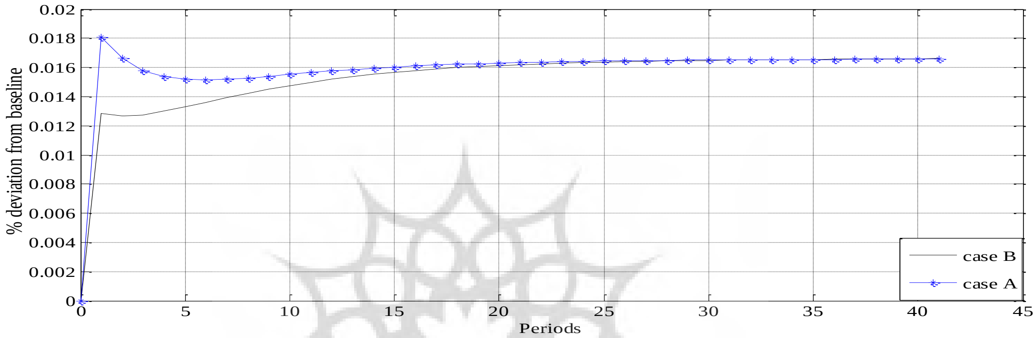

Figure 2: Government revenue

Source: Authors

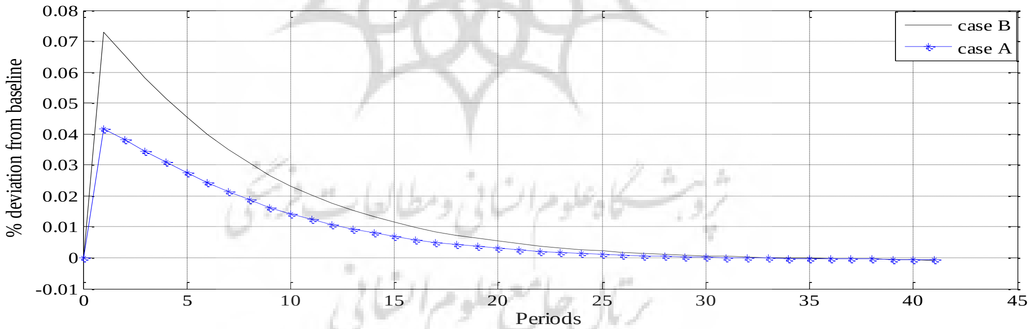

Figure 3: Price level

Source: Authors

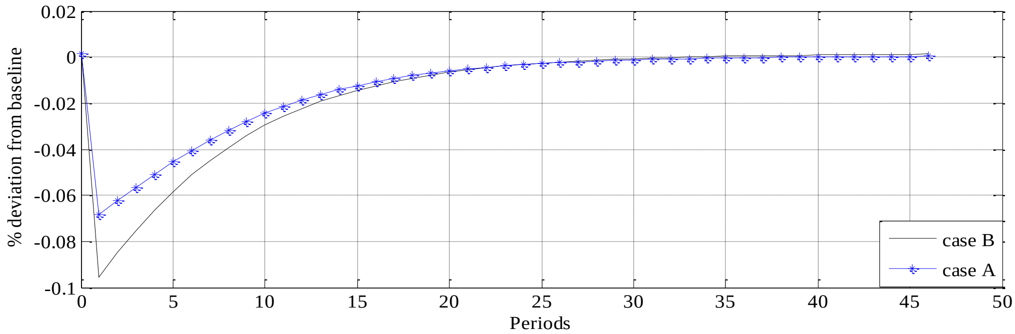

Figure 4: Real exchange rate

Source: Authors

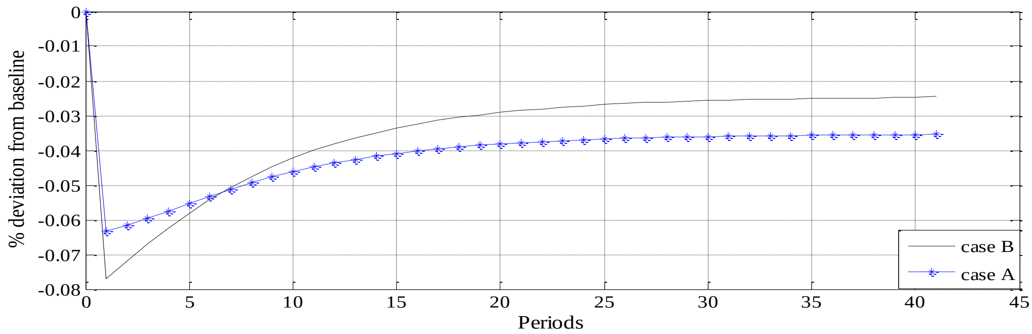

Figure 5: Non-oil trade balance

Source: Authors

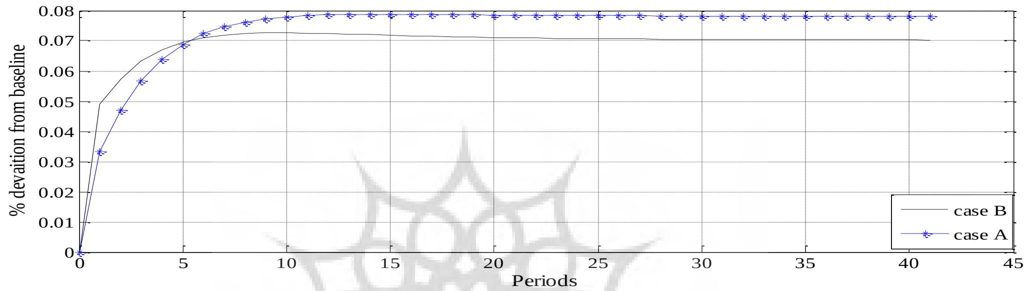

Figure 6: Private real wealth

Source: Authors

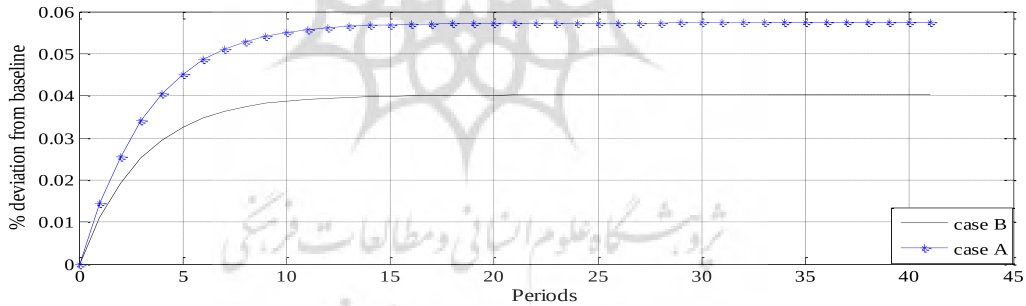

Figure 7: Private capital stock

Source: Authors

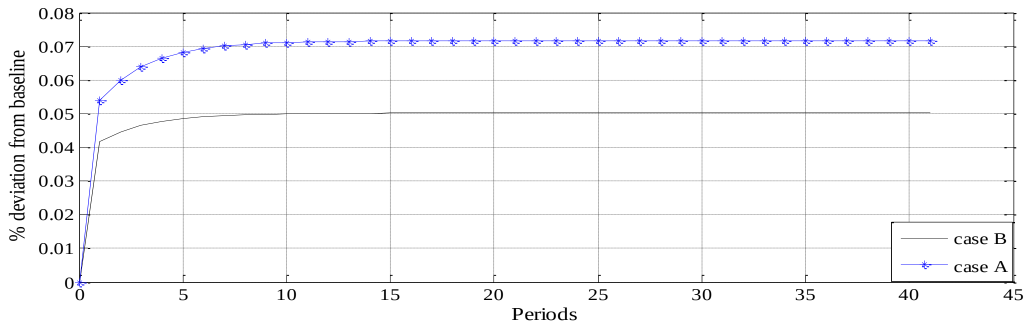

Figure 8: Real income

Source: Authors

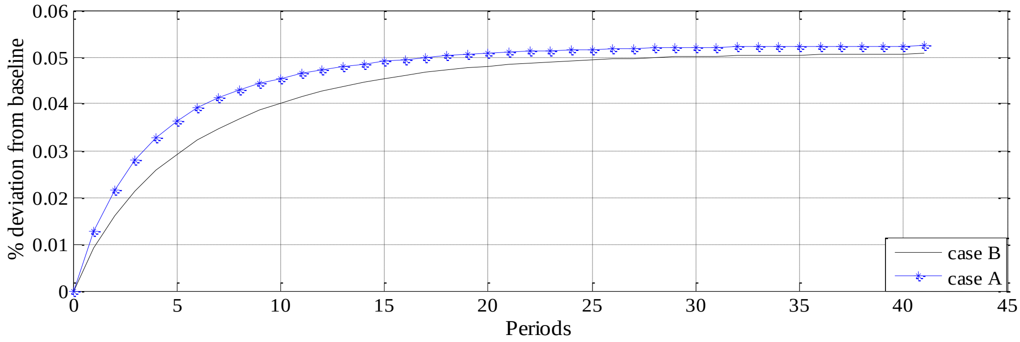

Figure 9: Non-oil output

Source: Authors

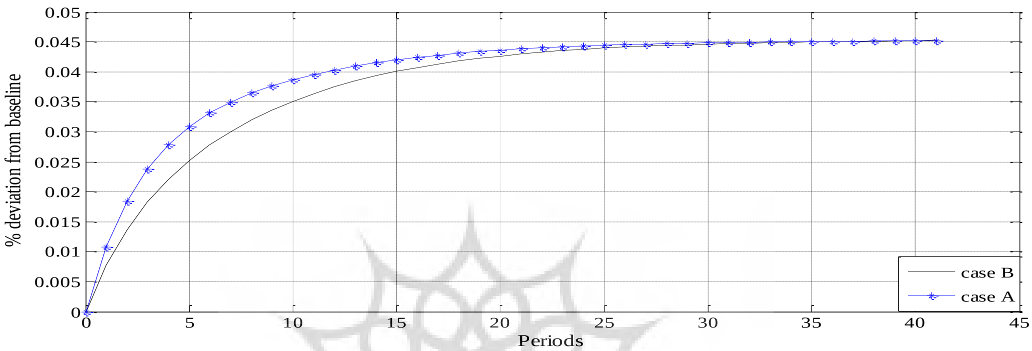

Figure 10: Public capital stock

Source: Authors

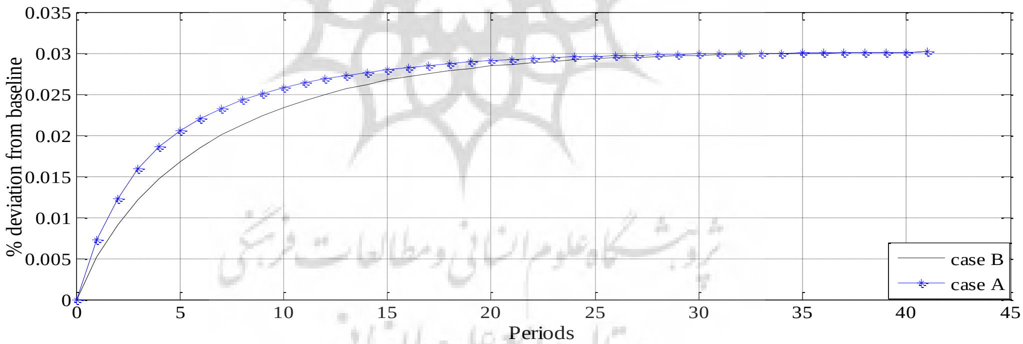

Figure 11: Human capital stock

Source: Authors

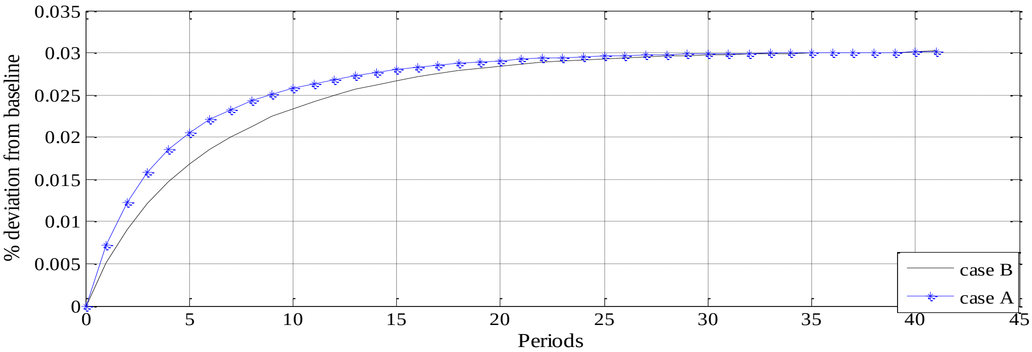

Figure 12: Imported capital stock

Source: Authors