Proceedings of the 5th Asian Mathematical Conference, Malaysia 2009

THE IMPACTS OF OIL SHOCKS ON MALAYSIA'S GDP GROWTH

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Abstract. *This paper suggests that instrumental variable regression is a good alternative to nonlinear specification model when estimating the impacts of oil shocks on GDP growth in Malaysia.*

1 Introduction

An enormous amount of literature suggests that there is a significant effect of oil price shocks on economic activity especially with respect to output, employment or real wages. However, this empirical relation between GDP growth and oil prices is unstable as indicated by many research results. For example, research results like there is a clear negative correlation between GDP growth and oil prices have been reported by Hamilton (1983), Burbidge and Harrison (1984), Gisser and Goodwin (1986), Rotemberg and Woodford (1996),Raymond and Rich (1997), and Carruth, Hooker, and Oswald (1998) and others. Beside this negative correlation between GDP growth and oil prices, researches on microeconomic data sets has also shown that there are significant correlations between oil prices and employment or real wages (Keane and Prasad, 1996; Davis, Loungani, and Mahidhara, 1996; Davis and Haltiwanger, 1997: Lee and Ni, 1999). Why does this empirical relation unstable? A number of authors have suggested the misspecification of the functional form in the above researches as the reason. A substantial amount of researches suggest that the relation between oil prices and economic activity is nonlinear. Nonlinearity between oil prices and economic activity implies the following results:

- Only oil price increases would affect the economy and oil price decreases cannot produce this effect.
- Oil price increases after a long period of stable prices would have a larger effect than those that simply correct previous decreases.

Empirical results from research done by Loungani (1986), Davis(1987a,b), Mork (1989), Lee, Ni and Ratti(1995), Hamilton (1996), Davis, Loungani, and Mahidhara (1996) , Davis and Haltiwanger (1997) , and Balke, Brown, and Yucel (1999) and many others confirm the above nonlinear behavior. However, there is an abundant amount of nonlinear specification models. How to decide which of these nonlinear specifications is the right one? One solution is to use a methodology recently developed by Hamilton (2000) to address this question. Another method is to examine why nonlinear specifications can do a better job. We focus on this second method and we are of the opinion that nonlinear specifications are performing well all because they can filter out the endogenous effects from the oil prices. We run instrumental variable regression IV to see if we can obtain similar interpretations as most of nonlinear specifications. The rest of the paper is organized as follows: Section 2 describes the data sets. In Section 3 the theoretical background of IV regression is presented with special emphasis on exogenous variable, instruments, testing of instruments, test for weak instrument, and lastly J test for exogeneity of the instruments for the case of overidentified IV regression. Section 4 describes four specification models used in the regression. Section 5 describes the instruments and exogenous variable and its implication from an economic point of view. Empirical results are presented in Section 6. Section 7 concludes this paper and Section 8 are the appendixes and references.

2 The Data Sets

As a whole, our empirical analysis uses 8 data series: GDP growth rate(G), Oil Price Shocks(OS),World Oil Production Shocks(PS), Industrial Production(IP), Difference in Local and International Petroleum Prices(DOP), Military Oil Production Disruptions(MOD), Consumer Price Index(CPI) and Fixed Deposit Interest Rates(FIR). The symbols inside the brackets denote the respective series. All these 8 series are quarterly data and are seasonally adjusted. We convert monthly into quarterly series by taking the entry at the end of every 3 months. IP, DOP, MOD and PS are the four instruments used in the analysis whereas CPI and FIR are used as exogenous variables. Our oil shocks (OS) is the first difference of the oil price series. We did not use percentage change between two consecutive quarters for oil prices because its values are too small relative to values of other series. This causes problem in OLS estimation procedure. By using the first difference, we have put more weights on recent quarter oil prices. Furthermore, there is an inherited problem in that the Malaysian petroleum pump prices are substantially subsidized. This created intermittent irregular shocks to the oil price series we used to construct the oil shocks.

3 Instrumental Variable Regression IV

Our Instrumental Variable Regression Model is shown in Equation (3.1) below:

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 w_{1t} + \beta_3 w_{2t} + \varepsilon_t \quad \text{for } t = 1,2,....,n \tag{3.1}$$

x represents the only endogenous variable, the oil shocks whereas w represents the exogenous variables. Our first primary concern is to identify four valid instruments by economic considerations. Endogeneity is basically caused by the demand and supply curves. But for the case of oil, when the demand increases, OPEC will increase production to offset the demand to a stationary level and the case is the same when the supply goes up, OPEC will decrease the production of oil. Thus as a whole the demand and supply of oil is regulated. To put it differently, oil prices respond quite dramatically to demand conditions which are undergoing constant adjustment and readjustment. Thus exogenous change in oil price can only be effected by disruption of supply due to military conflicts and other causes like industrial production of the country and difference in local and international petroleum pump prices.

3.1 Construction of the four instrument series

We construct our first valid instrument that is the oil price changes due to military conflicts. These military conflicts are external in nature and they should be independent of the error term. These historical military conflicts are listed in Table 1 below:

Table 1. Oil Supply Disruption due to Military Conflicts

Date	Event	Drop in world oil production
Dec. 1978	Iranian Revolution	8.9%
Oct. 1990	Persian Gulf War	8.8%
Sept. 2003	Second Gulf War	8.7%

We name this first instrument as MOD (s_1) which has three entries, 1st quarter of 1979, 8.9%; 1st quarter of 1990, 8.8% and 1st quarter of 2003, 8.7%. The rest of the observations are zero. Our second instrument, Industrial Production, is a series about industrial production output. In essence, if demand for industrial products increase, so do production and most of the energy used in the production is obtained from oil directly or indirectly. Thus industrial production will effect the oil price changes externally, satisfying the condition for exogeneity. World oil production is normally fluctuating with a lot of factors, one of these is the military conflicts and another one could be tropical storms that destroy the infrastructure of oil production and thereby causing disruption in supply. We constructed one series by taking the first difference of the world oil production series. This series of oil production shocks will effect oil price changes externally. The last instrument is the difference between world and local petroleum pump price. This is necessary because Malaysia practices oil subsidy and this subsidy will influence the effect of oil shocks. The selection of these instruments based on economic reasons is discussed in Section 5.

3.2 Test for Exogeneity of Instruments:

When the coefficients of the regression equation are exactly identified that is the number of endogenous variables and instruments are the same, then we have no proper statistical tests for the exogeneity of the instruments. In this case, we have to draw on expert opinion and personal knowledge of the impacts of oil shocks to justify the use of the particular instrument. However, when the number of instruments is more than the number of endogenous regressors, then, we have a situation which is referred to as overidentifying the coefficients of regression. For this case, we shall conduct a J test for overidentification of the coefficients (See Appendix B). In this test, we test for the hypothesis that the extra instruments are exogenous under the assumption that there are more than enough valid instruments to identify the coefficients of regression.

3.3 How to Ascertain Strong or Weak Instrument?

A strong instrument is one which can explain more the variation in endogenous regressor, oil prices while a weak instrument can explain little of the variation in oil prices. In short, a strong instrument can produce a more accurate estimator for the relevant coefficients, just like a large sample size produces a more accurate estimator. In our case, we have to identify and ascertain that the four instruments are strong. We use the rule that for weak instrument, when there is a single endogenous regressor, the first-stage F statistic must be less than 10 (see appendix A). This implies that when the first-stage F statistic is more than 10, we can accept that the instrument is strong. However, weak instruments may not produce consistent estimators. For weak instruments, we use the simple Anderson Rubin test to ascertain its validity. In addition, Hausman test is performed to check significant differences between the coefficients of the OLS and instrumental variable regression. Augmented regression test that suggested by Davidson and MacKinnon (1993) is also performed.

4 The Models

The effects of oil shocks on GDP growth have been characterized very well by different nonlinear specification models as explained in Section 1. As we intend to perform the same analysis by using instrumental variable regression which is linear in nature, it would be logical for us to start off by showing how linear specification suffers from parameter instability. Then we use one nonlinear specification model to characterize the oil shocks. Only after that, we use IV regression to conduct the same analysis again. Thus, we would run 4 regression models: one linear, one nonlinear and two IV regression models. These 2 IV regression models are to follow different specifications: each using a specific combination of the data sets as explained in Section 2. The followings are the four models and the functional form:

- **Functional Form Restriction**

Functional form restriction is imposed on our linear and nonlinear model because it is an acceptable fact that only oil price increases will cause economic slowdown, whereas oil price decreases cannot induce economic boom. Equation (4.1) shows this functional form restriction.

$$y_t = \begin{cases} \mu & \text{if } o_t \le 0 \\ \mu - \beta o_t & \text{if } o_t > 0 \end{cases} \tag{4.1}$$

where y_t and o_t are the GDP growth rate and oil shocks respectively.

- **Linear Specification Model:**

We regress $\boldsymbol{y_t}$ on four lags of y_t and four lags of o_t. The result is shown below in Section 6.

- **Nonlinear Specification Model:**

Functional form restriction in Equation (4.1) essentially means that oil shocks follow an asymmetric pattern. Hence, we construct a simple nonlinear specification model to estimate the effects of oil shocks on GDP growth. Let y_t, x_t, and o_t represent GDP growth, oil prices and changes in oil prices per quarter. y_{t-j} and o_{t-j} represents their respective lag. 4 lags are chosen because our data is quarterly and we expect the effects of oil shocks will be felt only after some quarters. We define the followings:

$$\begin{gathered} y_t = \alpha + \beta_1 y_{t-1} + \beta_2 y_{t-2} - \beta_3 y_{t-3} - \beta_4 y_{t-4} - \beta_5 o_{t-1} I_t - \beta_6 o_{t-2} I_t - \beta_7 o_{t-3} I_t - \beta_8 o_{t-4} I_t \\ I_t = \begin{cases} 1 & \text{if } o_t > 0 \\ 0 & \text{if } o_t \le 0 \end{cases} \end{gathered} \tag{4.2}$$

The model in (4.2) is motivated by empirical evidence that increase in oil prices result in the decrease in GDP growth. This is based on the economic argument that increase in oil will slow down industrial production, increase in production cost and ultimately results in increase in unemployment.

- **IV Regression Model Specification 1 and 2**

$$\begin{aligned} &\hat{o} = \hat{\alpha}_0 + \hat{\alpha}_i z_{it} + \eta_t \\ &y_t = \beta_0 + \beta_1 \hat{o} + \beta_j w_{jt} + \varepsilon_t \\ &\text{where } t = 1,2,....,n,\ i = 1,2,\ j = 1,2 \text{ for model 1} \\ &i = 1,2,3,4,\ j = 1,2 \text{ for model 2} \end{aligned} \tag{4.3}$$

z represents instruments, w_1 and w_2 represent the two exogenous regressor, Fixed Deposit Interest and Consumer Price Index.

5 Economic Considerations and Restrictions

In this section, we would like to discuss in detail the economic reasons on why the four instruments and two exogenous regressors are chosen for the models. Oil prices are regulated by the supply and demand curves. However, over the period 1948-1972, in the US, supply and demand of oil are regulated by commissions like the Texas railroad Commission. When demand drops, the commission would decrease the amount of oil production. On the other hand, if the demand increases, the commission would increase the amount of oil production. Thus endogenous factors had no effect on oil prices during this period in the US. After 1972, the situation remains almost the same except that in the global scale, decrease in the demand for oil would compel the OPEC organization to cut oil production rate in line with the weak demand to stabilize the oil price. It is also of the same trend for increase in oil demand. This effectively implies that oil prices are indeed endogenous to GDP growth. Thus, the only events that would change the oil prices were exogenous disruptions to supply. Disruptions to supply can come in many forms like due to military conflicts in the Middle East, and tropical storms or hurricanes destroy the oil production infrastructure. The other form is economic slowdown or rather recession, which would cause the demand for oil to drop and thereby causing a drop in oil prices. Thus, Malaysia's industrial production and world oil production shocks are another instruments. With this economic argument, we are of the opinion that the three instruments are valid.

There is a special feature of the Malaysia's petroleum pump prices. It is subsidized to a substantial amount unlike the petroleum pump prices in the US. This subsidized feature must be incorporated into our analysis even though the amount of subsidy will definitely depend on the world oil prices. After all, Malaysia's petroleum pump price is also depending largely on world oil prices. The amount of subsidy not only constitutes as an important exogenous shock on Malaysia's GDP growth but also on oil prices we used to track the movement of Malaysia's GDP growth. Hence, the inclusion of this petroleum subsidized data series in the form of the first difference between world and local petroleum pump prices, not only satisfies the exogenous criterion for regression analysis but also is able to filter out the residual endogenous effects of the oil prices after it is interacted with the instrumental variables.

6 Empirical Results

For the linear and nonlinear specification models, we impose the functional form as specified in Equation (4.1).

Linear Specification Model:

Regressing GDP on four lags of GDP and four lags of Oil Shocks, we found that Oil Shock lag 4 is statistically insignificant. Thus, we regress GDP on four lags of GDP and three lags of Oil Shocks. Four lags are used because we expect the effect of oil shocks will be felt after certain quarters especially when there is oil subsidy practiced in the country.

For sample 1 from 1980IV to 2000III (80 observations)

$$\begin{aligned} y_t = &\underset{(0.627)}{1.529} + \underset{(0.141)}{1.087}\, y_{t-1} - \underset{(0.1430)}{0.219}\, y_{t-2} - \underset{(0.181)}{0.0928}\, y_{t-3} - \underset{(0.104)}{0.000715}\, y_{t-4} \\ &- \underset{(0.0757)}{0.0869}\, o_{t-1} - \underset{(0.049)}{0.0835}\, o_{t-2} - \underset{(0.0622)}{0.135}\, o_{t-3} \end{aligned} \tag{6.1}$$

The coefficient on o_{t-3} is significant with a t-statistic of -2.17. The estimated values of coefficients for the three quarters imply that a 10 unit increase in oil prices will decrease the normal GDP growth by as much as 3 unit.

We construct sample 2 by adding observations from 1976I to 1980III and observations from 2000IV to 2007I.
By performing the same regression again for period from 1976I to 2007I, we obtain a smaller effect of decreasing the GDP growth, which indicates that the coefficient on o_{t-3} is about 90% of its value in the smaller sample. This result indirectly suggests that

- 10 unit decrease in oil prices cannot produce a 3 unit increase in GDP growth.
- The period from 1980-2000 corresponds to a period of decline in oil prices This effectively means that the coefficient in smaller sample 1 should be smaller than that in larger sample 2. However, we obtained an opposite result which is clearly against the existence of linear relationship.

Nonlinear Specification Model:

In this model, we impose the restrictions that negative oil shocks produce zero effect on GDP growth and that only positive oil shocks can exert slowdown effect on GDP growth. The result we obtained is shown in Equation (6.2). All errors are heteroskedasticity Consistent Standard Error (HCSE).

$$\begin{aligned} y_t &= \underset{(0.604)}{1.719} + \underset{(0.115)}{1.042}\, y_{t-1} - \underset{(0.144)}{0.211}\, y_{t-2} - \underset{(0.144)}{0.0298}\, y_{t-3} - \underset{(0.0913)}{0.0937}\, y_{t-4} \\ &+ \underset{(0.0563)}{0.0498}\, o'_{t-1} + \underset{(0.0492)}{0.00466}\, o'_{t-2} - \underset{(0.0626)}{0.0273}\, o'_{t-3} - \underset{(0.0607)}{0.121}\, o'_{t-4} \end{aligned} \tag{6.2}$$

The coefficient on o'_{t-4} has t – statistic of -1.99 which is significant. This indicates that the effect of oil shocks will be effectively felt after the fourth quarters. Thus a 10 unit increase in oil prices will produce a decrease of 0.94 unit in the level of GDP.

Instrumental Variable Regression:

We conducted two instrumental variable regressions: Model 1 and Model 2. Model 1 is exactly identified with two exogenous regressors and two instruments whereas Model 2 is overidentified two exogenous regressors and four instruments. The validity of all the four instruments has been verified argumentatively in Section 3. Statistically, these instruments are also verified to be fit as shown by results of Hausman test, Augmented regression test and J test. The results are shown in Table 2 below:

We conduct a pretest for the four instruments. It is found that all of them are weak as the F statistic for the first stage of the Two Stage Least Square Method is all less than 10. This result is shown in row 7 of Table 2. To make sure that our two stage least square estimator is consistent, we conducted the Anderson Rubin Test for the validity of the instruments. We found that the test is significant at 1% level for both of the models.

The coefficients for Model 1 and Model 2 are respectively -1.42 and -1.25. This in effect indicates that a 10 unit increase in oil price will produce 14.2 unit decreases in GDP growth for the Model 1, and for Model 2, it will cause 12.5 unit drops in GDP. As a whole, we can have two conclusions from these two instrumental regression models. They are:

- Oil shocks will cause slowdown in economy, for positive shocks.
- Positive oil shocks will cause a drop in the level of GDP. Negative oil shocks may also have that effect and it is not detected that negative oil shocks can result in the increase in GDP growth. Thus instrumental variable regression which is basically linear in nature verifies that oil shocks show asymmetric effect as have been estimated by nonlinear specification model. However, it has also been shown that linear specification model cannot show this asymmetric effect effectively. This leads us to conclude that nonlinear specification model is effective because it can filter out the endogenous effect from the oil shocks, as this is exactly what the instrumental regression model do to produce similar result.

Even though we have shown that instrumental regression can produce similar result as nonlinear specification model, there is a discrepancy in values of our result from nonlinear specification model and instrumental regression model. In nonlinear specification model, we have obtained that a 10 unit increase in oil price can cause a drop of GDP level as much as 0.94 unit whereas for instrumental regression, the drop in GDP is sharp, as much as 13.4 unit on average. Which is correct then in the Malaysia context?

In order to answer that question, we dissect our GDP growth and oil price series on a year to year basis. We pick out the statistic for the year when positive oil shocks cause a drop in GDP growth. Table 3 shows the summary statistics for these 9 years.

Table 2. Two Stage Least Square Estimates of Malaysia' s Growth Using Oil Shocks and Macroeconomic Data

Dependent Variable: GDP growth rate in Malaysia		
Endogenous Regressors	**Model 1**	**Model 2**
Oil Shocks	-1.423 (0.716)	-1.253 (0.522)
Exogenous Regressors		
Fixed Deposit Interest Rate	-1.155 (0.368)	-1.104 (0.315)
Consumer Price Index	-0.045 (0.035)	-0.047 (0.312)
Constant	17.56 (3.600)	17.41 (3.278)
Instruments	**First-Stage F Statistic**	
Industrial Production	6.066	6.066
Local and International Petroleum Pump Price Difference	2.864	2.864
World Oil Production Shocks		2.099
Military Conflicts Oil Disruptions		1.554
Anderson-Rubin Statistic –F Statistic	10.12**	7.379**
Summary Statistics		
SER	6.842	6.267
Reduced SER	3.684	3.658
Number of Observations	124	124
Hausman test (p-value) 0.0006** 0.0001**		
Augmented regression test (p-value)	0.0041**	0.0038**
Overidentifying Restriction J test statistic & p-value	1.9999(0.1573)	3.9991(0.2616)

Note: ** denotes 1% significant

Table 3 – Drop in GDP growth caused by 10 unit positive oil shocks

Years	1976	1977	1988	1995	1996	1998	2001	2004	2006	Average
Unit drop in GDP growth	-11.56	-69.47	-3.07	-4.24	-4.09	-7.69	-1.26	-1.48	-0.17	-11.4

The average drop in GDP from this dissection analysis is about 11.4 for every 10 unit increase in oil prices. The average drop in GDP from the results of the two instrumental regression models is 13.4. Thus our instrumental regression models give a good result when comparing to the actual drop in GDP due to oil shocks. But from the dissection analysis, it seems that negative oil shocks can also cause drop in GDP or increase in GDP without considering other causes of fluctuation of GDP growth.

7 Conclusion

An empirical result from Linear Specification Model suggests that a linear regression of GDP growth on lagged oil prices exhibits instability over time. This is clearly indicated by the difference in values of the parameters of the two samples used separately in the linear regressions. Comparing the estimated obtained from sample 1 and sample 2, there is strong evidence that the relationship between oil price changes and GDP growth is nonlinear in nature, nonlinear in the aspect that oil price increases can cause economic slowdowns but oil price decreases cannot cause economic boom.

The empirical results suggest that the implied consequences for GDP growth due to an increase of 10 unit in oil prices by using the nonlinear relation specification is reflected by a 0.9 unit drop in the level of GDP. However, the drop in GDP as produced by the linear instrumental variable regression is about 11.3 unit for every 10 unit increase in oil prices. This indicates clearly that linear instrumental variable regression can produce the asymmetric result similar to that produced by nonlinear specification model. However the drop in GDP for the instrumental variable regression case is rather sharp about 11.3 unit as compare to about 0.9 for the nonlinear specification model. The dissection analysis as shown in Table 3 suggests the drop is about 11.4 unit. This validates our linear instrumental variable regression results. This discrepancy in result could also be due to the fact that Malaysia practices oil subsidy. The final conclusion from this paper is that instrumental variable regression can filter out the endogenous effects from the oil prices to a substantial amount, and thus it can perform as well as a nonlinear specification model.

8 Appendix A

In this appendix, we show for the simple case of only an instrument and an endogenous variable in the regression, then if the F statistic for the stage 1 of the two stage least square estimation is less than 11, then the instrument is weak:

In matrix form, the bias of the OLS estimator is given by:

$$\hat{\beta}_{OLS} - \beta = (X'X)^{-1} X'u \tag{12.1}$$

For the case of a single regressor, we have:

$$\hat{\beta}_1 - \beta_1 = \frac{n\sum_{i=1}^{n} x_i u_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} u_i}{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2} \tag{12.2}$$

After dividing the nominator and denominator of Equation (12.2) by n and then factoring, we obtain:

$$\hat{\beta}_1 - \beta_1 = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})u_i}{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{12.3}$$

By using a similar approach, we obtain the Two Stage Least Square estimator (TSLS) as follows:

$$\hat{\beta}_1^{TSLS} - \beta_1 = \frac{\frac{1}{n}\sum_{i=1}^{n}(z_i - \bar{z})u_i}{\frac{1}{n}\sum_{i=1}^{n}(z_i - \bar{z})(x_i - \bar{x})} \tag{12.4}$$

Dividing (12.3) by (12.4), we obtain in terms of the F statistic for the 1st stage TSLS the following:

$$\hat{\beta}_1^{TSLS} - \beta_1 \approx \frac{(\hat{\beta}_1^{OLS} - \beta_1)}{E(F) - 1} \tag{12.5}$$

In most application, if the bias of the TSLS is about 10% of the bias of the OLS, then the bias is acceptable. Hence we can set E(F) = 10. If F < 10 for the 1st stage of TSLS, the instrument is weak. However, if F > 10, then the instrument is strong.

Appendix B

To ascertain instrument exogeneity, we can use expert judgment based on person knowledge of the application. However, if there are two instruments and only one endogenous variable, we can use the J statistic test to help to decide instrument exogeneity as well. In this appendix, we describe briefly the J statistic. J statistic is an overidentifying restrictions test. Let m be the number of instruments and k the number of endogenous regressor. For our case (Model 1), m = 2 and k = 1. Let $\hat{u}_i^{TSLS}$ be the residuals from TSLS estimation of the IV regression. Then we use OLS estimation for regressing $\hat{u}_i^{TSLS}$ on the two instruments and the two exogenous variables.

$$\hat{u}_i^{TSLS} = \alpha_0 + \alpha_1 z_1 + \alpha_2 z_2 + \alpha_{2+1} w_1 + \alpha_{2+2} w_2 + \alpha_{2+3} w_3 + \varepsilon_i \tag{12.6}$$

If $\hat{u}_i^{TSLS}$ is uncorrelated with the instruments and exogenous variables, then the instruments are exogenous. This would imply that we test the null hypothesis:

$$H_0 : \alpha_1 = \alpha_2 = 0 \tag{12.7}$$

$$H_a : \alpha_1 \neq \alpha_2 \neq 0 \tag{12.8}$$

The J statistics is defined as for two instruments and an endogenous variable as:

$$J = 2F \tag{12.9}$$

If ε_i is homoskedastic then in large samples, J is distributed χ^2_{m-k} where m – k is the degree of overidentification and in our case m – k = 2 – 1 = 1 (Stock & Watson, 2003).

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