

On the GCC Currency Union

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Abstract

Essentially, the impact of the currency union on member countries depends on whether the common currency area is optimal in the sense that the effect of the asymmetric shocks is small, Mundell (1961). Typically, researchers use VAR of different types to analyze the data. For robustness, we use different methodologies. First, we use different estimators to estimate a small textbook model for the panel of the Gulf Cooperation Council countries (GCC) from 1970 to 2006, where the short-run equilibrium real output and the real exchange rate are determined by the intersection of the assets and goods markets equilibrium schedules. And the central bank fixes the exchange rate by keeping the money supply at a level where the domestic interest rate is equal to the foreign interest rate. Then we test for symmetry using the nonparametric Triples test, Randles et al. (1980). Third, we introduce a nonparametric multivariate statistic to test whether the variances of the shocks (the conditional variance) are equal across countries.

حول الاتحاد النقدي الخليجي (العملة الخليجية الموحدة)

ملخص

إن تأثير الاتحاد النقدي على أعضائه يعتمد فيما إذا كانت المنطقة الموحدة تمثل ما سماه موندل منطقة مثالية ويقصد بذلك أن تأثير الصدمات العشوائية غير المتناظرة التي تعصف بدول الاتحاد يكون صغيراً. بمعنى آخر أن دول الاتحاد تتعرض لصدمات عشوائية تغير من كثير من جوانب الاقتصاد وأن هذه الصدمات تختلف من دولة إلى أخرى. وفي حالة كون الاختلافات صغيرة تكون هذه الدول متشابهة وتصلح لأن تكون اتحاداً فيما بينها. نستخدم في هذه الورقة طرق لم نستخدم من قبل في هذه الأدبيات لغرض تحليل البيانات وفحص درجة الاختلاف في الصدمات التي تعرضت لها دول الخليج. إن الغرض من استخدام طرق أخرى بالإضافة إلى الطرق المعمول بها هو لغرض الوصول إلى نتائج رصينة. نستخدم طرق إحصائية مختلفة لغرض حساب معاملات المرونة لنموذج صغير للمدى القصير حيث تحدد كمية الإنتاج وسعر الصرف عند تقاطع أسواق السلع والأصول، وأن البنك المركزي يحافظ على سعر الصرف الإسمي للدولار ثابتاً عن طريق تثبيت كمية النقد بشكل تتساوى معه أسعار الفائدة في دول الاتحاد النقدي وفي الولايات المتحدة. ثم بعد ذلك نقوم بفحص كون الصدمات متناظرة أم لا باستخدام طريقة غير معلمية تسمى Triples ثم بعد ذلك نستخدم طريقة غير معلمية متعددة المتغيرات لغرض تحليل درجة تساوي التباين المشروط لهذه الدول. وقد وجدنا بأن الصدمات التي تعرضت لها دول الخليج في سعر الصرف الثابت والإنتاج وسوق النقد والأسعار متناظرة إلا أنها تختلف في مقدار التباين الظاهري اختلافاً كبيراً. وهذا ربما يعني أن اقتصاد بعض هذه الدول عرضة لدرجة أكبر من الغموض من دول أخرى مما يسبب في زيادة المخاطر.

1. Introduction

Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates established the Gulf Cooperation Council (GCC) in 1981. These countries share a common language, culture, and history. The GCC created a trade area, i.e., customs union and harmonized a number of regulations.⁽¹⁾ Despite recent reservations made by Oman and the UAE about joining a currency union, and Kuwait's change of its exchange rate policy from pegging to the US dollar to a basket of currencies, the GCC countries intend to go ahead with establishing a currency union in 2010. So far, most of the convergence criteria for inflation, interest rates, fiscal deficits, public debt...etc. seem to have been met (Khan, 2009).

Laabas and Limam (2002) use cointegration analysis to examine whether, or not, the GCC constitutes an Optimum Currency Area. Abu-Bader and Abu-Qarn (2006) study the shocks that affect the GCC area; they conclude that it has been subject to asymmetric supply shocks. Proponents of the Optimum Currency Area theory say that highly integrated economies should be less susceptible to asymmetric shocks. It means that even if shocks are asymmetric *prior to* joining the union they will be less asymmetric or symmetric in the *post* union period as the economies become closely integrated. Another literature has focused on whether the GCC should peg the new currency to the US dollar or to another currency, see Erbas, et al. (2001) and Abed *et al.* (2003). Khan (2009) examines what exchange rate regime should the union adopts.

Essentially, there are costs and benefits for joining a common currency area. These costs and benefits must be quantified and analyzed. The main cost is the loss of monetary policy independence. The effect depends on whether the currency area is optimum in the sense that the effect of asymmetric shocks is small. Presumably, researchers should test whether the shocks are asymmetric first. Then they should measure the impact of these shocks.

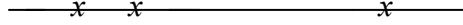
There are different ways to test for the symmetry of the shocks. However, most of the literature, if not all, uses different types of the VAR method. But, drawing structural inference from observed correlation can be problematic. Surely one cannot always expect to find credible identifying assumptions to identify the causal relations among an arbitrary set of variables, Hamilton (1994, p. 336). Economists have different models and make different assumptions about the relationships between variables. And, there are different methodologies to analyze the data. To ensure robustness to various models, assumptions, and methods of analyses, more of different approaches and methods to analyze to an issue are preferred to less. Granger's concept of "thick modeling", i.e., diversification, is surely the right strategy to ensure robustness, among other things. In this paper we use three different methods to analyze issues about GCC currency area.

First, we don't use a VAR, SVAR...etc but rather we estimate a small simultaneous equation model for the panel of the GCC countries from 1970 to 2006, where the short-run equilibrium real output and the real exchange rate are determined by the intersection of the assets and goods markets equilibrium schedules. And the central bank fixes the exchange rate by keeping the money supply at a level where the domestic interest rate is equal to the foreign interest rate. Second, we use the

nonparametric Triples test, Randles *et al.* (1980) and Razzak, (2001) to test for asymmetry.

Intuitively, the Triples test counts all possible triples from a sample of size N (i.e., $\binom{N}{3}$ combinations) of the data. When *most* of the triples are right-skewed the data are said to be asymmetric. If i, j and k are three distinct integers such that $1 \leq i, j, k \leq N$, the triple of observations x_i, x_j, x_k forms a *right triple* or skewed to the right if the middle observation is closer to the smallest observation than it is to the largest observation. This is illustrated by:

Right triple



Left triple



Third, we measure and test the statistical significance of the change in the variance of the shocks (the conditional variance). Typical measures of unconditional variance such as the standard deviation measures the total variation rather than the unexpected variation. Unbiased conventional measures of fluctuations could still exhibit a substantial sampling variation. The conditional variance, however, is our preferred measure of uncertainty and it describes the variance of the shocks.

Typical tests of variance in statistics test whether the variance a is equal to the variance b against alternative hypotheses. We introduce a nonparametric *multivariate* test to test whether the variance of several variables, i.e., shocks in our case, are equal. This test statistic differs from others in that sense that it is a multivariate statistic, where we could test P variates in a statistic called the Sample Generalized Variance. We find significant differences across the GCC countries. Bahrain, Kuwait and Qatar are more stable than the other three with Saudi Arabia and the UAE experiencing significant conditional volatility.

Next, we present our model. In section 3 estimate the model and discuss the results. In section 4, we use the Triples test to test for symmetry. In section 5 we derive a multivariate test statistic for the generalized variance. Section 6 includes the conclusions.

2. The model

Modeling is affected by the quantity and quality of data we have. The data, which we describe next and in the appendix, are annual from 1970 to 2006. We chose to have a simple estimable model with some testable restrictions.

We estimate the model using OLS and the Generalized Method of Moments (GMM). The OLS estimator is consistent under certain conditions such as, for example, an exogeneity condition. In the presence of endogeneity it is inconsistent and inference is invalid. Generally, an instrumental variable estimator is always consistent, but inefficient. Although it is not problems-free, we appeal to the facts that the GMM estimator is appropriate when the economic model is not fully

specified and that it is a robust estimator because it does not require information about the exact distribution of the error term. GMM will have a sufficiently large number of lags as instruments such that the dynamic is similar to that of a VAR.

The exchange rate and the country's national income are determined by the intersection of assets and goods markets. To hold the domestic interest rate i_t at i_t^* the foreign level, GCC central bank's foreign exchange intervention must adjust the money supply so that i_t^* equates aggregate real domestic money demand and the real money supply. Alternatively, they reset the lending rate.

In figure 1 (a), the schedule DD shows a combination of the exchange rate and output for which the goods market is in equilibrium. The schedule AA shows a combination of the exchange rate and output for which the asset market is in equilibrium. This is a straightforward textbook model.

Figure 1 (b), shows how the central bank has to adjust the money supply by buying/selling foreign assets to keep the exchange rate fixed. The foreign exchange market is in equilibrium when the interest parity condition holds, that is when the domestic interest rate i is equal to the foreign interest rate i^* plus $\Delta S^e / S$ the expected rate of depreciation of the domestic currency against the foreign currency. S_t is the nominal exchange rate (the domestic currency price of one unit of foreign currency (i.e., an increase denotes depreciation). At zero, people expect no depreciation and the domestic interest rate equal to the foreign interest rate.

The actual real exchange rate Q_t is defined as $(S_t P_t^*) / P_t$, where P_t^* is the foreign price, and P_t is the domestic price. There is a great debate in the economic literature about the exchange rate determination; it spans a period of more than forty years. Harrod (1933), Balassa (1964) and Samuelson (1964) show that the real exchange rate is a function of the productivity differential between tradable and non-tradable sector in the home and the foreign country. Messe and Rogoff (1983) argue that the exchange rate is a random walk process. Most asset prices follow a random walk process, which is also consistent with the efficient market hypothesis, e.g., Fama's (1970) influential paper. But, there are also several different theories such as the monetary model and various versions of it, e.g., Mussa (1982, 1986), Frenkel's (1967) real interest rate differential model, and Dornbusch's (1976) overshooting model. Generally speaking, these models suggest the real exchange rate is perhaps a function of real money balances differential (money and inflation effects could be separated), output differential, and the interest rate differential. Then we had another generation of models, where government expenditures are the main determinant of the exchange rate, e.g., Edwards (1989), Froot and Rogoff (1991) and Egert, *et al.* (2004).

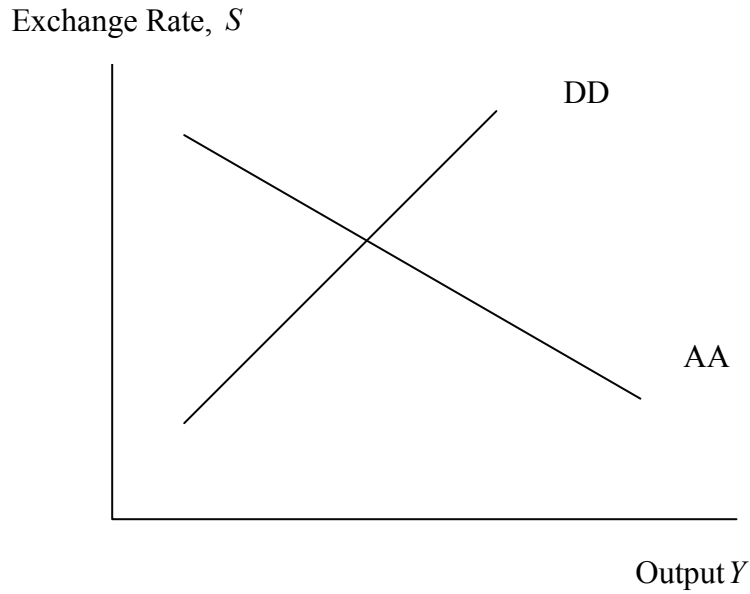


Figure 1 (a)

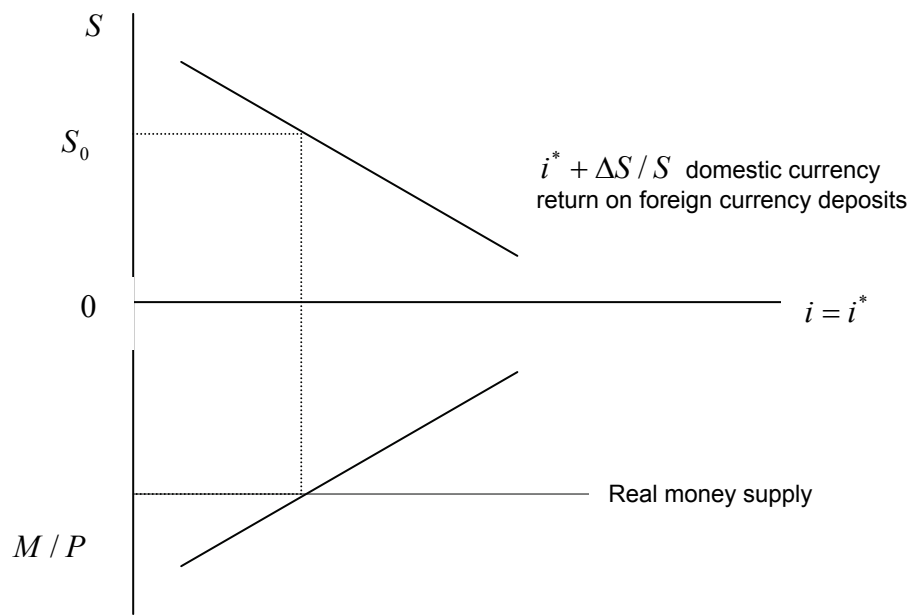


Figure 1 (b)

To encompass the models of the exchange rate determination, we assume that the real exchange rate has two components: a permanent component Q_t^P and a transitory component Q_t^T (e.g., Meltzer (1993) and Razzak (1995)).

$$(1) \quad Q_t = Q_t^P + Q_t^T$$

Further, we let the permanent component be a linear combination of last period actual real exchange rate and a vector of variables X_t , which

includes: $(M/P)_t, (M/P)_t^*, TOT, \hat{D}_t$, where M_t is money⁽²⁾, P_t is the GDP deflator, TOT_t is the term of trade index and $\hat{d}_t$ is productivity differential in tradable goods, which measures the difference in tradable sector's productivity between each of the GCC and their trading partners, i.e., the US, Europe and Asia). It is crucial that we include the term of trade in the model. Exports are mainly oil in the GCC. Therefore, it is crucial we control for the term of trade when measuring the effect of the price of oil on the real exchange rate.⁽³⁾ Real per-capita output in tradable good sectors is $\tilde{Y}_t$ for the GCC and $\tilde{Y}^*$ for their trading partners. The asterisk denotes the foreign country magnitude.

$$(2) \quad Q_t^p = \beta Q_{t-1} + (1 - \beta) X_t + \varepsilon_{2t}$$

Substituting in the actual real exchange rate we get:

$$(3) \quad Q_t = \beta Q_{t-1} + (1 - \beta) X_t + \varepsilon_{3t} ,$$

Where the error term ε_{3t} include ε_{2t} and Q_t^T . The real exchange rate is a random walk if $\beta = 1$.

The good market: We model real output Y_t as a function of foreign income, Y_t^* (which determines foreign demand), the price of oil ($P_t^O S_t$), the foreign *real* interest rate R_t^* and a random disturbance ζ_t that includes uncertainty and other shocks. Real interest rates in the GCC countries are not necessarily the same because expected inflation rates might differ. There is a large literature on the relationship between the *foreign* interest rate and the *domestic* economy. The foreign interest rate could operate through the effect on the expected real depreciation as we mentioned above; exports and in the case of the GCC, oil; and financial flows. For a discussion and review of this literature see Giovanni and Shambaugh (2006).

$$(4) \quad Y_t = f(P_t^O S_t; R_t^*; Y_t^*; \zeta_t),$$

We add a couple of equations to the model; one is the CPI, $\hat{P}_t$ which is a weighted average of the domestic price deflator P_t and the foreign price P_t^* . Non-oil production in the GCC is relatively small so we do not include the price of domestic goods. Average non-oil production as a percent of GDP in GCC in 2002, for example, was about 3.4 percent.

$$(5) \quad \hat{P}_t = (P_t)^{\gamma_1} * (P_t^* S)^{1-\gamma_1}$$

And another equation for the real money balances, which is given by:

$$(6) \quad M_t^s / P_t = L(i_t^*, Y_t)$$

where M_t^s is the domestic money supply, P_t is the domestic price level, and Y_t is real GDP. Given the price level and real GDP, the equilibrium condition above determine the money supply required to fix the exchange rate permanently such that it is consistent with asset market equilibrium at a foreign interest rate.

We would have closed the model with a UIP condition equation (figure 1), where the domestic interest rate is equal to the foreign interest rate plus the expected depreciation rate. However, data for GCC nominal interest rates are not available for the whole sample, but only from the mid 1980s.

Putting all together, the model consists of the following system of equations, where the subscript $i = 1, 2, \dots, 6$ GCC countries, i.e., a *panel* and lowercase variables denote the natural log.

$$\begin{aligned}
(7) \quad q_{it} &= \alpha_{11}q_{it-1} + (1 - \alpha_{11})[\alpha_{12}(m_{it} - p_{it}) + \alpha_{13}(m_t - p_t)^* + \alpha_{14}ToT_{it} + \alpha_{15}\hat{d}_{it}] + \varepsilon_{7it} \\
(8) \quad (m - p)_{it} &= \alpha_{21}y_{it} + \alpha_{22}i_t^* + \varepsilon_{8it} \\
(9) \quad \hat{p}_{it} &= \alpha_{31}(p_t) + (1 - \alpha_{31})(p_{it}^* + s_{it}) + \varepsilon_{9it} \\
(10) \quad y_{it} &= \alpha_{41}(p_{it}^o + s_{it}) + \alpha_{42}R_t^* + \alpha_{43}y_t^* + \varepsilon_{10it}
\end{aligned}$$

The model has several asset prices: the exchange rate (endogenous), real money balances (endogenous), domestic and foreign interest rates (exogenous) and real oil price (exogenous). Real output is endogenous. All foreign variables are strictly exogenous. The term of trade is most probably exogenous. There are more exogenous than endogenous variables in the model. The model is identifiable; it satisfies the rank and order conditions.

The model predicts that an increase in domestic real money balances depreciates the real exchange rate $\alpha_{12} > 0$. (Positive sign denotes depreciation).

The increase in the foreign real money balances due to the central bank sells of foreign reserves for domestic money appreciates the real exchange rate $\alpha_{13} < 0$.

An increase in the term of trade will appreciate the real exchange rate, which is consistent with a voluminous literature showing the appreciation of the real exchange rate, $\alpha_{14} < 0$.

We expect that $\alpha_{15} < 0$, i.e., an increase in productivity appreciates the real exchange rate. In the real money balances equation $\alpha_{21} > 0$. Given financial innovations in the GCC countries are not expected to be as high as those in the US we expect α_{21} to be greater than one perhaps. The effect of the nominal interest rate on the real money balances is negative, $\alpha_{22} < 0$.

In the real output equation, higher oil prices increase income of the GCC countries because they are major exporters of oil, so α_{41} is expected to be positive. The foreign real interest rate is predicted to have a negative effect on domestic

production, $\alpha_{42} < 0$, see Giovanni and Shambaugh (2006). Foreign real output has a positive effect on domestic output, $\alpha_{43} > 0$.

The restriction that domestic money and foreign money coefficients in the exchange rate equation sum to zero will be tested, i.e., $\alpha_{12} + \alpha_{13} = 0$. The restriction in the price equation will also be tested, i.e., α_{31} and $(1 - \alpha_{31})$. After we estimate the model above we solve it for the real exchange rate and compute the effect of the real oil price on the real exchange rate.

3. Data and estimation

The data we use are annual from 1970 to 2006 when the foreign country is the US. All data are in natural logs except the interest rate. Foreign real interest rates are the nominal 90-day rate minus last period inflation rate as a proxy for expected inflation. All data are from the IMF data base. The definitions are in the appendix and figures 2 to 11 plot the data. Data are available upon request.

All the data have trend except the US real interest rate (the 90-day interest rate minus last period inflation as a proxy for expected inflation). Kuwait's GDP (figure 6) has a break during the Gulf War I in 1990. The common unit root tests that we use are not designed to handle breaks in the data; they confuse the break with a unit root. Also, most of the unit root tests have low powers, some relatively different from others. We test the data for unit root using common unit root tests for time series and panel data.⁽⁴⁾ We could not reject the hypothesis that the log-level data have unit roots, except for the real interest rate.

Our model which is depicted in figure 1 represents a short-run equilibrium model. For that reason we estimate the regressions in first differences (except for the US real interest rate), but there are other good reasons: First, first differenced regression is approximately the same as fixed effect models and this is precisely what we want to estimate to account for the country-effect i.e., heterogeneity.⁽⁵⁾ Second, we are interested in the short-run because the exchange rate and the price of oil are asset prices, which are very persistent (i.e., unit root, near random walk or random walk) so the long run is very long. Typically, when good and asset price inflations are high the lags are short relative to the lags when good and asset inflations are low. Third, to compute the Generalized Sample Variance for the residuals, they have to be $I(0)$, which is guaranteed when we estimate *our* system in first differences because the levels are $I(1)$. Fourth, we could not appeal for cointegration to run the model in levels because testing the hypothesis of no cointegration in a panel is problematic when N (the number of cross sections) is small (6 observations only) and T (the length of time series sample) is not long.

Table 1 reports descriptive statistics for the log-differenced data (except for the real interest rates). These are period averages. The average real exchange rate depreciations are between -1 and -3 percent. But in 2006 all the currencies appreciated significantly in real terms, up to 13 percent for the UAE. Real money balance grew at rates between 6 to 8 percent on average across the GCC, just as high as the US. With exception of Kuwait, which experienced a high rate of growth in the

term of trade, most GCC countries' terms of trade grew between 3 and 5 percent on average.

All GCC countries productivity differential with their major trading partners in tradable good sectors are either zero or negatives. Relative to trading partners, the level of productivity in tradable goods in Bahrain increased in the mid 1980s, again in 2000 then flattened; increased right after the 1990s Gulf War, then flattened in Kuwait; fluctuated wildly in Oman; increased in the 1990s in Qatar then flattened; increased in Saudi Arabia over the 1970s but has been declining since 1980; and finally it has been declining all the way from 1970 in the USE. Kuwait's real GDP has a break during the Gulf War in 1990/1991.

Most of the RHS variables in equation 7 – 10 such as money, foreign money, the term of trade, oil prices, foreign real interest rate and foreign GDP, could be assumed exogenous. For the system of equations, Least Squares method is a reasonable initial estimator, except that the real depreciation rate equation of the *differenced* model includes a lagged dependent variable. Thus, $cov(\Delta \varepsilon_{7it}, \Delta q_{it-1}) < 0$. Thus, the coefficient α_{11} is biased downward in Least Squares. We would also expect the other coefficient estimates in the real exchange rate depreciation rate to be biased and inconsistent. For this problem, for not knowing the true model or the data-generating-process, and for robustness, we also report the Generalized Method of Moments (GMM) results.

In the GMM regression, the instruments are several lags of the RHS variables because these variables are the ones that are readily available. The instruments are all in first differenced form and include a constant in every equation. For equation (7), we include trend, 8 lags of the term of trade, 4 lags of productivity differential, and 4 lags of government expenditures. For equation (8) we have 4 lags of the change in the foreign real GDP and 4 lags of the change in the foreign nominal interest rate. In equation (9) we have 4 lags of the US price level, and in equation (10) we have 8 lags of the nominal price of oil and 8 lags of the nominal exchange rate. The number of instruments and the length of the lags have well-known disadvantages so we will restrict the number of the instruments to save some degrees-of-freedom. We should interpret the coefficient estimates carefully.⁽⁶⁾

Table 2 reports two regressions.⁽⁷⁾ We report Least Squares and GMM results. The effective sample sizes are different depending on the number of instruments used in the GMM regressions. All estimates are interpreted as *averages over the GCC countries and over the sample period*. The real exchange rate *depreciation rate* does not seem persistent. The coefficient α_{11} is 0.30 and 0.13 in the Least Squares and the GMM regressions respectively.⁽⁸⁾

Real money balances depreciate the real exchange rate, i.e., the sign is positive, and significant. The size of the coefficient α_{12} is 0.60 (GMM) and 0.66 (Least Squares), which is relatively large. Foreign real money balances appreciate the real exchange rate, i.e., the sign is negative, and significant.⁽⁹⁾ The coefficient α_{13} is -0.78 (GMM) and -0.54 (Least Squares). These coefficients sum to zero as some of the exchange rate determination models predict.⁽¹⁰⁾

The term of trade also appreciates the real exchange rate, the sign of α_{14} is negative, and the coefficient is significant. The size is relatively larger in GMM. It suggests that a one percent increase in the term of trade over last period's value leads the depreciation rate to fall (appreciation) by about $\frac{1}{2}$ percent in GMM and $\frac{1}{4}$ in Least Squares. This result is consistent with most of the findings in the literature on the effect of the term of trade on the real exchange rate. The GCC has experienced positive term of trade shocks lately because of the increase in the price of oil. More than 70 percent of the GCC exports are oil and gas.⁽¹¹⁾

Even though the model has productivity differential in tradable goods only, this variable is significant and has the right sign.⁽¹²⁾ An increase in productivity in tradable goods sector at home relative to that of the trading partners appreciates the real exchange rate. It increases the price of non-tradable goods relative to tradable good prices, and it may explain the latest increases in housing prices and services.

The income elasticity of the demand for real money balances is small in the Least Squares regression, 0.26, which is similar to estimates found in the literature for advanced countries. It is 0.43 in GMM.⁽¹³⁾ It is clear that the GCC banking system has come a long way. Financial services are very modern and the use of plastic cards and ATM is widespread, which might explain the surprisingly low elasticity.

The price equation is estimated in an unrestricted form and the restriction is tested. The restriction holds very well in the US dollar regressions. In GMM, the coefficients α_{31} (coefficient of the domestic price) and α_{32} (coefficient of the foreign price) sum to one.⁽¹⁴⁾ The result is self explanatory; on average more than 2/3 of the inflation in the GCC countries is imported from abroad, which is a very consistent feature of fixed foreign exchange rate regimes.

In the final equation, an increase in the real price of oil has a positive effect on output. Remember that these countries are oil producing countries, where oil and gas make up more than 2/3 of their production. Also, GDP data are expenditures side so when oil prices increase, oil revenues increase and with that expenditures, both public and private, increase. Our estimate suggests that a 100 percent increase in the real price of oil at Dubai increases real GDP growth by 5 percent, reasonably high. A one percent increase in the US real interest rate reduces output growth in GCC by about 1 percent. The magnitude seems large. The easy monetary policy in the US, i.e., lower exchange rate and lower interest rate, might explain the expansionary phase in the GCC and the consequent inflationary pressures. The US growth rate of GDP has a significant and large effect on GDP growth in the GCC countries. These results need no further explanation.

Because Kuwait has changed its exchange rate policy twice and because it was affected by the first Gulf war in 1991, we re-estimated the model without Kuwait. We found no significant effect on the *average* estimated coefficients in the panel.

4. The Triples test statistic for symmetry

The literature on asymmetric shocks is quite large and most of the applications have been in the context of the EU. Asymmetry refers to a situation where the impact

of a shock on a variable such as output, for example, in country A is different from its impact country B.

We use the Triples test, Randles et al. (1980) and Razzak (2001) to test the null hypothesis of symmetry against the alternative of asymmetry. It tests the hypothesis that the *distribution* of the data (time series or a panel), is symmetric about the unknown median θ against a broad class of asymmetric alternatives. There are different types of asymmetries. The data possess *steepness* if, upon first differencing, the resultant distribution is asymmetric. De-trended data possess *depth* if the distribution of the levels is asymmetric. The Triples test detects asymmetry and distinguishes between *positive* and *negative* asymmetry. A detection of positive asymmetry in the first difference of a time series indicates positive steepness. This implies that, in levels, the data tend to undergo rapid increases over short period of time, and slow, gradual decreases over long periods of time. Some GDP data display negative steepness, which means that they fall rapidly, but rise very slowly.

We will test the null hypothesis of symmetry against the alternative hypothesis of asymmetry for a variety of variables. First, we test the deviations of the log level of the four endogenous variables in our system from an HP trend – detrended data; the real exchange rate $q_{it} - HPtrend$; real output $y_{it} - HPtrend$, real money balances $(m - p)_{it} - HPtrend$ and the price $\hat{p}_{it} - HPtrend$. This test would be a test of *deepness*. (2) We test their first difference, i.e., a test for *steepness*. And (3) we test the shocks of the system $\varepsilon_{7,it}, \varepsilon_{8t}, \alpha_{9t}$ and ε_{10t} from both the OLS and the GMM regressions.

We report the results in table 3. We found no evidence of asymmetry. The null hypothesis of symmetry is rejected in every case. Shocks to the real exchange rate depreciation (asset market) and shocks to real output growth (the good market) in addition to real money balances growth and inflation shocks are symmetrical across GCC countries. Surely this kind of news are good for the optimum currency area. However, we will examine the generalized variance of these shocks, as a block, on each of the GCC countries.

5. The generalized conditional variability

A typical measure of unconditional variance, i.e., the standard deviation, measures the total variation rather than the unexpected variation. Unbiased conventional measures of fluctuations could still exhibit a substantial sampling variation. The conditional variance is a preferred measure of uncertainty. While ARCH, GARCH etc models are more informative about uncertainty than unconditional variance methods, they still lack economic rationales and are very sensitive to temporal aggregation.

Instead, we test whether the conditional variance of the model presented earlier, which consists of four equations that proxy market fundamentals, has remained constant against the alternative hypothesis that it increased.

For a multivariate normal variable the variance (of the population) is a *function* called the *Generalized Variance*, which is the determinant of a matrix, Σ -

the variance-covariance matrix. The determinant of the *sample* variance matrix S^2 is called the *Sample Generalized Variance*, where S^2 is the sample covariance matrix based on sample of size n .⁽¹⁵⁾

Anderson (1958) shows that a convenient statistic for the generalized variance is the following form of the sample generalized variance:

$$(11) \quad D_k = (n-1)P \left[\frac{|S_k^2|}{|\Sigma|} \right]^{1/P} > 0$$

And $k = 1, 2 \dots m$.

The matrix S^2 is computed by:

$$(12) \quad S_{ij}^2 = \frac{1}{n-1} \sum_{k=1}^m (\varepsilon_{ki} - \bar{\varepsilon}_i)(\varepsilon_{kj} - \bar{\varepsilon}_j)$$

And Σ is approximately:

$$(13) \quad \bar{S}^2 = \frac{1}{N-m} \sum_{k=1}^m (n-1)S_k^2$$

Which is the mean of S^2 .

Unfortunately, for $P > 3$ (in this paper we have four residuals so $P = 4$), the statistic D_k has no exact distribution so we cannot test for the significance level. Ganadesikan and Gupta (1970) approximated the distribution by a Γ (Gamma) distribution with two parameters, a shape and a scale parameter,. They showed that the Γ distribution is best approximated when $n = 10$. In this paper $28 \leq n \leq 34$, effectively, depending on whether we have an OLS residual matrix of a GMM residuals matrix. The window for which we calculate the statistics are decided by the panel. We have 6 countries and 28 to 34 observations for each depending on whether we have OLS or GMM residuals matrix. Thus we will have 6 values for D_k each represents the conditional generalized variance of a member-country of the GCC.

The two parameters defining the distribution of the statistic are the shape parameter

$$(14) \quad h = \frac{P(n-P)}{2}$$

and the scale parameter

$$(15) \quad A = \frac{P}{2} \left[1 - \frac{(P-1)(P-2)}{2n} \right]^{1/P}$$

To simplify the interpretation of the statistic D_k , we transform the Γ distribution into a standard normal by computing the following:

$$(16) \quad u_k = G_{h,A}(D_k)$$

Where G is the distribution function of the Gamma distribution with the two parameters above, and then the inverse of u_k

$$(17) \quad R_i(D_k) = \Phi^{-1}(u_k)$$

$R(D_k)$ and $R(S_i^2)$ are distributed standard normal and therefore the values could be $R(.) < 0 < R(.)$. A significant increase implies values of $R(D_k) > \pm 3\sigma$. The $\pm 3\sigma$ limits constitute a zone of 0.99730 intervals for the values of $R(D_k)$, which is also true for non-standard normal distribution (Tchebysheff's theorem). Values of $R(D_k)$ exceeding $\pm 3\sigma$ are considered to mean a significant change in the conditional variance.⁽¹⁶⁾ We plot the 6 values in figure 12 for both the residuals of OLS and GMM.

Note that the statistics for the conditional sample generalised variance are smaller for OLS than the GMM method. The results are only quantitatively different. There are striking differences. Bahrain, Kuwait and Qatar are significantly more stable economies than the rest of the GCC, and more so in the OLS system. Bahrain and Kuwait are more stable than Qatar. Oman, Saudi Arabia and the UAE have a significantly large conditional variance. Our interpretation of these results is that although the shocks seem symmetric across member-countries, they have significantly different variances. The four shocks together (real output growth, real depreciation rate, real money balances growth and inflation) seem to imply significantly different uncertainties.

6. Summary and more research question

In this paper, we estimated a simple simultaneous equation model, where the *short run* equilibrium real output and the real exchange rate are determined by the intersection of the goods and the assets markets schedules, and the central bank chose the level of the money supply such that the domestic short term interest rate is equal to the foreign (US) interest rate. We then tested the null hypothesis of symmetry against the alternative of asymmetry for the four shocks in the model, i.e., the real exchange rate, real output, real money balances, and the price level, using three different measures: deviation from HP trend, first difference, and the residuals of the system. We found no evidence of asymmetry. Finally, we calculated the *conditional generalized variance* of the shocks, i.e. the *generalized variance* of the estimated residuals. We introduced a *multivariate* test statistic and tested whether the *conditional sample generalized variance* of each member country is equal over the sample. This would tell us how individual GCC countries have been affected by the shocks. We found that Bahrain and Kuwait conditional real variability to be significantly lower from the rest of the pack.

Given the differences, one should ask more questions. First, would a historically small and stable economy (e.g., Bahrain) want to join in a currency union with another unstable economy (e.g., Saudi Arabia and UAE)? Second, would Bahrain, for example, be just as unstable as Saudi Arabia when facing the same shocks in the future where both countries are members of the same currency union? Put differently, as countries become more integrated after the union and shock effects become symmetrical as the argument goes, would the conditional variance of the shocks to the union as whole be as high as that of Saudi Arabia or as low as that of Bahrain? Three, to what extent a unified monetary policy affect the conditional variance of *real* shocks? These are some tough unanswered questions that one ought to answer before establishing the currency union, or not.

The assumption is that the new forthcoming currency union central bank will fix the new currency against either the US dollar or something else. One would have to wonder, what is the economic difference between the newly fixed currency to the US dollar and the old single-country currency which was fixed to the US dollar?

How much rests on the new central bank's objective(s)? If the new central bank decides to stick to stabilizing the exchange rate it should be able to do so just in the past where each country has done successfully. However, it will experience inflationary pressures and swings in oil prices every once in a while. Recent increase in inflation did not seem to matter for most GCC countries because they are relatively wealthy. It has been a cost paid to achieve oil revenue stability. The GCC countries obviously want to fix the exchange rate such that oil revenues are stable. Inflation hurts the poor more than it hurts the rich. Further, monetary policy will be ineffective. However, if the new central bank's objective will be price stability (inflation or price level targeting) then it has an effective monetary policy and more work to do. To ensure domestic price stability, the exchange rate will have to be freely fluctuating, which means it will have a bigger variance because the exchange rate acts like a shock absorber, and with it swings in oil revenues. On the other hand, one would expect the variances of the shocks to converge to small magnitudes in the currency area. We believe that there has been very little research in this area, and what's good for Europe cannot be necessarily good for the GCC.

Another important issue for research is that, mainly, the adjustments to shocks in an Optimum Currency Area take place in the labor market. A fuzzy area in this literature is the perception that the GCC labor markets are flexible (see for example, Khan, 2009) so that, presumably, labor can move freely across borders to the high labor cost area to lower wages and re-equilibrate the market. However, at least 2/3 of the labor force in the GCC countries is made of foreign workers. Foreign labor cannot move from one GCC country to another easily; they are subject to complex visa procedures. Most locals work for the government and it is highly unlikely that they move to work in another GCC country when unemployment increases in their own.

Another argument typically used for currency unions is that the single currency will reduce the cost of transaction thus it will increase trade. But trade is thin among the GCC.⁽¹⁷⁾ Would the union enhance trade? The answer is not so obvious. We are unaware of any research in this area or any back-of-the-envelope calculations.

Footnotes

¹ Deregulations began in January 1983. The GCC began with the removal of tariffs on products originated in the GCC member countries (products must have a minimum of 40% value added in one of the member countries and at 51% owned by a citizen of the GCC countries.) Although agricultural products, livestock; manufacturing; natural resources are exempt from duties, there are exemptions.

² The theory does not really say what measure of money. Researchers tried almost all different definitions of money and reported mixed results, but most of the evidence of the 1970s and 1980s models of the exchange rate determination found wrong signs.

³ It is conceivable that US variables play the most important role in affecting the real exchange rates of the GCC countries. The US government massive expenditures and investments in defense could directly affect the real exchange rate in the GCC countries. We know that in countries that are major exporters of materials (primary commodity and metals) such as New Zealand and Australia, the term of trade seems to play a role in affecting the exchange rate.

⁴ We used the Augmented Dickey- Fuller (1984), Perron (1997), Phillips (1987), Elliott (1991), Levin, Lin and Chu (2002), Im, Pesaran and Shin (2003), Sarno and Taylor (1998) and Taylor and Sarno (1998)). We estimated a variety of specifications (constant, time trend, etc.) and examined a variety of lag structures using different Information Criteria.

⁵ We could not allow *all* parameters to vary by country because we have a short sample and we would lose degrees-of-freedom.

⁶ For GMM see Wooldridge (2002).

⁷ In all regressions, we use a robust Newey-West method to calculate the variance-covariance matrix.

⁸ The *level* of the real exchange rate is a random walk, but the depreciation rate is not. The coefficients are statistically significantly different from 1. The p-value of the Wald statistic is zero.

⁹ Students of the exchange rate know that the literature on the monetary model of the exchange rate determination and the real interest rate differential model of the exchange rate determination is full of empirical studies that show that money has the wrong sign and that the models' restriction do not actually hold.

¹⁰ The Wald statistic's p-values to test this hypothesis are 0.8724 and 0.6828 for GMM and Least Squares respectively.

¹¹ We tried government expenditures, government expenditures to GDP ratio and the difference between government expenditures in the GCC countries and the US, and Europe. We found the coefficient estimates to be insignificant so we dropped these variables from the regressions.

¹² Productivity in non-tradable good sectors is very difficult to measure. The productivity differential in tradable good sectors between the GCC and their major trading partners such as Europe, Asia and the US, is calculated by the IMF staff.

¹³ We test whether $\alpha_{21} = 1$; the Wald statistic's p-value is 0.0000.

¹⁴ The p-value of the Wald statistic is 0.1683. The restriction also holds in Least Squares; the Wald statistic's p-value is 0.1257.

¹⁵ Anderson (1958) shows that the determinant of S^2 is proportional to the sum of squares of the volumes of all *parallelpipedes* formed by using as principle edges P vectors of $X_1, X_2, \dots, X_P$ as one set of end points, and the mean of $\mathcal{E}$ as the other with $\frac{1}{(n-1)^P}$ as the factor of proportionality.

¹⁶ A SAS – IML code to calculate the multivariate statistics for the case of three and more variables is in the appendix.

¹⁷ The UN (Comtrade website) and Arab Fund for Economic Development 2004 report that the share of exports among the GCC members in total exports, were 3.6% in 1990 and 5% in 2006. To put things in perspective, the same percentages for the EU were 64.9% and 66.2% respectively. Trade is thin among the GCC.

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Appendix

Table 1: Descriptive Statistics

Variable	Bahrain		Kuwait		Oman		Qatar		Saudi Arabia		UAE		USA	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Δq	-0.01	0.08	-0.02	0.12	-0.01	0.11	-0.04	0.15	-0.02	0.11	-0.06	0.11	-	-
$\Delta(m - p)$	0.07	0.18	0.05	0.13	0.08	0.13	0.07	0.17	0.08	0.12	0.06	0.23	-	-
$\Delta(m - p)^*$	-	-	-	-	-	-	-	-	-	-	-	-	0.07	0.16
ΔToT	0.02	0.11	0.08	0.27	0.05	0.27	0.03	0.29	0.05	0.25	0.05	0.22	-	-
$\Delta \hat{d}$	0.00	0.06	-0.04	0.13	0.00	0.10	-0.02	0.10	-0.01	0.08	-0.05	0.08	-	-
Δy^P	0.05	0.05	0.02	0.16	0.06	0.07	0.04	0.08	0.04	0.06	0.05	0.07	-	-
Δs (US)	-0.006	0.02	-0.006	0.03	-0.002	0.03	-0.007	0.02	-0.005	0.02	-0.007	0.02	-	-
Δm	0.11	0.18	0.10	0.09	0.14	0.13	0.15	0.13	0.15	0.15	0.16	0.19	-	-
Δp	0.05	0.09	0.05	0.12	0.05	0.11	0.07	0.15	0.06	0.12	0.09	0.18	-	-
$\Delta \hat{p}$	0.04	0.06	0.03	0.06	0.03	0.04	0.06	0.06	0.04	0.07	0.07	0.06	-	-
R^*	-	-	-	-	-	-	-	-	-	-	-	-	0.05	0.026
Δy^*	-	-	-	-	-	-	-	-	-	-	-	-	0.03	0.02

Δp^o														0.06	0.32
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$\bar{X}$ denotes the mean and S denotes the standard deviation. The sample is 1970-2006. All data are in natural logs except for the interest rates, asterisks denote the foreign magnitudes. Nominal exchange rate s defined as the domestic price of the foreign currency (USD and Euro alternatively); p is the GDP price deflator (2000=100); $\hat{p}$ is the CPI (2000=100); q is the real exchange rate; m is money plus quasi money; ToT is the term of trade (2000=100); $\hat{d}$ is tradable good productivity differential with trading partners; y is real GDP (expenditure side); p^0 is the real price of oil (Dubai), and R^* is the foreign 90-day interest rate.

The source of the data is the IMF-IFS and the World Economic Report.

Table 2 – System estimation

$$\begin{aligned}
7 \Delta q_{it} &= \alpha_{11} \Delta q_{it-1} + (1 - \alpha_{11}) [\alpha_{12} \Delta(m_{it} - p_{it}) + \alpha_{13} \Delta(m_t - p_t)^* + \alpha_{14} \Delta ToT_{it} \\
&+ \alpha_{15} \Delta \hat{d}_{it}] + \Delta \varepsilon_{7it} \\
8 \Delta(m - p)_{it} &= \alpha_{21} \Delta y_{it} + \alpha_{22} \Delta i_t^* + \Delta \varepsilon_{8it} \\
9 \Delta \hat{p}_{it} &= \alpha_{31} \Delta p_{it} + \alpha_{32} (\Delta p_t^* + \Delta s) + \Delta \varepsilon_{9it} \\
10 \Delta y_{it} &= \alpha_{41} \Delta(p_{it}^o + s_{it}) + \alpha_{42} R_t^* + \alpha_{43} \Delta y_t^* + \Delta \varepsilon_{10it}
\end{aligned}$$

Parameters	(1970-2006)			
	Least Squares		GMM ⁱⁱⁱ	
	coefficient	p-value	coefficient	p-value
α_{10}	-0.03	0.0003	-0.004	0.7564
α_{11}	0.30	0.0000	0.13	0.0010
α_{12}	0.66	0.0000	0.60	0.0000
α_{13}	-0.54	0.0848	-0.78	0.0542
α_{14}	-0.25	0.0000	-0.52	0.0000
α_{15}	-0.14	0.1313	-0.33	0.0007
α_{20}	0.06	0.0000	0.04	0.0000
α_{21}	0.26	0.0271	0.43	0.0440
α_{22}	-0.025	0.0003	-0.04	0.0000
α_{30}	0.006	0.2860	-0.01	0.0662
α_{31}	0.15	0.0000	0.41	0.0000
α_{32}	0.70	0.0045	0.85	0.0001
α_{40}	0.02	0.0712	0.03	0.0049
α_{41}	0.06	0.0012	0.04	0.0520
α_{42}	-1.04	0.0003	-1.06	0.0000
α_{43}	1.20	0.0002	1.00	0.0012
	3.90E-09 ⁱ		4.48E-09 ⁱ	
			0.1569 ⁱⁱ	

i-Determinant of the residuals covariance matrix.

ii-J statistic to test for the over-identification of the instruments, distributed χ^2 .

iii-The instruments are all in first differenced form and include a constant in every equation: eq. (7) [trend, eight lags of the term of trade, four lags of productivity differential, and four lags of government expenditures]; (8) [four lags of the change in the foreign real GDP and four lags of the change in the foreign nominal interest rate]; eq. (9) [four lags of the US price level] and eq. (10) [eight lags of the nominal price of oil and eight lags of the nominal exchange rate]. Kernel is Bartlett, Bandwidth fixed equal to 4, no pre-whitening, coefficients iterated after one-step weighting matrix. Convergence achieved after 1 weight matrix and 6 total coefficient iterations. Kernel is Bartlett. Bandwidth is fixed equal to 3. no pre-whitening, coefficients iterated after one-step weighting matrix. Convergence achieved after 1 weight matrix and 6 total coefficient iterations. The restriction in equation (9) that $\alpha_{31} + \alpha_{32} = 1$ is tested and the Wald statistic P-values are 0.1257, 0.1701 respectively.

Table 3: The Triples Test Statistic

Variables	Depth		Steepness					
	Level	P value	Difference	P value	OLS shock	P value	GMM shock	P value
y_{it}	-1.37	0.0853	-1.06	0.1446	-1.07	0.1423	-0.40	0.3445
q_{it}	-0.41	0.3409	-0.61	0.2709	-1.30	0.0968	-0.10	0.4601
$(m - p)_{it}$	-0.53	0.2980	0.10	0.5398	-0.10	0.4601	0.44	0.6700
$\hat{p}_{it}$	0.70	0.7580	1.34	0.9098	1.57	0.9418	-0.78	0.2177

Level means deviation of the log level of the variable from an HP trend.

Difference means first difference of the log level

OLS shock is the $\hat{\varepsilon}_{it}$ from the OLS regression, shock to real output etc.

GMM shock is the $\hat{\varepsilon}_{it}$ from the GMM regression, shock to real output etc.

Figure 2: Log Real and Nominal Exchange Rates in US dollar

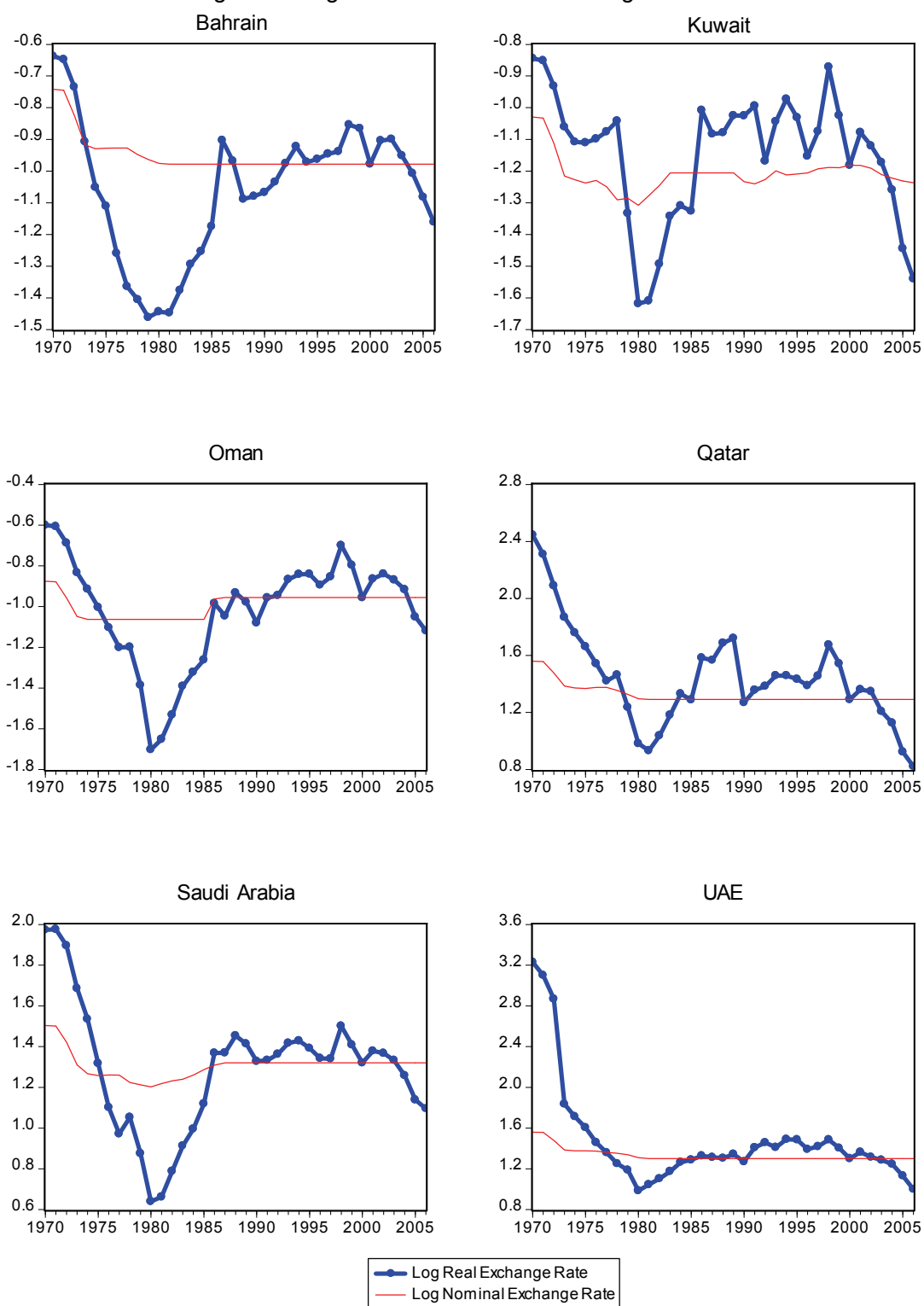


Figure 4: Log Real Money Balances

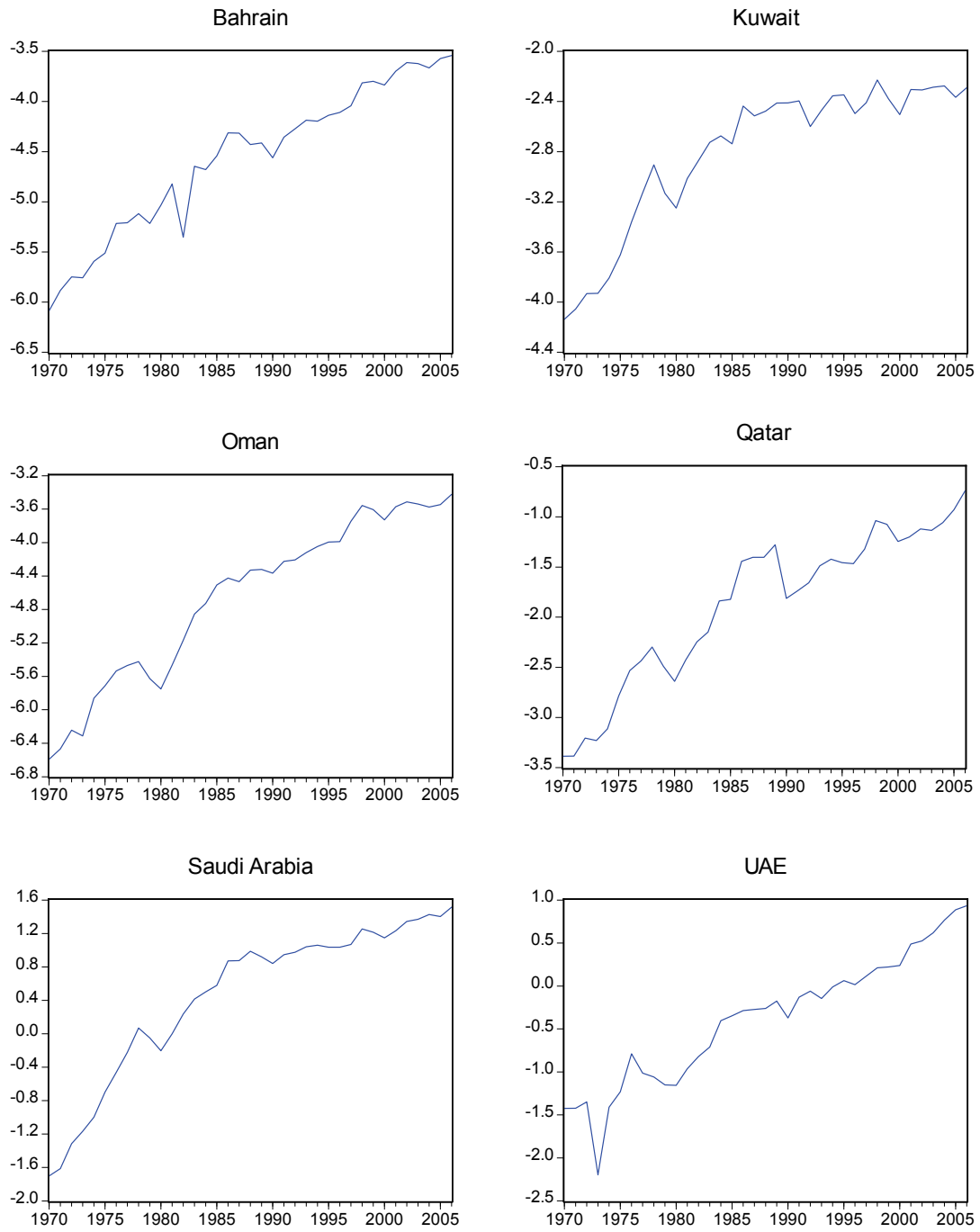


Figure 5: Log Term of Trade

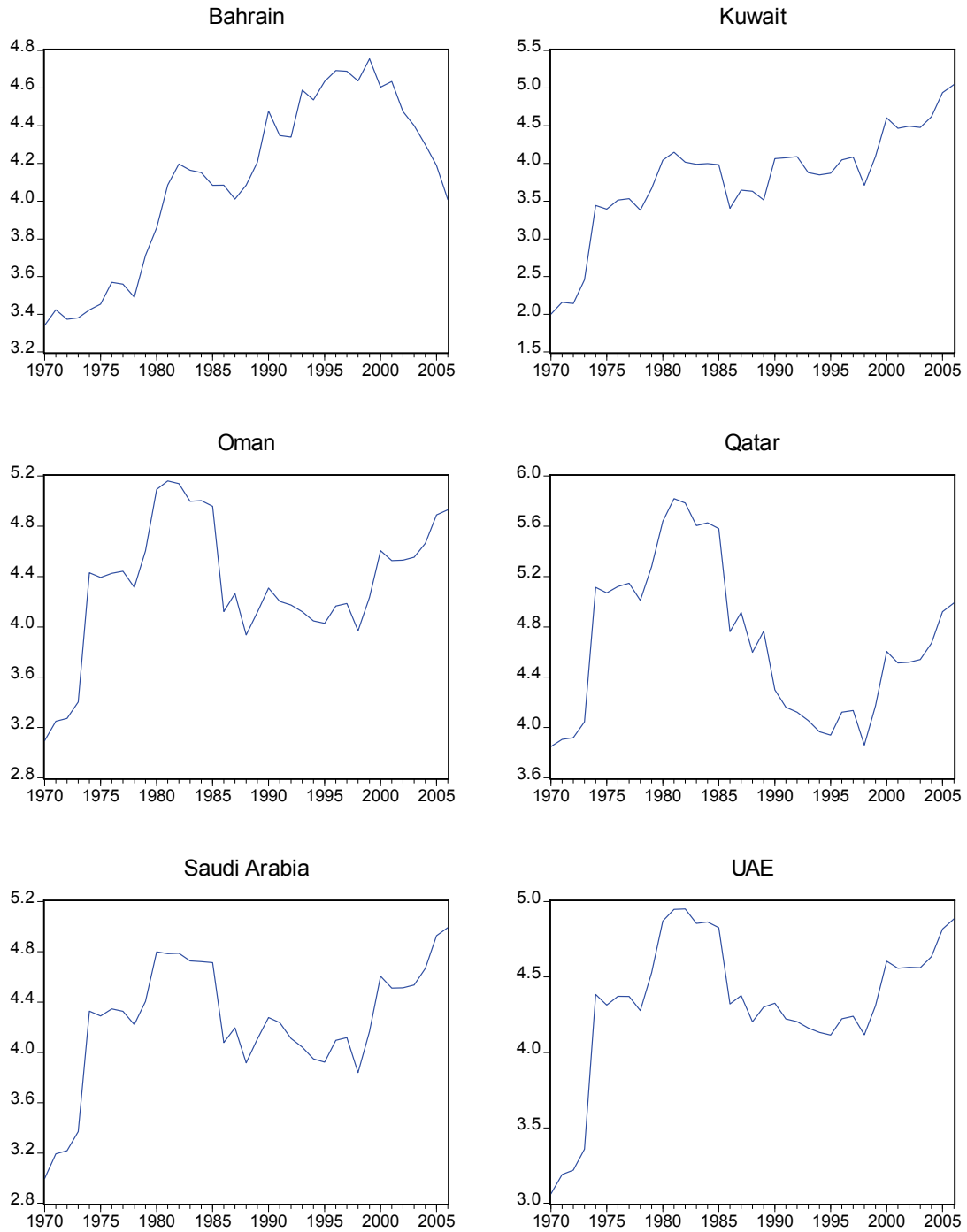


Figure 6: Log Real GDP

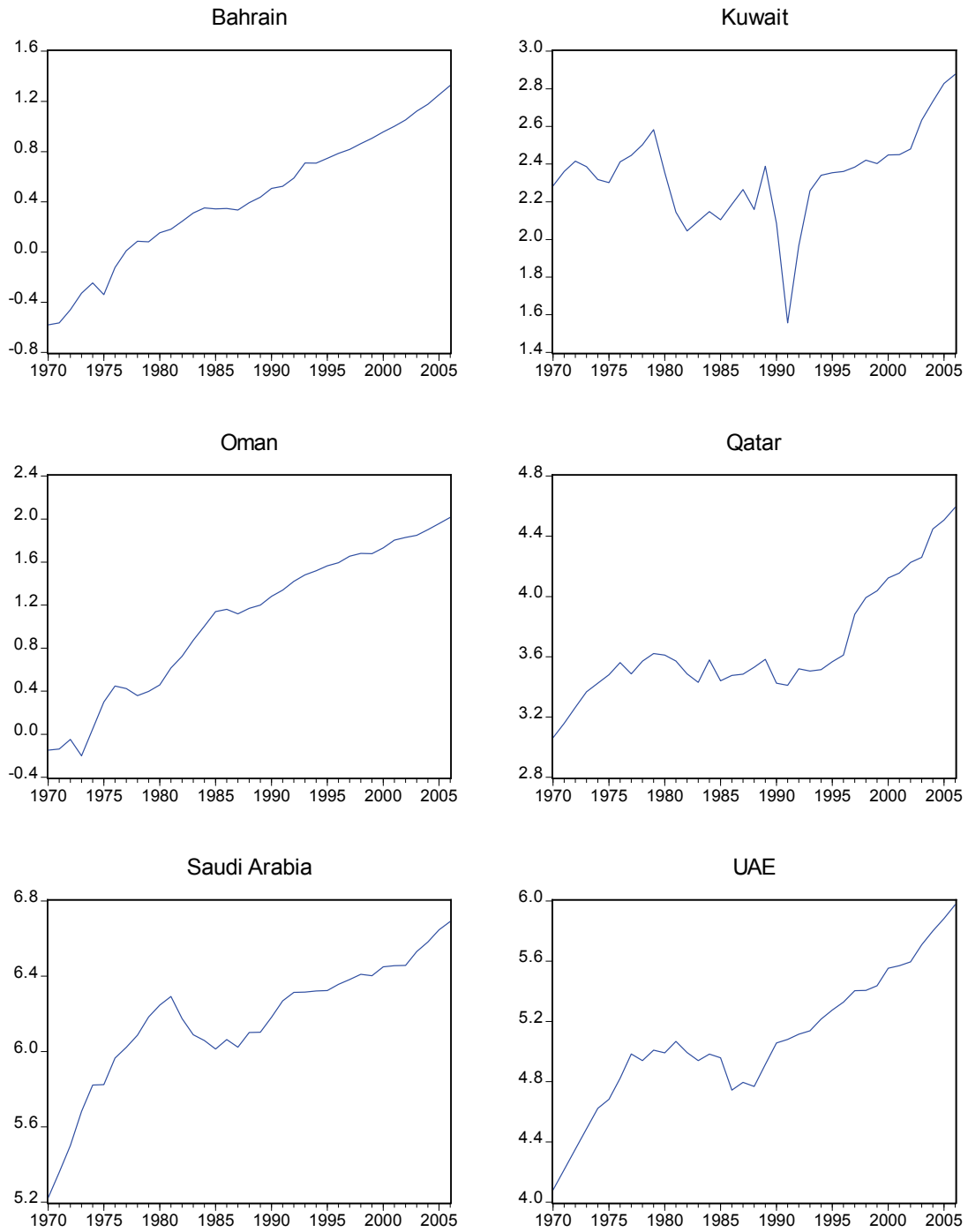


Figure 7: Log Price of Oil

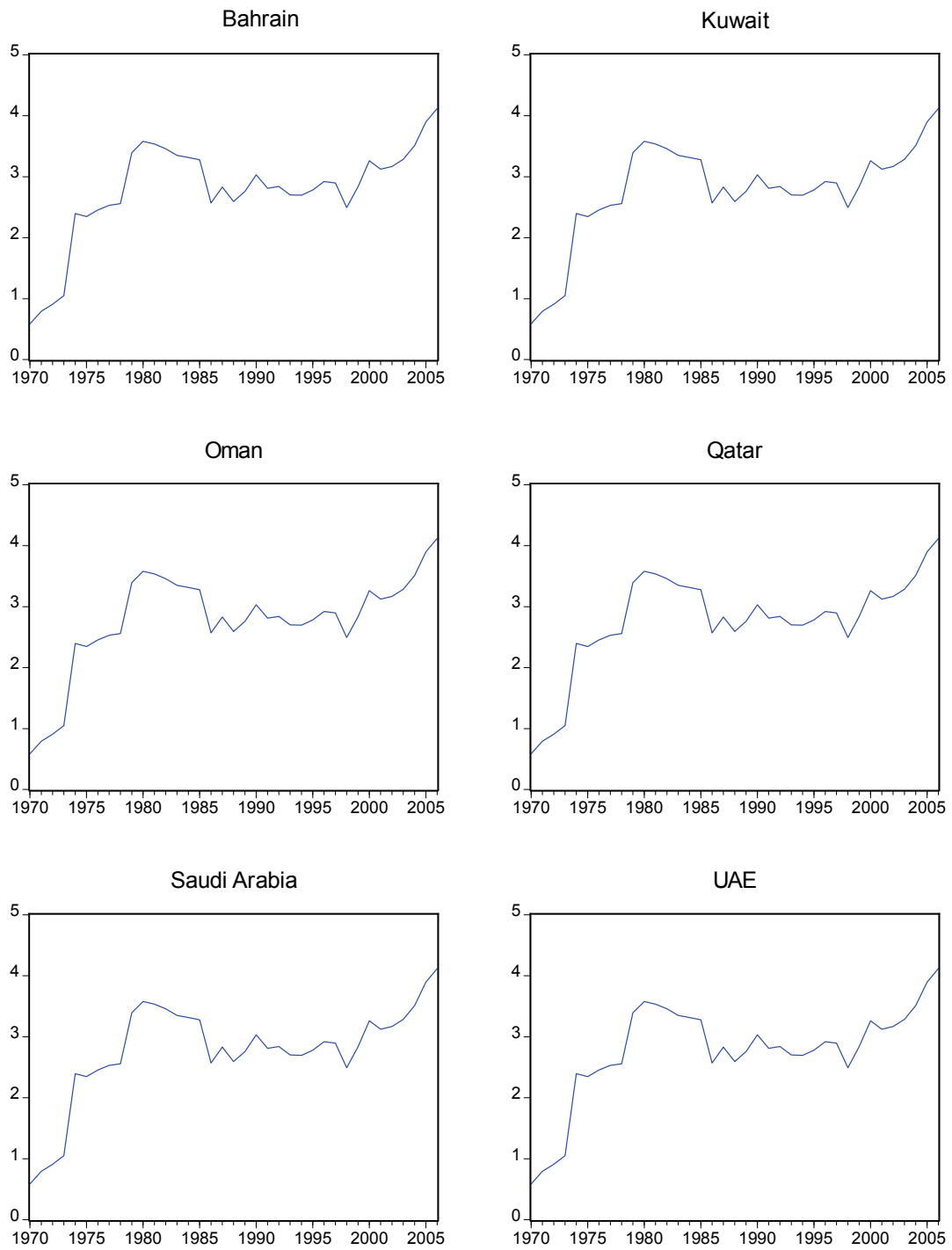


Figure 8: Log GDP Deflator

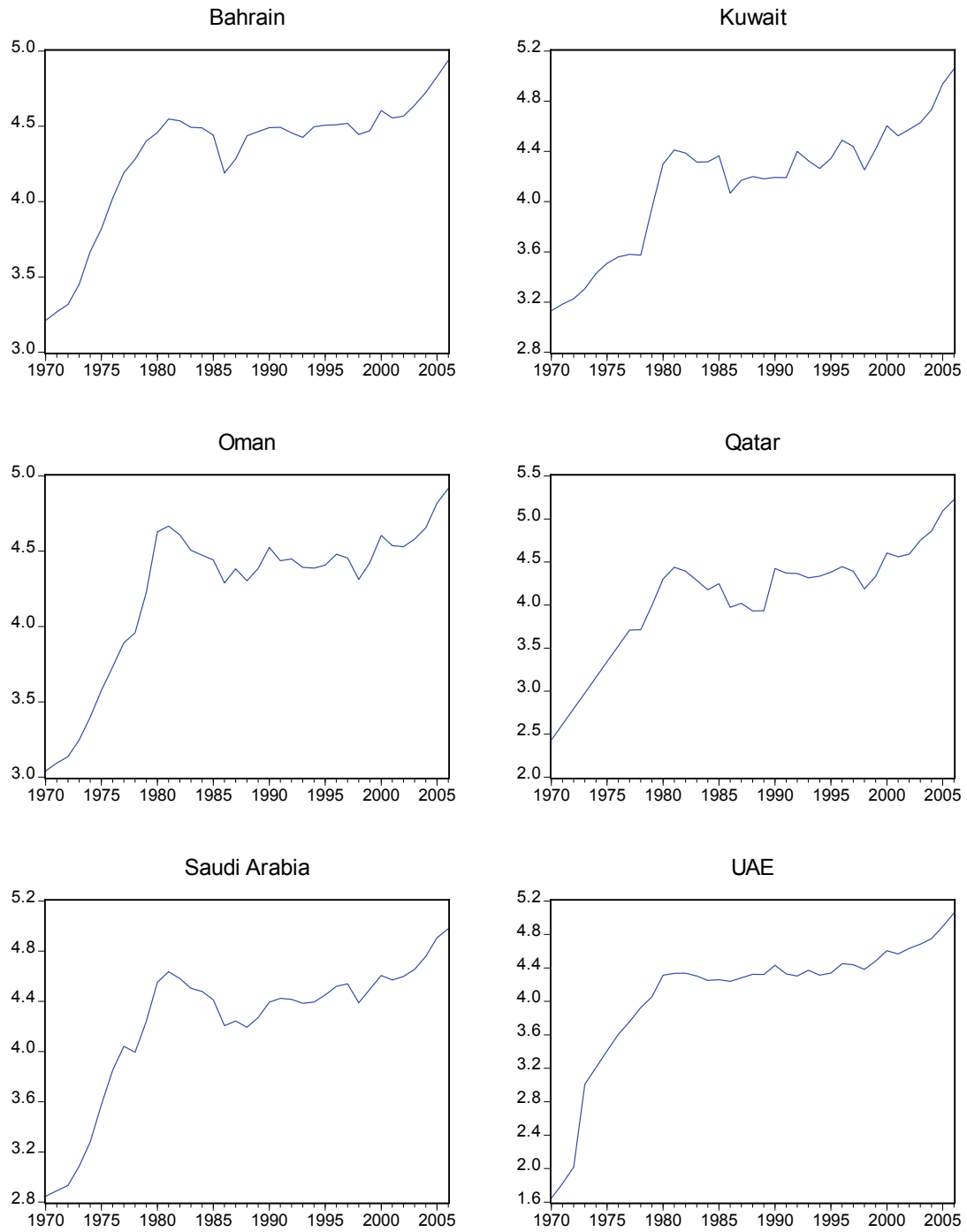


Figure 9: Log Productivity Differential

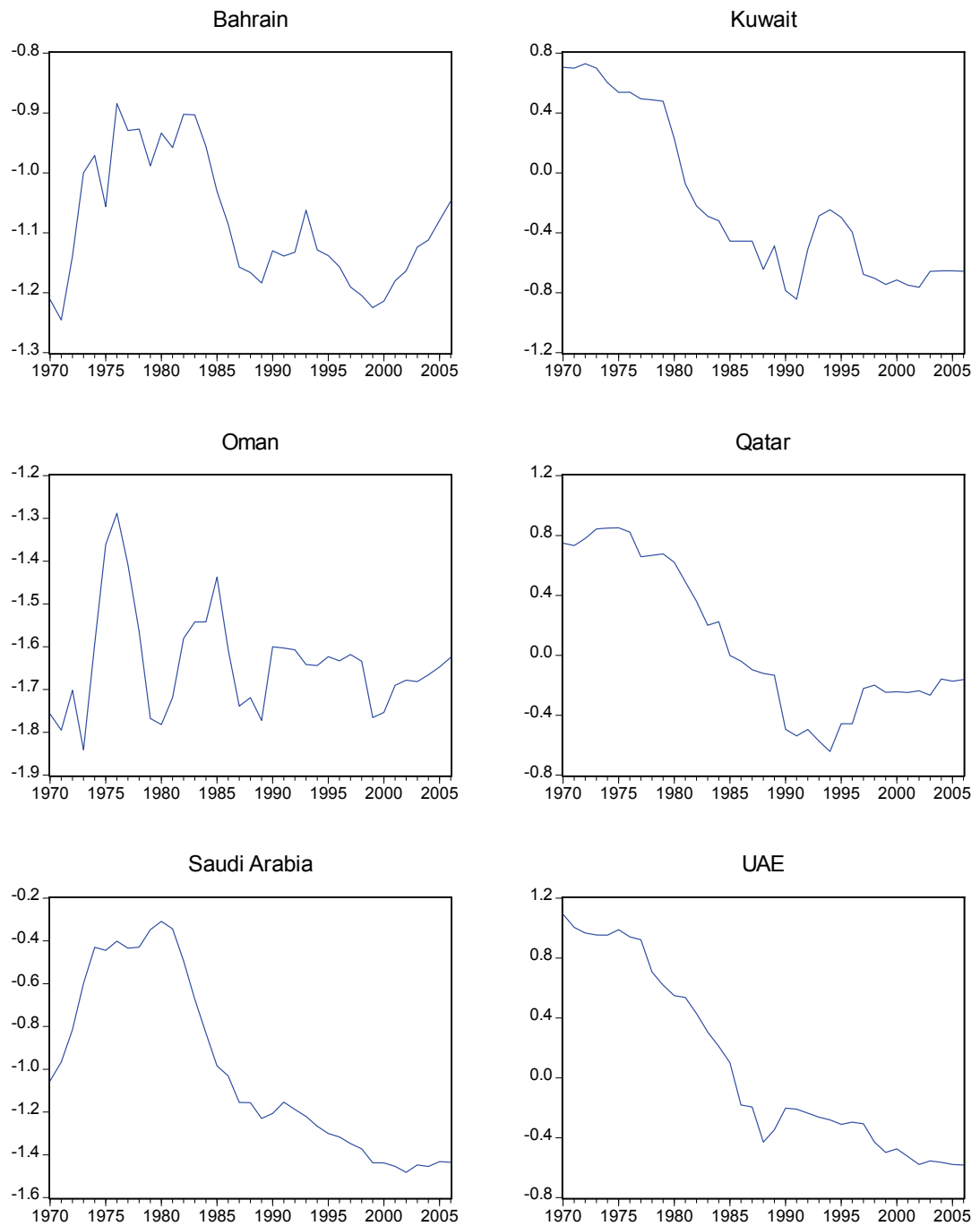


Figure 10: US Real Money Balances

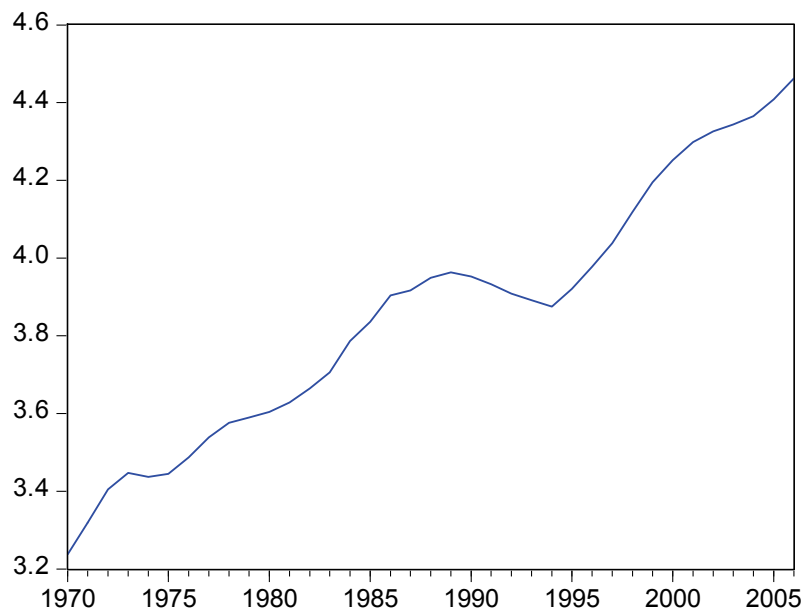


Figure 11: Log US Real GDP

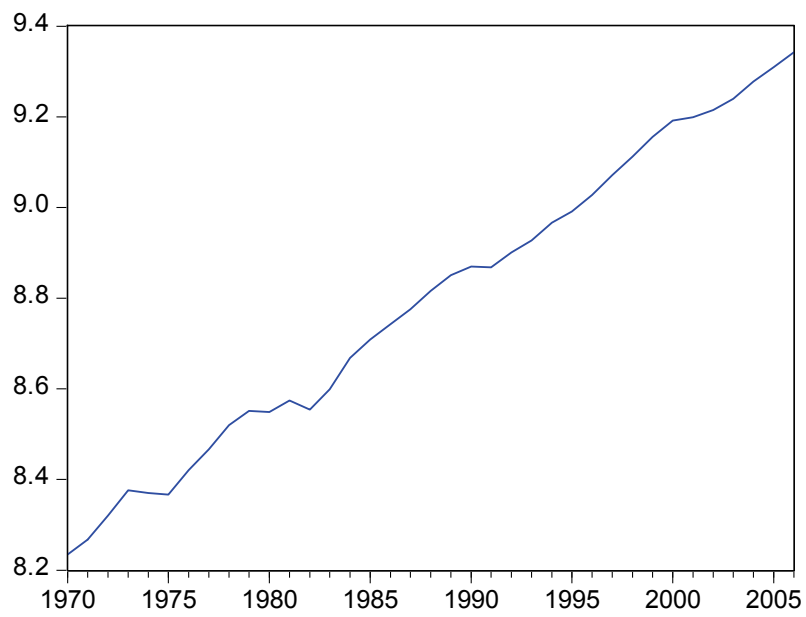
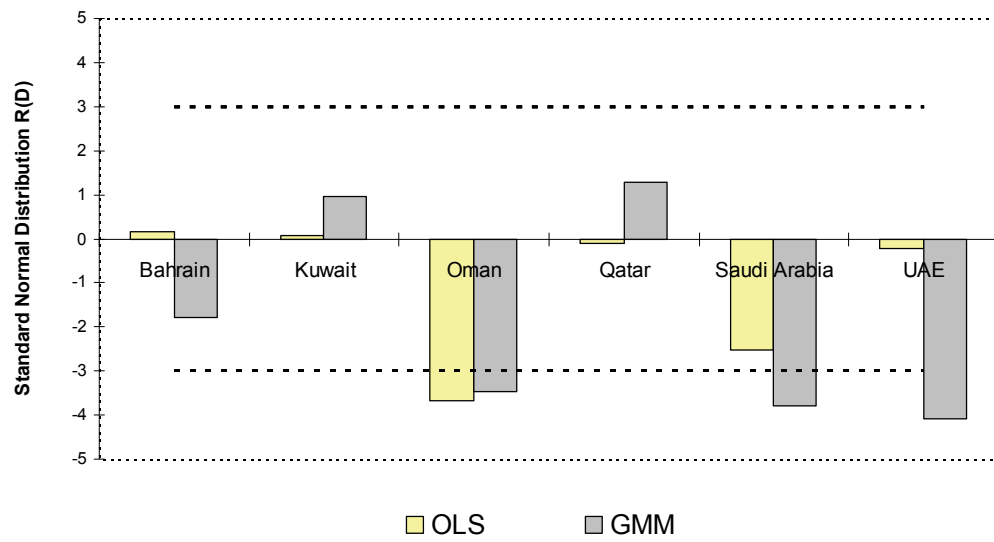


Figure 12: Multivariate Test Statistic for Conditional Sample Generalized Variance



Appendix 1: Data

Variable	
s	Nominal exchange rate defined as the domestic price of a unit of a foreign currency (increase means depreciation)
p	Domestic GDP deflator (2000=100)
p^*	Foreign GDP deflator (2000=100)
$\hat{p}$	Domestic CPI (2000=100)
q	$s + p^* - p$
m	Domestic money plus quasi money
m^*	Foreign money plus quasi money
tot	Term of trade index (2000=100)
$\hat{d}$	Tradable good productivity differential with the GCC trading partners
y	Domestic expenditure side real GDP (production side GDP is not available)
y^*	Foreign expenditure side real GDP
p^o	Dubai price of oil in US dollars deflated by the last period CPI
R^*	The 90-day real interest rate measured by the 90-day rate minus last period inflation rate as a proxy for expected inflation

Source: IMF database, IMF-IFS and the World Economic Report. Data are available upon request.

Appendix 2: Residuals Matrix

$$\begin{aligned}
 [BAH] & \begin{bmatrix} \Delta q \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta(m-p) \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta p \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta y \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \\
 [KWT] & \begin{bmatrix} \Delta q \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta(m-p) \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta p \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta y \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \\
 [OMN] & \begin{bmatrix} \Delta q \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta(m-p) \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta p \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta y \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \\
 [QTR] & \begin{bmatrix} \Delta q \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta(m-p) \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta p \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta y \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \\
 [SAD] & \begin{bmatrix} \Delta q \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta(m-p) \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta p \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta y \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \\
 [UAE] & \begin{bmatrix} \Delta q \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta(m-p) \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta p \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix} \begin{bmatrix} \Delta y \\ \mathcal{E}_1 \\ \vdots \\ \mathcal{E}_{35} \end{bmatrix}
 \end{aligned}$$

BAH=Bahrain; KWT=Kuwait; OMN=Oman; QTR=Qatar; SAD=Saudi Arabia; and UAE=United Arab Emirates.

```
/*SAS – IML code to computes the Sample Generalized variance for a system of 4
variables and the test statistic  $\sim$  Gamma then converts to S Normal (q1)*
/* Paper: On the GCC Currency Union"*/
```

```
%macro razzak(dataset=A, Variables= RESID07 RESID8 RESID9 RESID10, K=6,
S=34);
proc iml;

use &dataset;

read all into x var {&variables};

k=&k; /*-number of samples-*/

s=&s; /*- sample size which is denoted n in the paper-*/

p=ncol(x); /*-number of variables-*/

n=nrow(x); /*-total number of observation=k*s -*/

b=j(s,1,1);

j=(p-1)*(p-2)/(2*s);

scale=(p/2)*(1-j)##(1/p);

shape= p*(s-p)/2 ;

start qc;

do h=s to n by s;

gp=x((h-s+1):h,);

mgp=gp(:,);

if h=s then xb=mgp; else xb=xb//mgp;

cssg=gp-(mgp@b);

ssg=(cssg`*cssg);

covg=(cssg`*cssg)/((s)-1);

dcovg=det(covg);

if h=s then do ;

ssp=ssg;;dcov=dcovg ; end;
```

```

    else do ;ssp=ssp+ssg;dcov=dcov//dcovg; end;

end;

xdb=x(:,l)@b;

b=j(k,1,1);

cov=ssp/(n-k);/* this is a S bar matrix (see your notes)*/

dsbar=det(cov);

gamma=((s-1)*p)*(dcov/dsbar)##(1/p);

y=gamma/scale;

gamma=probgam(y,shape);

xdb=x(:,l)@b;

t2=(s*diag((xb-xdb)*inv(cov)*(xb-xdb`)))(l,+);

sample=(1:k);

colchr={'Z1' 'Z2' 'Z3' 'Z4' 'Z5' 'Z6' 'Z7' 'Z8' };

u=probchi(t2,p);

q=probit(u);

u1=probgam(y,shape);

/* The R(D) statistic in the paper */

q1=probit(u1);

output2=output2//((sample`||gamma||u1||q1);

colchr2={'Sample' 'Gam' 'u1' 'Q1'};

output=output//((sample`||t2||u||q||dcov);

colchr1={'SAMPLE' 'T SQUARE' 'U' 'Q' 'DET S'};

*print cov(|colname=colchr rowname=colchr|);

* print output(|colname=colchr1|);

* print output2(|colname=colchr2|) ;

```

```

create p0 from output(|colname=colchr1|);

append from output;

close p0;

create p1 from output2(|colname=colchr2|);

append from output2;

close p1;

finish ;

start main;

run qc;

finish;

run main ;

quit;

proc print data=p0;
title2'IML OUTPUT Dataset=P0';
run;

proc print data=p1;
title2'IML OUTPUT Dataset=P1';
run;

%mend;
%razzak(dataset=A , variables=RESID07 RESID8 RESID9 RESID10, k=6,s=34);

```

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