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Rzigui, Lotfi

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Source of Output dynamics in USA vs. Great Britain: supply, demand or nominal shocks

Lotfi RZIGUI *
(URDEE)

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Abstract

The purpose of the present paper is to extend Clarida and Gali (1994) from structural specification to common trend specification and to study the relative importance of nominal, supply and demand shocks in relative output dynamics. Using their long run restrictions for given cointegration vectors, we can identify number of permanent shocks assumed to affect long run dynamics of real activity and estimate the common trend model. From the estimated model we analyze source of output dynamics in USA vs. Great Britain during 1950-2004. The common trend analysis indicates that supply shock is more important than others shocks to explain real activity dynamics and confirms stylized fact of real business cycle theory.

Key words: Supply Shock, Demand Shocks, Nominal Shocks, Output Dynamics, Common Trend Model

JEL classification: C32; E32; F41

* URDEE Faculté des Sciences économique et de Gestion de Sfax 3029, Tunisie. rzigui_lotfi@yahoo.fr

I. Introduction

A fundamental problem in economics is to explain behavior of real activity and study the source of GDP dynamics. The idea is to identify empirically the forces that govern economic fluctuations. The motivation is to evaluate the relative importance of real versus demand or nominal shocks in the variation of real GDP. Analysis of sources of economic fluctuation and impulsion mechanisms has been well researched in business cycle literature. For examples, theoretical studies include papers by King et al (1988), Blanchard and Quah (1989), King et al (1991), Gali (1999). This theory assumes that economic fluctuations are governed by supply shocks, especially productivity and technological shocks. Other recent studies by Baxter (1994), Benassy (1995), Hairault (1999), and Collard (1999) have attempted to introduce nominal, demand and fiscal shocks to study business cycle.

To account various shocks transmission and to quantify their effect on economic activity we need to consider appropriate framework. Shocks propagation has been examined by means of several empirical models, ranging from vector autoregression model, structural VAR and common trend model. VAR and SVAR models cannot be used to examine a large number of shocks and they can't account both permanent and transitory component of time series. We attempt, in this paper, to use Clarida and Gali (1994) specification and their long run restrictions extended from structural representation to common trend representation.

The main contribution of the present paper is to extend Clarida and Gali (1994) from structural specification to common trend specification and to study the relative importance of nominal, supply and demand shocks in GDP dynamics. Using their long run restrictions for given cointegration vectors, we can identify number of permanent shocks assumed to affect long run dynamics of real activity. So we use non stationarity and cointegration tests to identify and estimate common trend model. This paper is organized as follows. Section II presents a stylized theoretical model of Clarida and Gali (1994) and gives its short and long run equilibrium implications. Section III extends this model from structural specification to common trend specification. Section IV summarizes empirical estimation, shocks identification and result. Section V concludes.

II. Theoretical model

The model is a stochastic version of Mundell-Fleming-dornbusch and focuses on short and long run output – price – nominal exchange rate dynamics. The model assumes the presence of price rigidity in short run and money neutrality in long run. Except of interest rate, all variables are in natural logarithms and represent home relative to foreign levels, as in Clarida and Gali (1994). The model can be written as follows:

$$y_t^d = d_t + \eta (s_t - p_t) - \sigma (i_t - E_t(p_{t+1} - p_t)) \quad (1)$$

$$p_t = (1 - \theta) E_{t-1} p_t^e + \theta p_t^e \quad (2)$$

$$m_t^s - p_t = y_t - \lambda i_t \quad (3)$$

$$i_t = E_t(s_{t+1} - s_t) \quad (4)$$

Where y^d denotes demand output, d_t is the demand shocks, s_t is the nominal exchange rate, p_t is the relative price of output, $E_t(p_{t+1} - p_t)$ is the relative inflation rate expected in t , i_t is the relative interest rate, p_t^e is the flexible price level and m_t^s is the money supply. Equation (1) is an open economy IS equation in which the demand for home output to foreign output is increasing in the real exchange rate and a relative demand shock, and decreasing in the real interest rate differential in favor of home country. Equation (2) is the price setting equation. According to (2), the relative price level in period t is weighted average of the expected market clearing price and price that would actually clear the output market in period t . equation (3) is LM equation and equation (4) is an interest parity condition.

Before solving the model, Clarida and Gali (1994) specify the stochastic processes that drive the relative supply of output, the relative demand shock and relative money. They refer to these processes by three structural shocks: supply shock, demand shock and nominal shock, and they assume random walk for supply of output and relative money while the demand shock has a permanent and a transitory component. These stochastic processes are given by:

$$y_t^s = y_{t-1}^s + \varepsilon_t^s \quad (5)$$

$$d_t = d_{t-1} + \varepsilon_t^d + \gamma \varepsilon_{t-1}^d \quad (6)$$

$$m_t = m_{t-1} + \varepsilon_t^m \quad (7)$$

Where $\varepsilon_t^s, \varepsilon_t^d$ and ε_t^m are assumed to be iid mean-zero innovations. The long run rational expectation flexible price equilibrium of the model is written as follows:

$$y_t^s = y_t^e \quad (8)$$

$$q_t^e = \frac{y_t^s - d_t}{\eta} + \frac{\lambda \gamma \varepsilon_t^d}{(1 + \lambda)(\eta + \varepsilon_t^d)} \quad (9)$$

$$p_t^e = m_t - y_t^s + \frac{\lambda \gamma \varepsilon_t^d}{(1 + \lambda)(\eta + \varepsilon_t^d)} \quad (10)$$

In the long run, the level of output is not affected by either nominal and demand shocks. The level of real exchange rate is not affected by nominal shock. These three restrictions imply a triangular representation of the system.

Clarida and Gali (1994) then solve the model for the short run with price adjustment. They conclude, contrary to the flexible price equilibrium, that not only supply shocks but also demand and nominal shocks affect relative output in the short run. In deed, a positive supply shocks increase output. A positive demand or nominal shocks create a temporary increase in output¹.

III. Empirical model

The model helps to main purposes. First, the model explicit specification of several shocks that could be source of economic fluctuations of output – price – real exchange rate. Second, long run restrictions on the structural specification are imposed to identify these shocks. Clarida and Gali (1994) assume the Wold representation of the dynamic equations system:

$$\Delta X_t = \delta + C(L)\varepsilon_t \quad (11)$$

¹ Short run equilibrium conditions are not reported here, the interested reader may find further details concerning analytical frame work in Clarida and Gali (1994).

Where $X_t = (y_t, q_t, p_t)$ is a vector of I(1) endogenous variables, $C(L)$ is a matrix polynomial in the lag operator L and $\varepsilon_t = (\varepsilon_t^s, \varepsilon_t^d, \varepsilon_t^m)$ is a vector of shocks that are serially uncorrelated with $E[\varepsilon_t] = 0$ and $E[\varepsilon_t \varepsilon_t'] = \Sigma$. Using Taylor theorem, they can separate out the long run dynamics as follows²:

$$\Delta X_t = \delta + C(1)\varepsilon_t + (1-L)\tilde{C}(L) \quad (12)$$

$C(1)$ contains the long run multipliers. Similar to Blanchard and Quah (1989), Clarida and Gali (1994) impose long run restrictions on $C(1)$ ³ and estimate a structural vector autoregression.

If we develop equation (12) we obtain:

$$X_t = X_0 + \delta t + C(1)\sum_{j=0}^{\infty} \varepsilon_{t-j} + \tilde{C}(L) \quad (13)$$

Equation (13) is the multivariate version of Beveridge-Nelson decomposition. King et al (1987, 1991) and Warne (1993) derived this representation to obtain the called "Common Trend representation"⁴:

$$\begin{aligned} X_t &= X_0 + A\tau_t + \tilde{C}(L)\varepsilon_t \\ \tau_t &= \mu + \tau_{t-1} + \varphi_t \end{aligned} \quad (14)$$

To determine how to estimate the common trend model, we assume that X_t is generated by the vector autoregressive of order p .

$$A(L)X_t = \rho + \varepsilon_t \quad (15)$$

If X_t in (15) is cointegrated of order (1, 1) with r cointegration vectors, we know from Granger's representation theorem that: $\text{rank}[A(1)] = r$ and $A(1) = \alpha\beta'$ ⁵. The matrix α and β are of dimension $N \times r$, β is the matrix of cointegrating vectors. Under the assumption of cointegration,

² Where $\tilde{C}(L)$ satisfies $(1-L)\tilde{C}(L) = C(L) - C(1)$.

³ Blanchard and Quah (1989) identification assume that only permanent supply shocks can affect the long run level of output. The tradition of identification is always used by empirical studies to identify supply shock.

⁴ Warne (1993) make algorithm to estimate the called representation and give a Gauss code to estimate model.

⁵ See Engle and Granger (1987) and Johansen (1988)

an alternative form of (15) is known as the vector error correction model and $C(1)$ has a reduced rank⁶. In fact, from (14) and (13) we can find that the equality of the trend components imply that⁷:

$$A\phi_t = C(1)\varepsilon_t, \quad AA' = C(1)\Sigma C(1)' \quad \text{and} \quad A\mu = C(1)\delta$$

To identify common trend model, we need to estimate the matrix A and Σ . While Σ can be estimated directly from (15), King et al (1991) and Warne (1993) note that matrix A estimation require some theoretical restrictions on the long run matrix $A0$ ⁸.

IV. Empirical result

The data for this study is annual beginning from 1950 and ending in 2004. The relative output and price is defined as the ratio of home (USA) to foreign (Great Britain) real GDP and consumption price index (CPI). The corresponding GDP and CPI data for both countries were obtained from GGDC database⁹. Real exchange rate is approximated by Great Britain Market rate index (line 15) and provided from the IMF's international statistics.

1. Specification tests

Since basic shocks have a permanent component, the Clarida and Gali's theoretical model imply that all three variables are non stationary in levels but stationary in first differences. An additional implication of the model is that the relative output, the real exchange rate and price are not cointegrated¹⁰. Before estimating the model, the data need to be examined for nonstationarity and possible cointegration relationships. We first checked for stationarity of the variables by means of the augmented Dickey Fuller test (ADF) with show that all three series are treated as integrated processes¹¹.

⁶ Under cointegration restrictions $rank[C(1)] = N - r$

⁷The trend component in (13) is given by $\delta t + C(1)\sum_{j=0}^{\infty} \varepsilon_{t-j}$. See Warne (1993) for proof

⁸ King et al (1991) identify the long run matrix as: $A = A_0\Pi$, where A_0 is $(N \times k)$ matrix and Π is $(k \times k)$ matrix. We impose restrictions on A_0 matrix

⁹ Groningen Growth and Development Centre and The Conference Board, Total Economy Database, , January 2005, <http://www.ggdc.net>

¹⁰ Same assumption is used by Prasad (1999) to study response of international trade to these three shocks. This assumption is justified by the fact that the long run dynamics of the systems are governed by different shocks.

¹¹ Results from ADF tests are not reported in the paper, they are available from the authors.

Cointegration analysis is carried out using Johansen tests. Three lags of each variables are included on the basic of diagnostic tests show that residual are serially uncorrelated. Both trace and max-eignvalue tests suggest the existence of one cointegration vector at 1% and 5% level of significance, the results are given in table 1. This is in conflict with the underlying model of Clarida and Gali (1994) which assumes that there are three stochastic trends in the data. RBC models that focus solely on supply shocks (productivity shocks) would also not the case. In our case we assume that supply and demand shocks have permanent effects on the system¹².

Table 1: Johansen Cointegration tests

<i>H2</i>	λ_{trace} <i>statistics</i>	λ_{max} <i>statistics</i>	<i>5%</i> <i>Critical value</i> λ_{trace}	<i>1% critical</i> <i>value</i> λ_{max}
$r = 0$	37.67958	29.17161	24.31	17.89
$r \leq 1$	8.507974	8.217922	12.53	11.44
$r \leq 2$	0.290052	0.290052	3.84	3.84

2. shocks identification and estimations results

In the CT frame work as outlined by King et al (1987-1991) and Warne (1993), the existence of one cointegrating vector among three variables implies the presence of two permanent shocks affecting the system and interpreted here as supply shock and demand shock. Using Blanchard and Quah (1989) and Clarida and Gali (1994) long run restrictions, we can specify supply shock (productivity shock) as having long run effect on domestic variables.

CT estimation necessitates restrictions on long run matrix $A0$, some of these restrictions are cointegration restrictions. Other restrictions are imposed according to economic theory. These assumptions imply that: $a2 = 0$ and $\beta'A0 = 0$. The long run matrix is written as follow:

$$A0 = \begin{pmatrix} a1 & 0 \\ a3 & a4 \\ a5 & a6 \end{pmatrix} \quad (16)$$

Consider X_t the vector containing all three variables. The cointegrating vector presented in the order (y_t, q_t, p_t) is given by:

¹² Using Clarida and Gali's long run restriction we can assume that nominal shock has transitory effect on the system.

$$\hat{\beta} = \begin{pmatrix} 1.0000 \\ -2.68568 \\ 2.20338 \end{pmatrix}$$

Using A0 specification and Johansen cointegrating vector we can write the common trend representation¹³ as presented bellow. The estimated coefficient of matrix A are positive and statistically significant in response to demand shock. A positive supply shocks increase relative output, decrease relative price and leads to depreciate exchange rate. With respect to long run flexible price equilibrium, the common trend model expects that solely supply shocks affect relative output.

$$X_t = \begin{pmatrix} y_0 \\ q_0 \\ p_0 \end{pmatrix} + \begin{pmatrix} 0.01348 & 0.00000 \\ (0.0038) & - \\ -0.01744 & 0.034014 \\ (0.0163) & (0.0101) \\ -0.02737 & 0.04145 \\ (0.0209) & (0.0123) \end{pmatrix} \begin{pmatrix} \hat{\tau}_{st} \\ \hat{\tau}_{dt} \end{pmatrix} + \tilde{C}(L)\hat{\varepsilon}_t \quad (17)$$

$$\begin{pmatrix} \hat{\tau}_{st} \\ \hat{\tau}_{dt} \end{pmatrix} = \begin{pmatrix} 0.578536 \\ -0.021341 \end{pmatrix} + \begin{pmatrix} \hat{\tau}_{st-1} \\ \hat{\tau}_{dt-1} \end{pmatrix} + \hat{\varphi}_t$$

3. Impulse responses

We begin by studying the estimated impulse responses of the estimated common trend model. Figures 1, 2 and 3 present the impulse responses functions of the levels of the system in the response to one standard deviation of supply, demand and nominal shocks respectively. Figure 1 indicates that supply shock immediately raises the level of real activity. A positive demand or nominal shocks create temporary increase in level of relative output. These results of relative output are similar to those reported in some real business cycle model and confirm those of Clarida and Gali (1994).

As shown by figures 1, 2 and 3, supply shock leads to depreciate real exchange rate, reflecting the reduction in the price level. Demand shock generates a permanent rise in level of relative price and an appreciation of the real exchange rate. Finally, figure 3 shows that similar

¹³ Estimation has been carried out using the CT Rats package of Warne and Hansen. Data and model estimation are available from the authors.

inflationary effects (a temporary increase in real activity and price and exchange rate appreciation) are produced by a positive nominal shock

These results are comparable to some other studies in which structural vector autoregression is used to estimate a system of the same quarterly or monthly data. These include Prasad (1999) and Filosa (2004). Our results are more encouraging than those of Detken et al (2002). According to them, the various shocks do not affect the level of real activity and price or on exchange rate. Their effect has the opposite sign to that expected by Clarida and Gali (1994).

Figure 1: Impulse responses to a supply shock

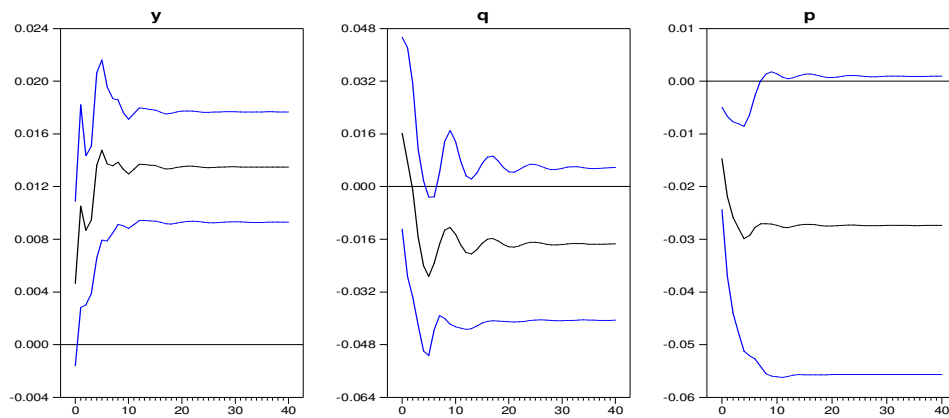


Figure 2: Impulse responses to a demand shock

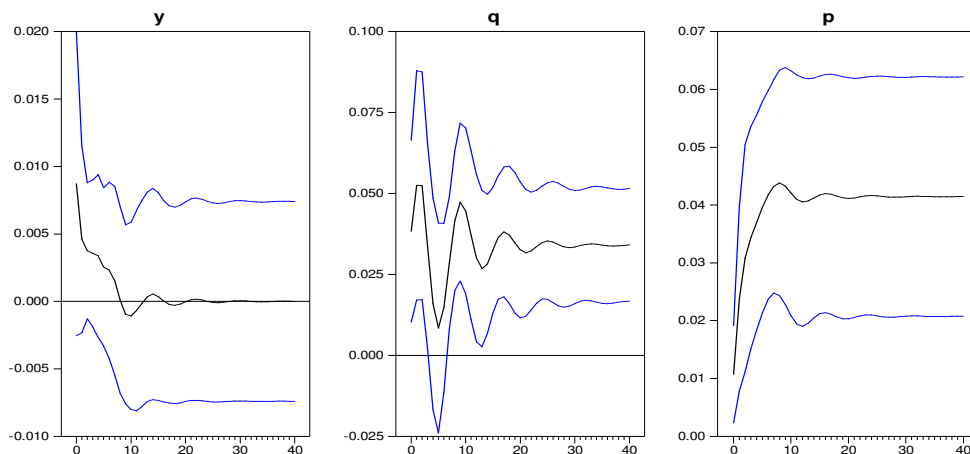
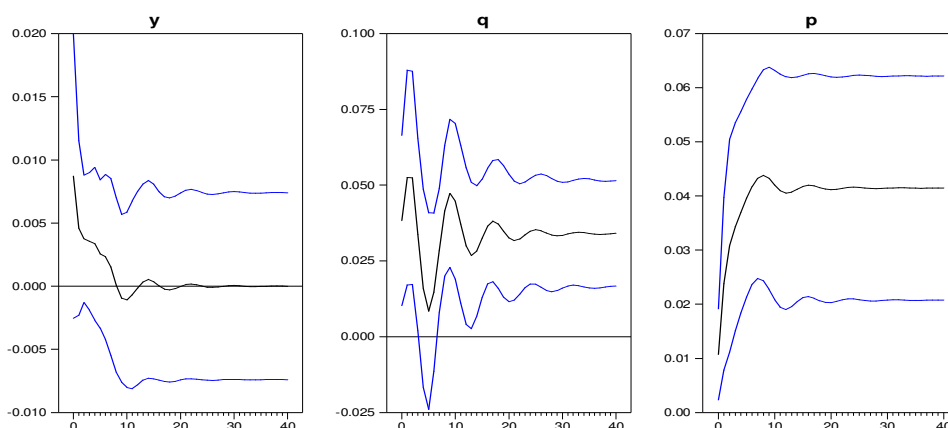


Figure 3: Impulse responses to a nominal shock



4. Variance decompositions

The relative importance of macroeconomic shocks to explain variation in economic activity is checked by computing the forecast error variance decomposition from the CT representation. Variance decompositions provide information on the role played by different shocks on the three series at different horizons. The results are presented in Table 2. The table presents the percentage of the variance of the k -years-ahead forecast error of particular variable that is due to each of the shocks, for $k = 1, 3, 7, 10, 20, 30, 40$.

An examination of the variance decomposition of real GDP reveals the predominance of supply shock in explaining real economic activity. This result is also confirmed by responses functions to shocks. Table 2 shows that contribution of supply shocks is higher than those of demand and nominal shocks for 3 horizons after a shock. Indeed, supply shock contributes from 48.9% third horizon to 96.2% for fortieth horizons to GDP dynamics. By contrast, almost none of the variation of real output is explained by non-monetary and monetary shocks at medium run horizons. Supply shocks therefore not only govern real activity dynamics in the long run, but they are also important for short and medium run output fluctuations.

In one hand, the results of the relative output dynamics are very similar to those of real business cycle theory. On the other hand, this result disagrees with neo-Keynesian theory which advocates that at least in the short run output should be due to demand shock innovations. The result that supply shocks are the most important factor for variation of relative GDP is confirmed

by many other studies. These studies include Ahmed et al (1993), Clarida and Gali (1994), Prasad (1999), Filosa (2004)...

Demand shock is important to explain about two thirds of real exchange rate dynamics. On the other hand, supply shock (nominal shock) contributes to this dynamics in the range of 10-20 (5-35) percent. Relative price fluctuation is governed by supply and demand shocks for short and long horizons. Nominal shock hasn't any effect on variation of relative price. This justifies the fact that monetary shock has a transitory effect on the system and contradicts Clarida and Gali (1994). These differences are due to our model specification concerning cointegration.

In conclusion, our results reveal the predominance of supply shock to drive economic activity fluctuations. Demand shock as well as supply shock is important in explaining real exchange rate and relative price dynamics. Nominal shocks can not affect the dynamics of the system; this is due to the fact that monetary shock is transitory shock in our specification.

TABLE 2: Variance decompositions of the three variables

<i>Variance Decompositions of the level of relative output</i>			
<i>Year (s) ahead</i>	<i>Supply shock</i>	<i>Demand shock</i>	<i>Nominal shock</i>
1	11.5	40.7	47.7
3	48.9	26.2	24.9
7	77	12.8	10.2
10	84.3	8.8	6.9
20	92.3	4.3	3.4
30	94.9	2.9	2.2
40	96.2	2.1	1.7

<i>Variance Decompositions of the level of real exchange rate</i>			
<i>Year (s) ahead</i>	<i>Supply shock</i>	<i>Demand shock</i>	<i>Nominal shock</i>
1	9.6	53.6	36.8
3	10.4	62.4	27.2
7	17.4	62.3	20.3
10	17.7	69	13.3
20	17.6	73.5	8.9
30	18.7	75	6.3
40	19.2	75.9	4.9

<i>Year (s) ahead</i>	<i>Supply shock</i>	<i>Demand shock</i>	<i>Nominal shock</i>
1	63.4	34	2.6
3	44.5	53.2	2.4
7	38	61.1	0.9
10	34.1	65.3	0.6
20	32.1	67.6	0.3
30	31.5	68.3	0.2
40	31.2	68.7	0.1

V. Conclusion

In this paper we analyze output dynamics in USA vs. Great Britain during 1950-2004 using common trend model in which cointegration constraints are imposed. Our concerns are if there are shocks with permanent effect on relative output, and what the source of these shocks may be. To study these questions we follow the restrictions made by Clarida and Gali (1994) and Blanchard and Quah (1989). Using Johansen (1988) cointegration tests we can assume that only supply and demand shocks affect long-run dynamics. Examining impulse-response functions and variance decompositions, we conclude that supply shock govern short and long run dynamics of real activity. Demand shock, as well as supply shock, can affect relative price and real exchange rate (inflationary effect). As expected by cointegration restrictions, nominal shock can not affect any variables.

Our results confirm stylized fact of real business cycle theory concerning long run effect of supply shock and contradict neo-Keynesian prediction concerning response of relative output to nominal or demand shocks at short horizons. Clarida and Gali stylized facts are confirmed by our econometric specification except of those of non cointegration and nominal shock effect.

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