Technology Shock and the Business Cycle in the G7 Countries: A Structural Vector Error Correction Model

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Abstract

This paper investigates the importance of technology shock in explaining fluctuations over business cycles and its contractionary effects. Applying the SVEC model on quarterly data of G7 countries and accounting for long cycles in hours worked, there is evidence of a decline in employment as measured by hours worked and investment following a positive technology shock. Hours worked show a persistent decline in France and UK, and this lasts for seven years in Italy, three years in Japan, two years in the USA and Canada; and one year in Germany. However, our findings suggest that technology shocks may play only a limited role in deriving the business cycles in the G7 countries; for they only account for under 30 percent of the business cycle variation in hours and investment, under 35 percent of the business cycle variation in consumption, and under 50 percent of the business cycle variation in output of most of the G7 countries. Our findings do not support the conventional real business cycle interpretation; instead, they are consistent with the predictions of the sticky-price model.

JEL classification: E32, E24

Key words: Business cycle, G7, sticky-price model, SVEC, technology shock

1 Introduction

Technology-driven business cycles have been at the forefront of macroeconomic research. The interest has switched from sample correlations among macroeconomic time-series to conditional correlations to identify a counter-cyclical behaviour of factor inputs following a technology shock.

Solow (1957) defines technological change as the change in output that is not due to the weighted growth in inputs. As pointed out by Prescott (1986), the Solow residual measures the rate of technological progress. Moreover, substantial fluctuations in measured total factor productivity indicate that the economy's ability to convert inputs into outputs varies substantially, and this puts in evidence the important role of technological disturbances as a source of business cycle fluctuations (Mankiw 1989). The corrected measure of technology has been adopted by a number of researchers of which Basu, Fernald and Kimball [BFK] (2006) and Miyagawa et al. (2006).

For the New Keynesian theorists, fluctuations arise from a mixture of aggregate demand shocks and the shocks to fiscal policy or animal spirits (Mankiw 1989). On the other hand, the classical view of economic fluctuations assume that the rate of technological change is random (Shapiro and Watson 1988). Moreover, the Neo-Keynesian approach suggests that macroeconomic fluctuations are mostly related to monetary shocks while the Neo- classical relates it to technological shocks. Accordingly, as pointed out by Carmen and Vincent (1991), a neo-classical-Keynesian framework describes the dynamics of output better than the alternative framework that accords no role to monetary shocks.

There is a plethora of studies on fluctuations in the macroeconomic variables. Some of the scholars attribute these fluctuations to technology shocks. Other studies attribute the changes in macroeconomic variables to monetary shocks. The results of the previous studies lead to a conclusion that the RBC model does not reflect the evidence drawn from the data. A positive technology shock results in a contraction of hours worked as exemplified in the works of Canova, Lopez-Salido and Michelacci (2010), and Gali (1999) for the majority of the G7 countries. These results, however, are consistent with the models with imperfect competition, sticky prices, and variable effort, as also confirmed in different studies such as Francis and Ramey (2005) and Gali (1999), among others.

The majority of studies done so far focus on the US data and make use of the Structural Vector Autoregression (SVAR) methodology. This paper applies the Structural Vector Error

Correction (SVEC) model to analyse contractionary effects of technology shocks on the business cycle in the G7 countries. The SVEC methodology allows to take into consideration the co-integrating relationships between variables. Our research has another advancement on the existing literature since we incorporate monetary variables in our analysis.

2 Previous Research

Using quarterly US data from 1951:1 to 1987:2**,** Shapiro and Watson (1988) investigate the sources of business cycle fluctuations in the US economy. They find three important facts: technological change accounts for roughly one-third of output variation; adverse technological shocks are not an important factor in recessions except for the recession in 1970; and favourable technology shocks play an important role in explaining the strong growth in 1960.

Gali (1999) employs a structural VAR to investigate the effects of technology shocks on business cycle fluctuations in US data covering the period from 1948:1 to 1994:4. Results from a bivariate model suggest that technology shocks induce a high and statistically significant negative correlation between productivity and employment. Applying the bivariate VAR to the G7 countries, Gali (1999) finds the same results except for Japan.

Similary, Kawamoto and Nakakuki (2005) using non-manufacturing in addition to manufacturing data, and Miyagawa et al. (2006) using quarterly data both find a negative response of hours to a positive technology shock in Japan. The latest work by Tancioni and Giuli (2012) examines the contractionary effects of technological shocks in US data. Their results confirm the standard theoretical prediction that supply shocks are expansionary in the long run. On the other hand, Lindé (2004) argues that the fact that hours worked drop while productivity rises after a permanent technology shock cannot be taken as evidence against the RBC model of US business cycles. Allowing for the possibility that the technology shock is slightly correlated over time in growth terms, Lindé (2004) asserts that the standard RBC model can produce a substantial fall in hours worked along with a reasonable rise in labour productivity after a positive permanent production shock. Furthermore, empirical findings of positive technology shocks causing hours worked to fall cannot be used as evidence in support of NK models per se, instead, such findings likely relate to important rigidities such as ‘habit formation and investment adjustment cost’, which may cause hours to shrink as a result of technological improvement even when prices are flexible (Sims 2012).

Christiano, Eichenbaum and Vigfusson [CEV] (2003), based on Canadian and US annual data, point out that hours worked rise after a positive technology shock. But, they argue that the difference in results comes from the way hours worked are incorporated in the statistical analysis. Indeed, Canova et al. (2010) assert that the response of hours worked appears to depend on a number of statistical assumptions, including the treatment of long cycles in hours, the lag length of the empirical model and the horizon at which the identifying restrictions are imposed.

3 Data and Methods

3.1 Data Source, Variable Definition and Unit Root Tests

Our analysis is performed on hourly productivity, consumption, investment, inflation rate, hours worked and the nominal short term interest rate. The series expand from the second quarter of 1980 to the fourth quarter of 2012 except for Germany, whose series are limited to 1992-2012 period. All these series were collected from the Organization for Economic and Cooperation and Development (OECD) economic outlook. The definitions of the variables are based on the OECD glossary of Statistical terms. Details on data transformation are provided in Appendix.

Unit root tests are performed to identify the order of integration of the series. Two tests are applied-the augmented Dickey Fuller test (ADF), which constructs the null hypothesis of a unit root against the alternative of stationarity, and the KPSS (1992) that tests the null hypothesis of stationarity against the alternative of a unit root. Results are reported in Appendix.

3.2 The SVEC Methodlogy and Model Specification

Consider the initial Structural Vector Autocorrelation model (SVAR) of the form:

$$\mathbf{A}_0\mathbf{y}_t = \sum_{i=1}^{p} \mathbf{A}_i^{*}\mathbf{y}_{t-i} + \mathbf{B}\boldsymbol{\varepsilon}_t \tag{1}$$

where $\mathbf{B}$ is the matrix of structural shocks. The relationship between the reduced form errors and structural errors is as follows:

$$\mathbf{u}_t = \mathbf{A}_0^{-1}\mathbf{B}\boldsymbol{\varepsilon}_t$$
$$\mathbf{A}_0\mathbf{u}_t = \mathbf{B}\boldsymbol{\varepsilon}_t$$

According to Granger representation theorem (Engle and Granger 1987), when economic variables are co-integrated I (1) processes, the system has a reduced rank and there exists an appropriate error correction model. Moreover, Following King et al. (1991), the Structural Error Correction Model (SVECM) whose structural formulation for the endogenous variables $Y' = [y_t \ \text{dp h}_t \ \text{r c}_t \ \text{i}_t]$ is specified under the assumption that there are no contemporaneous correlations among variables and the SVECM, is derived from the SVAR as presented in equation (1):

$$\mathbf{A}_0 \Delta \mathbf{y}_t = \Pi^* y_{t-1} + \sum_{i=1}^{p-1} \Gamma^* \Delta \mathbf{y}_{t-i} + \mathbf{B}\boldsymbol{\varepsilon}_t$$

Given that the structural form cannot be estimated, a reduced form is provided below:

$$\Delta \mathbf{y}_t = \Pi y_{t-1} + \Gamma \Delta y_{t-1} + u_t \quad (2)$$

$$\Pi = A_0^{-1} \Pi^*$$

Where $\Gamma_i = A_0^{-1} \Gamma_i^*$

$$u_t = A_0^{-1} B \varepsilon_t$$

$\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t}, ..., \varepsilon_{mt})'$ is the structural shocks matrix, and is normally distributed with mean zero and variance covariance matrix $\sum m \times m$. u_t is the reduced form matrix of innovations that have no direct interpretation. The equation $u_t = A_0^{-1} B \varepsilon_t$ is used to relate the underlying shock of the reduced form to the structural shock ε_t . Hence, B contains the contemporaneous structure of the system including the contemporaneous correlations among variables and errors.

In the presence of co-integration, the long run matrix Π is a reduced rank matrix and can be decomposed into $\Pi = \alpha\beta'$, with α and β full column rank matrices containing respectively, the loading coefficients and the r co-integrating vectors. The vector of disturbances $\varepsilon_t \sim (0; Im)$ contains the orthonormal structural innovations. The system of linear equations relating the estimated reduced-form errors u_t to the structural shocks is thus $A_0^{-1} u_t = B\varepsilon_t$, which implies $\Omega = uu' = BB'$

3.2.1 Lag Order Selection

Taking into account the autocorrelation and high order memory, two lags are imposed on the starting VAR for Canada, UK, Japan, France and USA; three lags for Italy and four lags for Germany. These lags are, for most of the countries, different from the maximum lag order as suggested by the information criteria but France and Japan. Accordingly, for Canada, Germany and UK the imposed lag order corresponds to the maximum suggested by the Akaïke information while the Schwartz information suggests one lag. For Italy the information criteria suggests one lag and four lags according to the Schwartz and Akaïke information criteria respectively, whereas for the US two and five lags are suggested.

3.2.2 Cointegration

Johansen (1988) developed the maximum likelihood estimators of co-integrating vectors and provided the rank test to determine the number of co-integrating vectors, r. The LR trace test indicates the presence of four stationary components. The results of the rank test are reported in Appendix.

Following the order of the variables, the first two CI relations define the stationary great ratios of the economy: $c_t - \beta_{11} y_t$ and $i_t - \beta_{21} y_t$. These coefficients are significant, but only marginally consistent with the hypothesis of balanced growth theory ($\beta_{11}= \beta_{21}=-1$); the same results as in KPSW (1991). The third CI relation defines the fisher interest parity, i.e. $r - \beta_{32} dp$. The fourth CI relation relates to the stationary hours worked.

$$\beta' y_{t-1} = \begin{bmatrix} \beta_{11} & 0 & 0 & 0 & 1 & 0 \\ \beta_{21} & 0 & 0 & 0 & 0 & 1 \\ 0 & \beta_{32} & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} y_{t-1} \\ dp_{t-1} \\ h_{t-1} \\ c_{t-1} \\ r_{t-1} \\ i_{t-1} \end{bmatrix} = \begin{cases} \beta_{11} y_{t-1} + c_{t-1} = z_{1t-1} \\ \beta_{21} y_{t-1} + i_{t-1} = z_{2t-1} \\ \beta_{32} dp_{t-1} + r_{t-1} = z_{3t-1} \\ h_{t-1} = z_{4t-1} \end{cases} \quad (3)$$

3.2.3 Identification of the SVMA Representation

As in Gali (1999), Francis and Ramey (2005), and CEV (2003), the assumption underlying this study is that the only type of shock that affects the long-run level of average labour productivity is a permanent technology shock. However, as pointed out by CEV (2003), it is important to note that there exist models in which this assumption is not satisfied, like in the 'endogenous growth model, where all shocks affect productivity in the long run and in an otherwise standard model when there are permanent shocks to the tax rate on capital income'.

In this respect, the structural vector moving average (SVMA) is used to verify the effect of the technology shock on the subsequent variables. We provide the impulse response functions (IRFs) and Forecast Error Variance Decompositions (FEVDs).

Below is the Beveridge-Nelson SVMA representation of the SVECM:

$$y_t = C(1)\sum_{i=1}^{t} B\varepsilon_i + C^0(L)B\varepsilon_t + \tilde{y}_0 \qquad (4)$$

Where $C(1)$ refers to the long-run effects matrix, and $C^0(L)$ is a convergent infinite order polynomial for the impact and interim multipliers of the shocks. Since the system has r transitory components (stationary components) and m-r permanent components (no-permanent stochastic trends), the matrix $C(1)$ B has r zero columns and m-r non-zero columns because they have long-term effects different from zero only for relationships outside the CI space.

From the underlying relationship of the shock of the reduced and the structural form, the number of identifying restrictions must be equal to the number of variables squared, i.e., m*m to achieve exact identification; SVAR automatically uses m (m+1)/2 by setting the covariance matrix for the structural shocks to the identity matrix. The remaining m(m-1)/2 restrictions are imposed on the matrix of contemporaneous relations and the long run matrix. (m-r)r =8 restrictions are imposed on the matrix of the long run effects. In addition, as only technology shocks have permanent effects on productivity, an additional restriction is imposed on $C(1)$ B matrix, with the element C_{12} equal to zero.

$$C(1)B = \begin{bmatrix} C_{11} & 0 & 0 & 0 & 0 & 0 \\ C_{21} & C_{22} & 0 & 0 & 0 & 0 \\ C_{31} & 0 & 0 & 0 & 0 & 0 \\ C_{41} & C_{42} & 0 & 0 & 0 & 0 \\ C_{51} & 0 & 0 & 0 & 0 & 0 \\ C_{61} & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The remaining six restrictions r(r-1) /2 are imposed on the matrix B of contemporaneous relations. The latter are based on the theoretical speculation that is valid for the short term. With respect to the order of the variables: $Y_t' = \left[y_t \ \mathrm{dph}_t \ \mathrm{rc}_t \ \mathrm{i}_t \right]$ the matrix of contemporaneous relations with four co-integration relations is provided below:

$$B = \begin{bmatrix} B_{11} & B_{12} & B_{13} & B_{14} & B_{15} & B_{16} \\ B_{21} & B_{22} & B_{23} & B_{24} & B_{25} & B_{26} \\ B_{31} & B_{32} & B_{33} & B_{34} & B_{35} & B_{36} \\ B_{41} & B_{42} & 0 & B_{44} & B_{45} & B_{46} \\ B_{51} & B_{52} & 0 & 0 & B_{55} & B_{56} \\ B_{61} & B_{53} & 0 & 0 & 0 & \beta_{66} \end{bmatrix}$$

3.3 Stability and Autocorrelation Tests

For a model to be stable, the roots of the characteristic polynomial must lie outside the unit circle. According to Blanchard and Kahn(1980) technique, the condition of stability states that if the number of roots outside the unit circle are equal to the number of variables in the expectations then there exists a unique balance (equilibrium saddle path); if the number of roots outside the unit circle exceeds the number of variables in the expectations then the model has no stable solution, and if the number of roots outside the unit circle is smaller than the number of variables in the expectations then there exists an infinity of solutions and hence the equilibrium is indeterminate. For all countries under study, the eigenvalues of the companion matrix confirm the stability of the model as shown in Appendix.

To test for autocorrelation, two tests are performed, the LM-type test statistic for which the null hypothesis is the absence of autocorrelation in the residuals against the alternative that residuals follow a VAR of order twelve, and the Ljung-Box-type test statistic for which the null hypothesis is that residuals are serially uncorrelated against the alternative of 14th order residual correlation. Results are reported in Appendix.

4 Results and Discussion

SVEC-based results are summarized using impulse response functions (IRFs) and the Forecast Error Variance Decompositions (FEVD).

4.1 SVEC-based IRFs

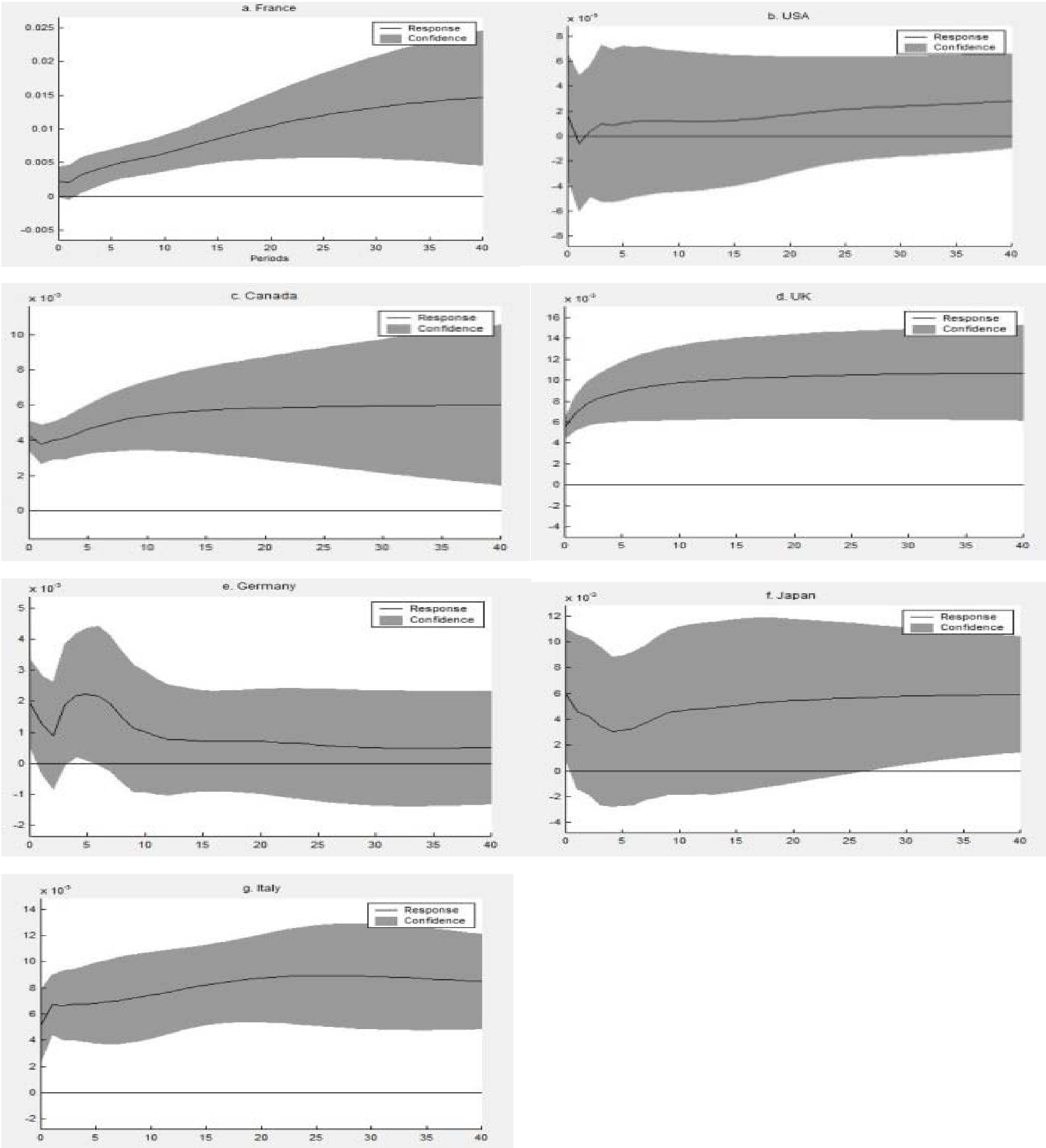

Fig. 1 IRFs for Output

Figure 1 displays the impulse response functions of output to a one standard deviation productivity shock for the seven countries under study. There is an initial increase in output of nearly 0.21 for France, 0.16 for US, 0.42 for Canada, 0.55 for UK, 0.12 for Germany, 0.59 for Japan, and 0.51 percent above the baseline for France, US, Canada, UK, Germany, Japan and Italy. After only one quarter, output gathers pace for US, Canada and France; and increases in the following 25 quarters for France, 23 quarters for US and 10 quarters for Canada to a level about 1.4, 1.5 and 0.5 percent respectively , higher than the base line and thereafter follows that new equilibrium.

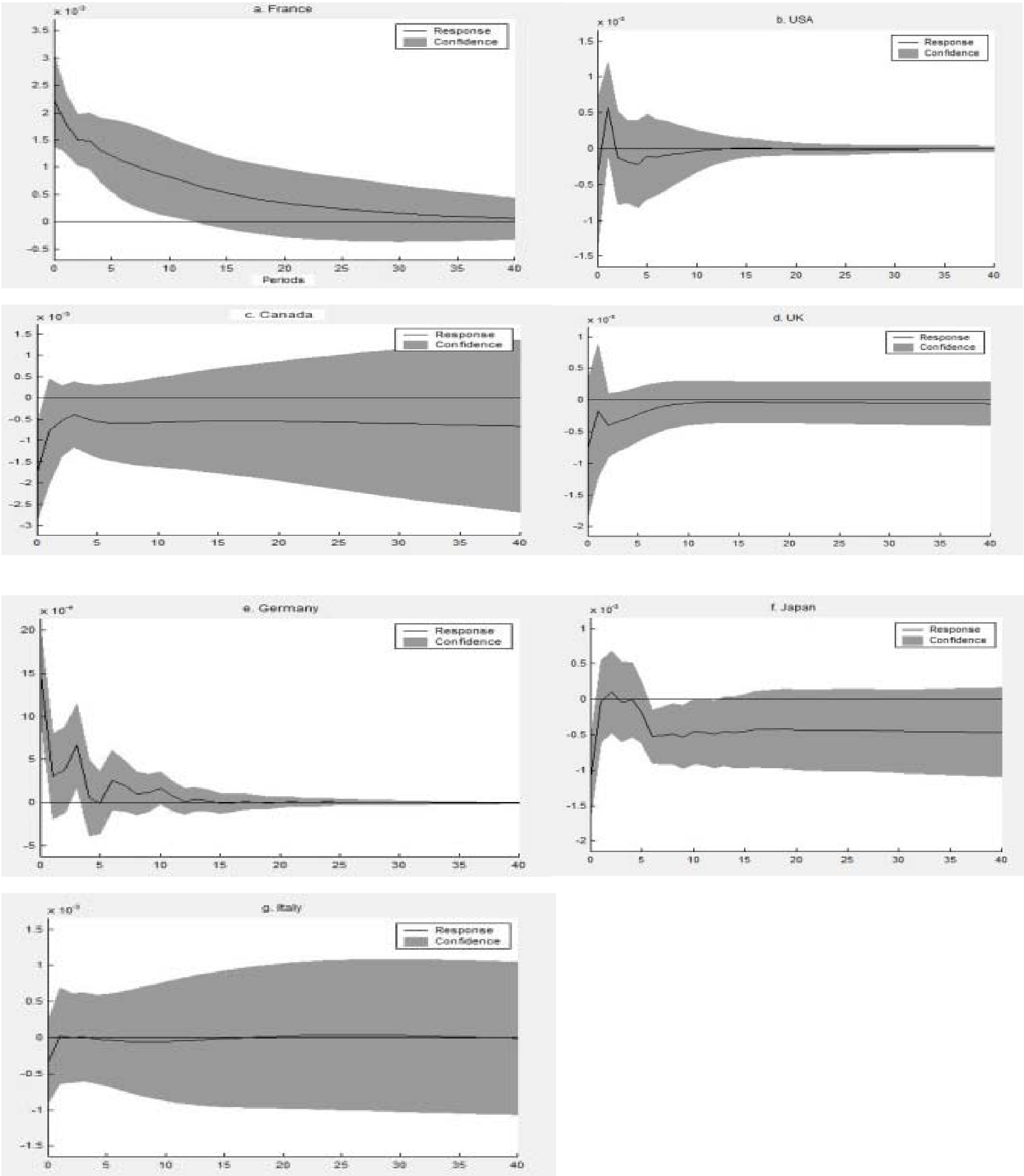

Fig. 2 IRFs for Inflation rate

The inflation rate response to a one standard deviation technology shock is depicted in Figure 2. Inflation rate decreases for all countries but Germany and France. The impact for Italy does not last long, it dies after only two quarters suggesting that the monetary policy reaction offsets the effect of the increase in productivity after two quarters. While for Germany it takes about twelve quarters to die, Japan inflation response gets to the base line after about two quarters and decreases again to reach its new equilibrium value after four more quarters. Canada gets to its new equilibrium only after four quarters. France's inflation response is positive on impact and goes on decreasing, and in the long-run the inflation rate approaches its initial value.

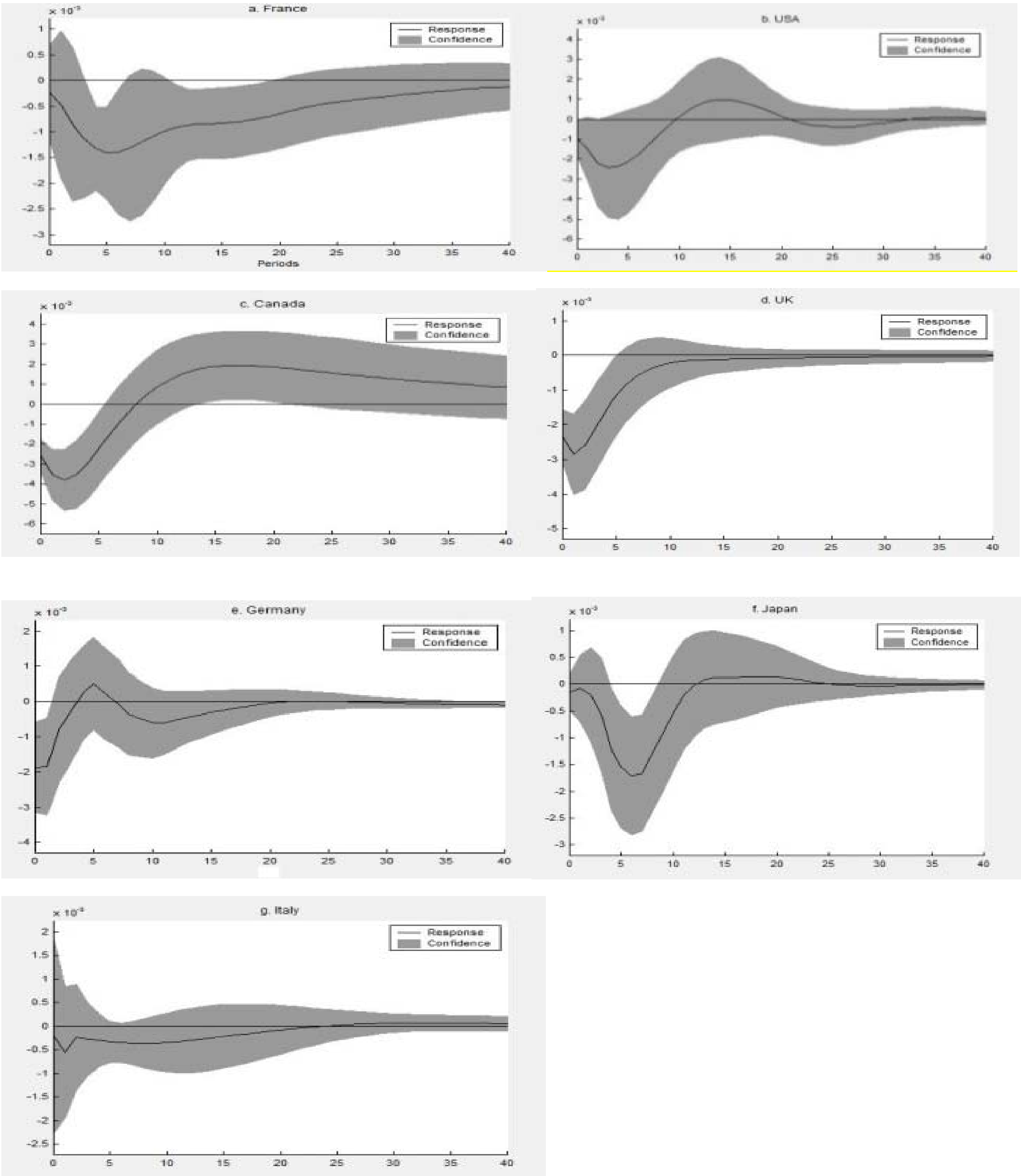

Fig. 3 IRFs for Hours Worked

The responses of hours worked to one standard deviation technology shock are illustrated in Figure 3. Similarly to the findings by Gali(1999), Gali and Rabanal (2004), and Tancioni and Giulia(2012), hours decline in a hump shaped pattern immediately after a supply shock, peaking at nearly four quarters for France and US; two quarters for Germany, Italy, UK and Canada;

and six quarters for Japan. After the short-run impact, labour input gradually adjusts upward, returning to its original level but for UK and France, the negative effect is persistent. These results are in line with the findings of Gali (1999).

The negative response of hours worked following a positive technology shock may be explained by factors such as nominal frictions combined with certain monetary policies, and real explanations. Accordingly, employment experiences a short run decline in response to a positive technology shock "unless the central bank endogenously expands the money supply in proportion to the increase in productivity" (Gali and Rabanal 2004).

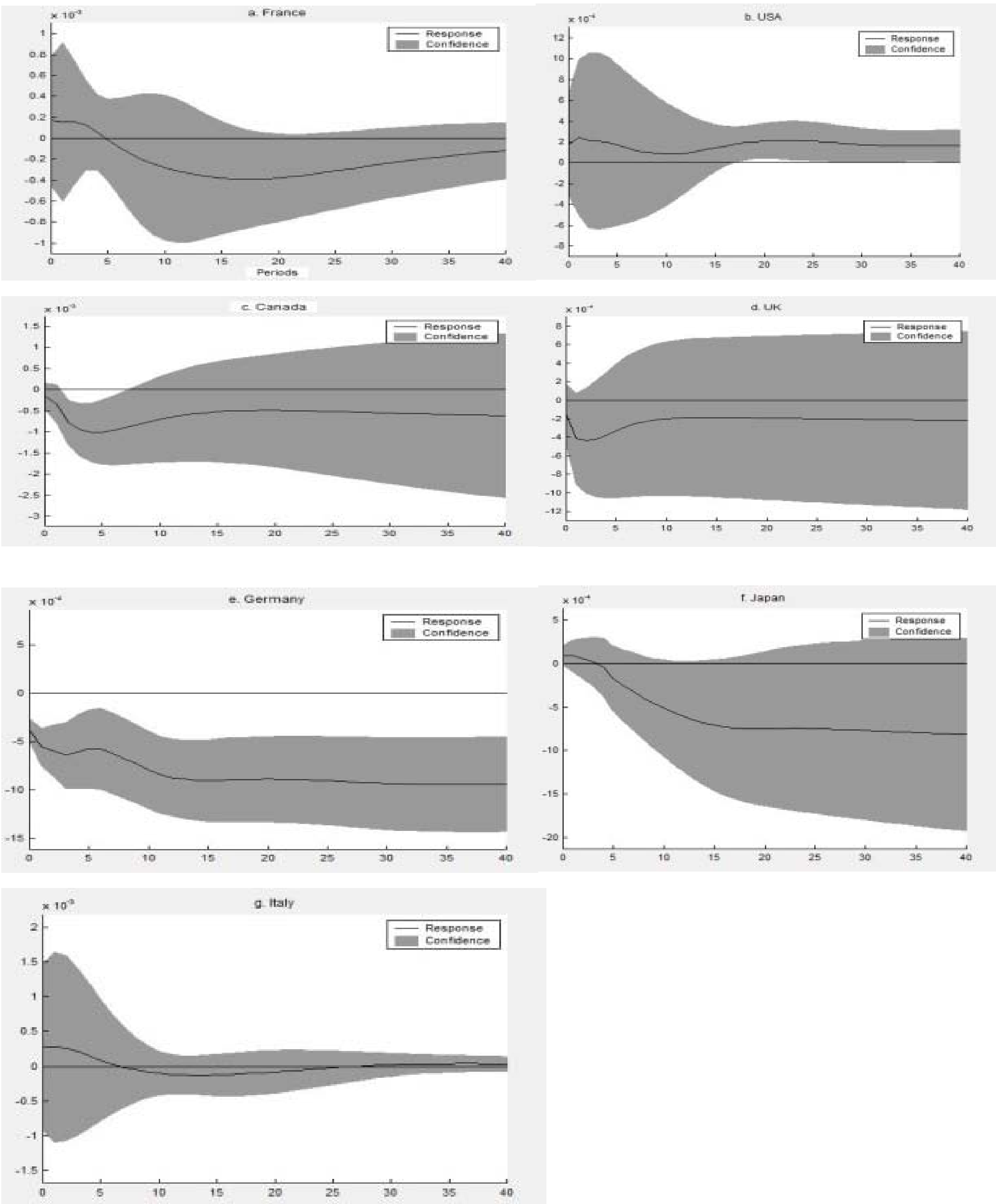

Fig. 4 IRFs for Nominal Interest Rate

In Figure 4, France, US, Japan and Italy interest rates rise following a positive productivity shock while Canada, UK and Germany experience a decline. The effect dies in Italy nearly after the 25th quarter, implying that in the long run the technology improvement does not affect the central bank decision and in the US the effect is positive and persistent. Overall, the response in nominal interest rates denotes the gradual accommodation, confirming the inertia displayed by monetary policy.

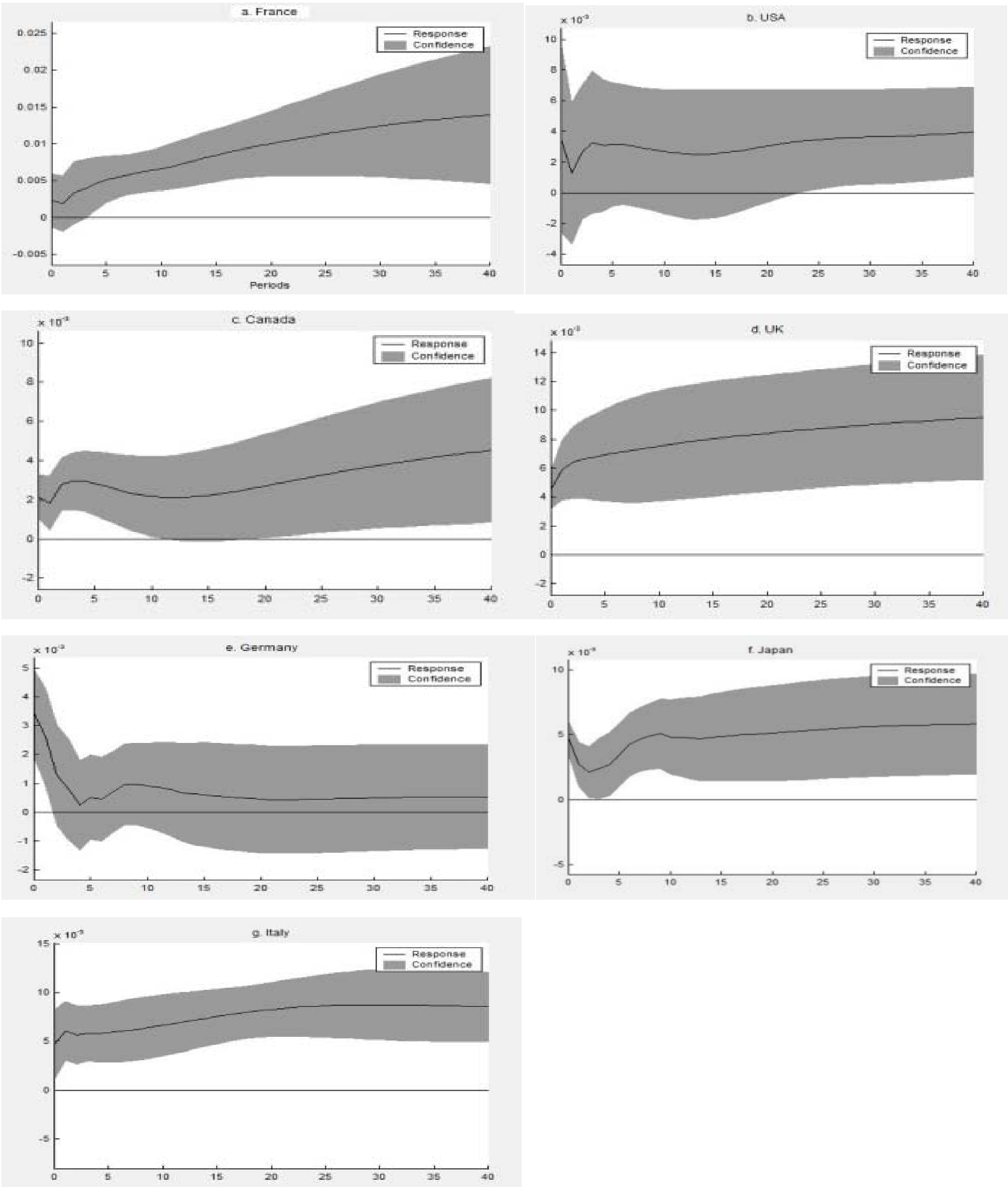

Fig.5 IRFs for Consumption

Figure 5 depicts the responses of consumption to a one standard deviation technology shock. Both the impact and the long-run responses of consumption are positive for all the G7 countries. The impact responses are 0.21, 0.23, 0.32, 0.47, 0.47, 0.45 and 0.35 percent above the base line, for Canada, France, Germany, Italy, Japan, UK and USA respectively.

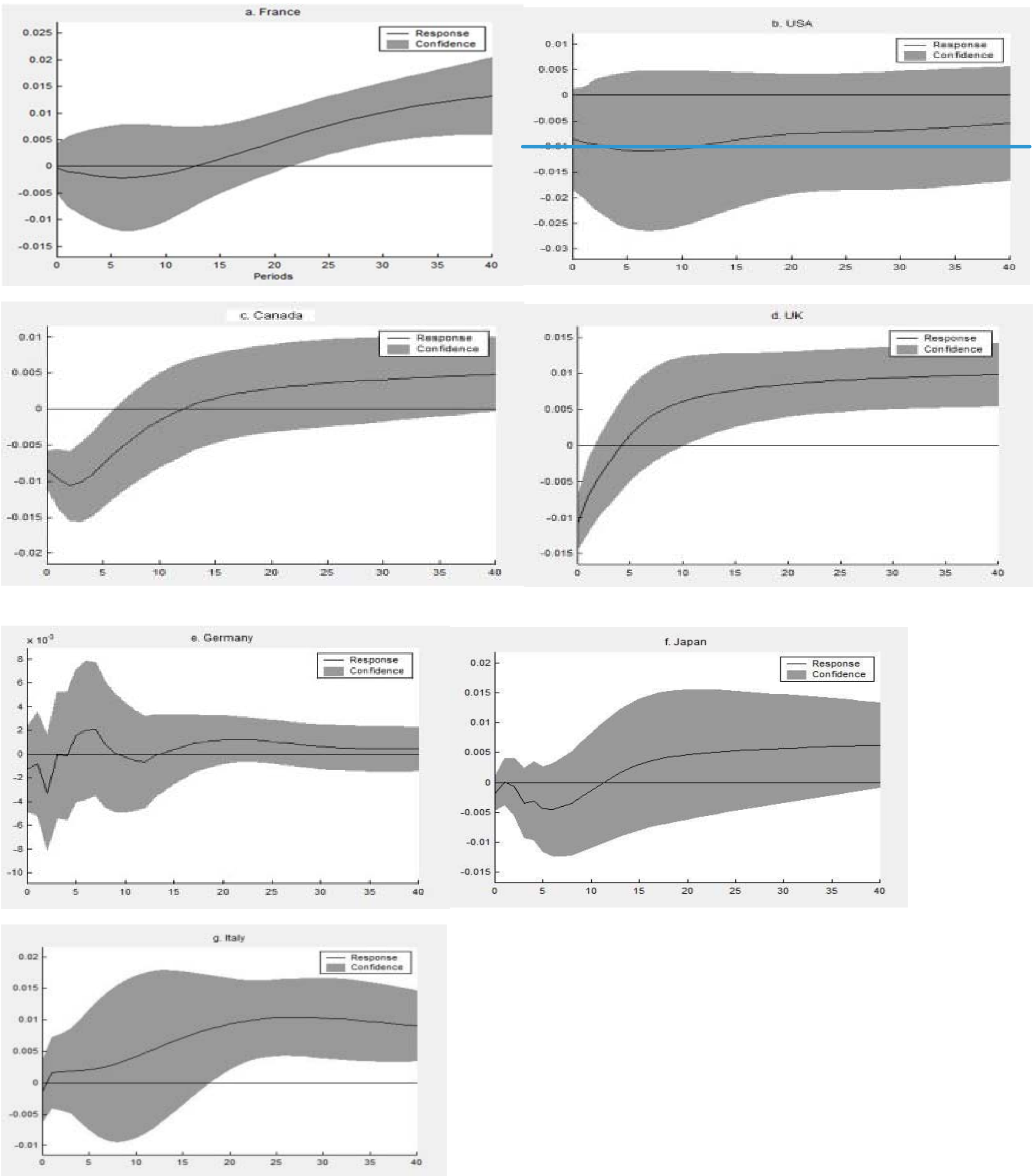

Fig. 6 IRFs for Investment

Figure 6 shows the responses of investment to one standard deviation productivity shock. On impact, the investment response to a positive productivity shock is negative for all the countries under consideration. However, while France, Canada and Japan impulse responses estimate crosses the zero line after twelve quarters, the USA impulse response does not cross. For all the countries, except UK, investment shows a hump-shaped short-term negative response denoting a slow convergence to its long-run value.

The long-run responses of real variables (output, consumption and investment) are positive, confirming the standard theoretical prediction that supply shocks are expansionary in the long-run. Furthermore, the short-term responses of output and consumption are consistent with the predictions of standard business cycles. Consumption grows on impact more than output in USA, Germany and France, signalling that the interpretation of the productivity-employment puzzle based on flexible price models with a relevant rigidity in consumption (Francis and Ramey 2005; Smets and Wouters 2007) is not supported by the data.

4.2 The Forecast Error Variance Decompositions

Variance decomposition breaks down the proportion of the variability that resulted from the shock of the variable and the variability that is the result of shocks in other variables. Table1 shows the fraction of FEV attributed to a positive productivity shock in the G7 countries. Few periods are highlighted to capture the contribution in the short, medium and long-run.

Table 1 Variance Decompositions

Periods	France						USA						Canada						UK				
	yt	**dp**	**Ht**	**r**	**ct**	**it**	**yt**	**dp**	**ht**	**r**	**ct**	**it**	**yt**	**dp**	**ht**	**r**	**ct**	**it**	**yt**	**dp**	**ht**	**r**	**ct**
1	0.14	0.66	0.01	0.01	0.13	0.001	0.3	0.1	0.18	0.5	0.16	0.26	0.58	0.07	0.26	0.01	0.105	0.27	0.63	0.01	0.24	0.006	0.2
4	0.23	0.76	0.06	0.01	0.22	0.01	0.1	0.4	0.19	0.4	0.16	0.28	0.62	0.06	0.27	0.08	0.168	0.22	0.66	0.02	0.26	0.03	0.3
8	0.43	0.75	0.17	0.01	0.46	0.014	0.2	0.4	0.20	0.3	0.21	0.29	0.72	0.05	0.22	0.10	0.209	0.19	0.74	0.02	0.25	0.02	0.3
12	0.58	0.74	0.20	0.03	0.60	0.014	0.2	0.4	0.18	0.3	0.22	0.29	0.80	0.05	0.20	0.09	0.209	0.16	0.80	0.02	0.25	0.02	0.4
16	0.69	0.74	0.23	0.06	0.70	0.014	0.3	0.4	0.16	0.4	0.21	0.30	0.85	0.05	0.22	0.08	0.208	0.16	0.84	0.02	0.24	0.01	0.4
20	0.78	0.74	0.25	0.10	0.78	0.03	0.3	0.4	0.16	0.5	0.22	0.30	0.88	0.05	0.23	0.08	0.218	0.16	0.87	0.02	0.24	0.01	0.3
40	0.93	0.73	0.28	0.16	0.93	0.44	0.9	0.4	0.16	0.10	0.31	0.29	0.95	0.05	0.27	0.06	0.4	0.21	0.93	0.02	0.25	0.01	0.6

Periods	Germany						Japan						Italy					
	yt	**dp**	**Ht**	**r**	**ct**	**it**	**yt**	**dp**	**ht**	**r**	**ct**	**it**	**yt**	**dp**	**ht**	**r**	**ct**	**it**
1	0.08	0.30	0.106	0.494	0.224	0.004	0.45	0.12	0.006	0.021	0.355	0.013	0.53	0.02	0.002	0.024	0.358	0.011
4	0.07	0.29	0.121	0.427	0.22	0.014	0.31	0.10	0.01	0.007	0.215	0.014	0.71	0.007	0.01	0.02	0.571	0.016
8	0.10	0.26	0.092	0.43	0.184	0.019	0.26	0.16	0.16	0.027	0.307	0.029	0.70	0.003	0.02	0.016	0.599	0.019
12	0.09	0.26	0.094	0.551	0.162	0.019	0.28	0.14	0.18	0.076	0.411	0.022	0.69	0.003	0.03	0.017	0.608	0.03
16	0.09	0.27	0.095	0.658	0.14	0.021	0.31	0.15	0.17	0.116	0.448	0.02	0.71	0.002	0.04	0.02	0.639	0.058
20	0.08	0.28	0.094	0.725	0.127	0.031	0.34	0.16	0.17	0.141	0.475	0.026	0.75	0.002	0.04	0.021	0.684	0.102
40	0.08	0.33	0.096	0.847	0.16	0.078	0.51	0.17	0.17	0.17	0.617	0.08	0.87	0.001	0.04	0.022	0.842	0.329

In Table 1 above, at the business cycle frequency of one year, after four quarters technology shocks explain 23; 10; 62; 66; 7; 31; and 71 % of variation in productivity for France, USA, Canada, UK, Germany, Japan and Italy, respectively. The portion of the variation in productivity that is explained by technology shocks increases with time and reaches 93; 90; 95; 93; 8; 51 and 87 % for the same countries after forty quarters.

The portion of variation in inflation rate accounted for by technology shocks is quite negligible in all the countries under consideration except for France. The contribution of technology shocks to the fluctuations in hours worked does not significantly change over time; after 40 quarters the technology shocks account for 28; 16; 27; 25; 10; 17 and 4 % for the same countries in their order as stated above.

It can be observed that technology shocks contribute very little to the fluctuations in nominal interest rates of most of the G7 countries, except Germany where they are the main determinants of long-run behaviour of nominal interest rate in Germany.

Technology shocks are important in determining the behaviour of consumption in the G7 countries and is particularly the main driver of the long-run behaviour in Italy, France, Japan and UK. After four quarters, the percentage of variability in consumption that is explained by technology shocks is 22 for France; 16 for USA; 17 for Canada; 35 for UK, 22 for Germany, 21 for Japan and 57 for Italy.

Finally, the FEVDs reveal the weak contribution of technology shocks in determining the fluctuations in investment for the G7 countries; technology shocks fail to explain the short, medium, and the long run behaviour of investment in Japan, Germany and France. Moreover, it explains a moderate portion in the variability of the business cycle and the long run investment in the remaining countries.

5 Conclusion

This paper sought to analyse the importance of technology shocks in explaining fluctuations over business cycles and their contractionary effects. A six variables SVEC model on quarterly data of the G7 countries was used. Assuming that only technology shocks can have permanent effects on labour productivity and accounting for long cycles in hours, we found that both employment and investment decline following technology improvement. Employment as measured by the hours worked shows a persistent decline in France and UK and this lasts for seven years in Italy, three years in Japan, two years in the USA and Canada; and one year in Germany.

However, these findings suggest that technology shocks play only a limited role in driving the business cycles in the G7 countries. And for all the variables in the model, the variability accounted for by technology shocks increases with time. Our findings do not support the conventional real business cycle theory; instead, they are consistent with the predictions of sticky-price models(Basu 1998).

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Appendices

A. Data Source and Transformation

The gross domestic product at market price(Y), Households final consumption expenditure(C), private non-residential investment(I), GPD price deflator (πY), labour force(L), total employment(N) and the treasury bill rate(TBR) were collected from the OECD-economic outlook No.93. Hourly productivity (y_t), investment (i_t) and consumption (c_t) were calculated by dividing the total quarterly hours worked ($N_t \times H_t / 4$). The labour supply was calculated dividing the total quarterly hours worked by the total available time. The total available time is the product of labour force and a constant T approximating quarterly available time. The consideration of labour supply is similar to the one used by Gali and Rabanal(2004). Labour force was used instead of the population to avoid autocorrelations that would be generated by the annual population.

Variable	Definition	Transformation
Y	Gross domestic productivity at market price	$y_t = \log\left(\frac{Y_t}{N_t \times H_t / 4}\right)$
C	Household final consumption expenditure	$c_t = \log\left(\frac{C_t}{N_t \times H_t / 4}\right)$
I	Private non- residential investment	$i_t = \log\left(\frac{I_t}{N_t \times H_t / 4}\right)$
H	Hours worked per employee, total economy	$h_t = \log\left(\frac{N_t \times H_t / 4}{L \times T}\right)$
TBR	Treasury bill rate	$r = \log\left(1 + \frac{TBR}{400}\right)$
πY	GDP price deflator	$dp = \log\left(\frac{\pi Y_t}{\pi Y_{t-1}}\right)$
N	Total employment	…
L	Labour force	…

B. Unit Root Tests

Country	Variables	Order of integration			
		ADF		KPSS	
		Constant	constant&trend	Constant	Constant&trend
Canada	yt	I(1)	I(1)	I(1)	I(1)
	dp	I(1)	I(1)	I(0)	I(0)
	ht	I(0)	I(1)	I(1)	I(1)
	r	I(0)	I(1)	I(1)	I(0)
	ct	I(1)	I(1)	I(1)	I(1)
	it	I(1)	I(1)	I(1)	I(1)
France	yt	I(1)	I(1)	I(1)	I(1)
	dp	I(0)	I(0)	I(1)	I(1)
	ht	I(0)	I(0)	I(0)	I(0)
	r	I(0)	I(0)	I(1)	I(0)
	ct	I(1)	I(1)	I(1)	I(1)
	it	I(1)	I(1)	I(1)	I(1)
Germany	yt	I(1)	I(1)	I(1)	I(1)
	dp	I(0)	I(1)	I(0)	I(1)
	ht	I(1)	I(1)	I(1)	I(1)
	r	I(0)	I(0)	I(1)	I(0)
	ct	I(1)	I(1)	I(1)	I(1)
	it	I(1)	I(1)	I(1)	I(1)
Italy	yt	I(1)	I(1)	I(1)	I(1)
	dp	I(1)	I(0)	I(1)	I(1)
	ht	I(1)	I(1)	I(1)	I(0)
	r	I(1)	I(1)	I(1)	I(1)
	ct	I(1)	I(1)	I(1)	I(1)
	it	I(1)	I(1)	I(1)	I(1)
J	yt	I(1)	I(1)	I(1)	I(1)

	dp	I(1)	I(0)	I(1)	I(0)
	ht	I(0)	I(0)	I(0)	I(0)
	r	I(1)	I(1)	I(1)	I(1)
	ct	I(1)	I(1)	I(1)	I(1)
	it	I(1)	I(1)	I(1)	I(1)
	yt	I(1)	I(1)	I(1)	I(1)
	dp	I(0)	I(0)	I(1)	I(1)
	ht	I(0)	I(0)	I(0)	I(0)
	r	I(0)	I(0)	I(1)	I(1)
	ct	I(1)	I(1)	I(1)	I(1)
UK	it	I(1)	I(1)	I(1)	I(1)
	yt	I(1)	I(1)	I(1)	I(1)
	dp	I(0)	I(0)	I(0)	I(0)
	ht	I(0)	I(1)	I(0)	I(1)
	r	I(1)	I(1)	I(1)	I(0)
	ct	I(0)	I(1)	I(1)	I(1)
USA	it	I(1)	I(1)	I(1)	I(1)

C. Cointegration Test

I (1) Analysis

France

Rank	Eigenvalues	90% quantile	Trace tests
0	0.4363	112.6500	212.4514
1	0.3834	84.3800	138.5065
2	0.2460	60.0900	76.1355
3	0.1750	39.7500	39.7022
4	0.0802	23.3400	14.8854
5	0.0313	10.6700	4.1037

USA

Rank	Eigenvalues	90% quantile	Trace tests
0	0.3656	112.6500	160.4971
1	0.1674	84.3800	102.2454
2	0.2460	54.2813	60.0900
3	0.1321	30.8253	39.7500
4	0.0727	12.6858	23.3400
5	0.0234	10.6700	3.0265

Canada

Rank	Eigenvalues	90% quantile	Trace tests
0	0.4715	112.6500	193.3417
1	0.2919	84.3800	111.0774
2	0.2438	60.0900	66.5473
3	0.1144	30.4991	39.7500
4	0.0677	23.3400	14.8331
5	0.0439	10.6700	5.7969

UK

Rank	Eigenvalues	90% quantile	Trace tests
0	0.3450	91.1100	147.5002
1	0.2709	65.8200	92.9209
2	0.1798	44.4900	52.1724
3	0.1317	27.0700	26.6097
4	0.0409	13.4300	8.3949
5	0.0231	2.7100	3.0113

Germany

Rank	Eigenvalues	90% quantile	Trace tests
0	0.4527	112.6500	137.6507
1	0.3134	84.3800	89.4291
2	0.2530	59.3499	60.0900
3	0.2219	36.0129	39.7500
4	0.1016	23.3400	15.9425
5	0.0881	10.6700	7.3757

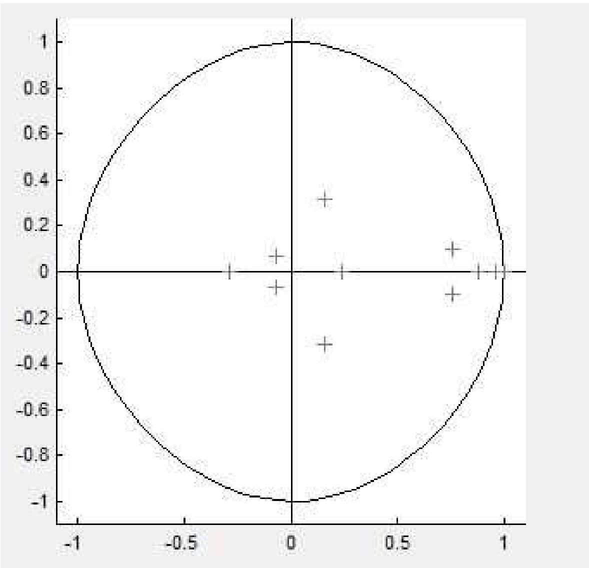
Japan

Rank	Eigenvalues	90% quantile	Trace tests
0	0.3541	112.6500	147.7057
1	0.2134	84.3800	92.6313
2	0.1789	60.0900	62.3827
3	0.1499	37.5522	39.7500
4	0.0694	23.3400	17.0864
5	0.0881	10.6700	8.0233

Italy

Rank	Eigenvalues	90% quantile	Trace tests
0	0.3608	91.1100	133.8593
1	0.2214	65.8200	76.1231
2	0.1426	43.8443	44.4900
3	0.0940	27.0700	27.0700
4	0.0584	13.4300	11.2636
5	0.0267	2.7100	3.4946

D. Stability Test



E. Autocorrelation Tests

	the LM-type test statistic		Ljung-Box-type test statistic	
Country	LM	PV	LB	PV
France	LM(36) = 43.6439	0.1784	LB(504)= 475.3930	0.8153
USA	LM(36) = 43.7386	0.1759	LB(468)= 506.5675	0.1058
Canada	LM(36) = 33.2320	0.6009	LB(504) = 544.6860	0.1021
UK	LM(36) = 25.5776	0.9017	LB(504) = 514.9026	0.3587
Germany	LM(36) = 30.1687	0.7417	LB(216) = 249.9516	0.0563
Japan	LM(36) = 47.8281	0.0898	LB(360) = 370.4435	0.3408
Italy	LM(36) = 43.6321	0.1788	LB(504) = 538.8555	0.1369