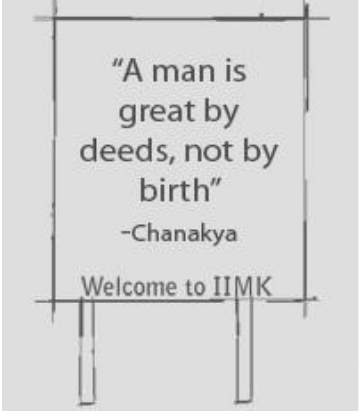

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Sources of Uncertainty and the Indian Economy

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IIMK WORKING PAPER

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Abstract

Indian economy is exposed to various forms of uncertainty. Theories of investment under uncertainty and real options predict that increased uncertainty tends to depress real investment. Literature finds that uncertainties regarding oil price and real exchange rate adversely affect domestic capital formation. The socio-economic realities of India together with the lack of penetration of formal financial institutions make gold as a one of the main modes of investment for Indian households. However, over-investment in gold may have adverse consequences for the real economy as it drives away resources from productive capital. Moreover, higher inflation uncertainty makes it harder to extract information from the price system and thus may reduce economic efficiency. In this paper, we use a bivariate GARCH-in-mean VAR model to estimate the interrelationships of various uncertainty measures and the real economy. We find that the Indian economy is not particularly vulnerable to real exchange rate or oil price uncertainties. However, gold price uncertainty has a significant positive effect on output growth. Higher WPI inflation uncertainty is detrimental to growth rates of private consumption expenditure and gross capital formation. Moreover, a rise in the growth rate of government expenditure following a positive CPI inflation shock may partially explain the lack of any detrimental effect on output growth.

Keywords: C32; E32; O47; O53
JEL: Uncertainty; output growth; bivariate GARCH-in-mean VAR; India

1. Introduction

Economic literature has recognized uncertainty to be an 'amorphous concept'.[1] The sources of uncertainty can be many – some originate in the minds of economic agents about the future, while others come from uncertainties about macro or micro phenomena. Sometimes the uncertainty is considered to be exogenous to the economic system whereas some other times this uncertainty feeds into and is fed by the economic variables, making it endogenous. Given its nature, the economic literature has spent a great deal of time appropriately defining, measuring and modelling its influence. In this paper, we focus on the uncertainty about the path of macroeconomic variables such as inflation, real exchange rate, real oil price and real gold price. We measure uncertainty about our macroeconomic variables as the standard deviation of the one-step-ahead forecast error. Using a bivariate GARCH-in-mean VAR model for India, we estimate the interrelationships of our macroeconomic uncertainty measures and the real economy.

Our results indicate that gold price uncertainty has a significant positive influence on the real GDP growth of India. We also find that uncertainty about the Wholesale Price Index (WPI) inflation significantly depresses growth rates of private consumption expenditure and gross capital formation. This is particularly revealing as such a negative influence on the real economy is absent when we consider Consumer Price Index (CPI) inflation uncertainty. CPI inflation uncertainty is, however, observed to boost government consumption expenditure in our sample. Moreover, we find that the Indian economy is not particularly vulnerable to real exchange rate or oil price uncertainties.

Recent import statistics for India indicate that 'Petroleum, Crude & Products', 'Capital Goods,' and 'Gold & Silver' have been consistently among the top three categories in terms of their share in total imports.[2] [3] Hence, the Indian economy is likely to be vulnerable to shocks in real oil price, real exchange rate and real gold price. There is a long literature trying to understand the effects of oil price uncertainty on the real economy. Edelstein and Kilian (2007 and 2009) estimates the influence of oil price uncertainty on real investment and real consumption expenditures for the US economy. They find the effects of oil price uncertainty to

[1] See Bloom (2014) for an extensive discussion on the concept of uncertainty and its interrelationships with the economic environment.
[2] Source: The Directorate General of Commercial Intelligence and Statistics, Ministry of Commerce, Government of India.
[3] Source: The Reserve Bank of India (RBI) Bulletin.

be negative on both real investment and real consumption expenditures. Their findings are consistent with the theories of investment under uncertainty and real options that predict that uncertainty about oil prices is likely to depress real investment by firms and real consumer durable expenditure by households. The literature has also argued that the effects of oil price uncertainty is likely to be asymmetric in nature, in the sense that the effect of a positive shock will be different from that of a negative shock. However, Edelstein and Kilian (2007 and 2009) find little evidence of asymmetric response of consumption and investment to oil price shocks. Elder and Serletis (2010) uses a bivariate GARCH-in-mean VAR model to estimate the effects of oil price uncertainty on the US economy. They find that uncertainty about the price of oil has a negative and significant effect on US real GDP and the responses to positive and negative real oil price shocks are asymmetric. Using quarterly data on the growth rate of real crude oil price (Indian basket) and real GDP growth for the Indian economy, we also estimate a bivariate GARCH-in-mean VAR model and instead find real oil price uncertainty to have no significant effect on real GDP growth or on any other measures of real economic activity such as real private consumption expenditure growth or real government expenditure growth or the growth rate of real gross capital formation. Although India is a large importer of energy and is likely to be vulnerable to oil price shocks, the lack of empirical evidence supporting that hypothesis may point to the fact that the Indian government by way of adjusting the excise duty on petrol and diesel effectively manages the price paid at the gas stations within a tight band. During periods of high oil price, the government typically lowers the excise duties on petrol and diesel and thus controls the upward pressure on these prices at the gas stations and during period of low oil prices by doing the opposite it effectively shields the Indian economy from both favorable and adverse oil price shocks. This prudent oil price management by the Indian government may explain our empirical results regarding the oil prices shocks and the real economy.

Serven (2003) argues that many developing economies experience high real exchange rate volatility. This volatility in real exchange rates translates into higher volatility in profitability of investment in the traded and nontraded goods sectors of the economy. Moreover, since developing economies are primarily capital goods importers this also causes the cost of new capital goods to be uncertain, further depressing capital formation. Using a GARCH-based measure of volatility the author finds that real exchange rate volatility has a strong negative effect on investment in these economies. Further there is evidence of a potential threshold effect

of this influence, in the sense that this uncertainty matters for the real economy only when it exceeds certain critical level. However, we find that the Indian economy is not particularly vulnerable to real exchange rate shocks. This could be due to the fact that the Reserve Bank of India (RBI), as a matter of policy, regularly intervenes in the rupee-dollar exchange market to control excessive volatility of the exchange rate. Since the RBI explicitly manages the rupee-dollar exchange rate volatility and since volatility is our measure of uncertainty, we conclude that this prevents the exchange rate uncertainty to cross the critical threshold beyond which its effect is felt on the real economy. This result indeed conforms to the general finding of a threshold effect uncovered by Serven (2003) for developing economies.

India's culture and tradition makes gold a very special commodity. Between 2009 and 2014, the average annual demand for gold in India was around 895 tonnes, accounting for 26 per cent of world's total physical demand for gold.[4] Moreover, since formal capital markets are still out of reach for large sections of the Indian population, beyond its traditional use as jewellery, gold serves the purpose of an important asset for Indian households, especially under an environment of moderately high inflation. In fact, the WPI inflation averaged around 7 per cent per annum and CPI inflation averaged around 7.4 per cent per annum for the period 1960-2013. This dual use of gold is further corroborated by a recent FICCI-World Gold Council research report[5] where a key finding from a survey of around 4800 Indian households is that Indian consumers view gold as both an investment and an adornment.

In the literature relating to the impact of uncertainty on the real economy, real gold prices have been used as a measure of financial uncertainty. Carruth et al. (2000) find that real gold price growth has a negative and significant short-run and long run impact on real investment growth in UK. However, we have so far not been able to find any published work assessing the impact of real gold price uncertainty on the real economy. We believe given the importance of gold as an asset for Indian households, which is also well known for its use as a collateral in financing various consumption and investment needs[6], the econometric modelling of the impact of real gold price uncertainty on the Indian economy is likely to be both novel and fruitful.

[4] Source: World Gold Council (2015).
[5] FICCI-World Gold Council Report (2014).
[6] The FICCI-World Gold Council survey finds that almost 30 percent of Indian households buy gold for the purpose of using it for collateral.

Indeed we find that real gold price uncertainty has a significant positive influence on the real GDP growth of India.[7] This result can be explained by the fact that increased uncertainty in real gold prices is likely to discourage gold investment (as theories of investment under uncertainty and real options would predict), which in turn may either encourage Indian households to boost consumption expenditure or may channelize investment into residential real estate and possibly into other forms of collateralizable productive assets such as capital machinery, thus leading to higher real GDP growth. Moreover, by way of discouraging household savings in terms of gold, gold price uncertainty may bring in more bank deposits and may also potentially increase government expenditure. However, although our results are robust to alternative structural orderings of our GARCH-in-mean VAR variables, we could not find significant effects of gold price uncertainty on either private consumption expenditure growth or government expenditure growth or on the growth rate of gross capital formation for India.

Friedman (1977) in his Nobel lecture envisaged a potential link between high inflation uncertainty and lower output growth. He argued that increased inflation uncertainty may change the optimal wage contract length and the degree of indexation and that may in turn lead to higher unemployment rates, particularly during the transition period. Moreover, inflation uncertainty may make information extraction from the price system difficult and this increased noise in the price system may reduce economic efficiency and raise unemployment, at least temporarily. Grier and Perry (2000) uses a GARCH-in-mean model to test Friedman's hypothesis. Their key result is that inflation uncertainty significantly lowers real output growth in the US. Grier and Grier (2006) also find that inflation uncertainty has a negative and significant effect on the growth rate of the Mexican economy. Grier et al. (2004) uses a more general econometric specification and not only finds that higher inflation uncertainty is significantly negatively correlated with lower output growth, but also that there is significant asymmetric responses to positive and negative shocks of equal magnitude. However, in a recent study by Fountas (2010), the author uses annual data over a century for 22 industrial countries of the world and finds that although there is a significant positive effect of inflation uncertainty on inflation, inflation uncertainty is not necessarily detrimental to growth, thus putting a question mark on the recent overemphasis of central banks world over on price stability. In line with the result obtained by Fountas (2010), our estimation with Indian data suggests that neither the CPI-based inflation

[7] Also see Dey (2016) for a role of gold price in the monetary transmission mechanism of the Indian economy.

uncertainty measure nor the WPI-based inflation uncertainty measure has any significant effect on real GDP growth. However, once we re-estimate our model for the two subcomponents of real GDP, we find that uncertainty in WPI inflation (and not CPI inflation) has a significantly negative effect on private consumption expenditure growth and on the growth rate of gross capital formation for the Indian economy. These results may be explained by a possible increase in precautionary savings [see Dotsey and Sarte (2000)] by economic agents in response to higher inflation uncertainty that gets fed into the economy by way of higher government expenditure, thus neutralizing the negative effects on real GDP growth arising due to a fall in private consumption expenditure growth and the growth rate of gross capital formation. We do, indeed, find that government expenditure increases in response to higher CPI inflation (and not WPI inflation) uncertainty in our sample, thus partially explaining the lack of any growth impact after a rise in inflation uncertainty for the Indian economy. Similar to the results obtained by Grier et al. (2004), we find asymmetric responses to positive and negative inflation shocks of equal magnitude.

2. Data

The data on real GDP, real private consumption expenditure, real government expenditure and real gross capital formation are collected from the Reserve Bank of India's *Database on Indian Economy*. These variables are all measured in constant 2011-12 Indian rupees at quarterly frequency. Real gross capital formation is calculated as the sum of real fixed capital formation, change in stocks and valuables. Quarterly data on Consumer Price Indices and Wholesale Price Indices are obtained from the IMF's *International Financial Statistics*. The data on Real Broad Effective Exchange Rate (REER) for India at quarterly frequency is obtained from the *FRED* database of Federal Reserve Bank of St. Louis. The gold price data is obtained from the World Gold Council as quarterly average prices in Indian rupees. Crude oil price (Indian basket) is obtained from the Government of India's Ministry of Petroleum & Natural Gas as quarterly averages of monthly prices in Indian rupees. Conversion of the monthly crude oil price data from US dollars to Indian rupees is done using the monthly average USD-Rupee nominal exchange rates. The nominal gold and oil prices are then converted into real prices by deflating them with quarterly CPI data. Except oil prices, all other data are available from

1996Q2 to 2015Q4. Oil prices are observed from 2000Q2 to 2015Q4. All the variables used in the estimation are stationary[8], which was achieved by converting these variables as log-differences of the current quarter values from their corresponding values a year before.

3. Empirical Model

Following Elder and Serletis (2010), we use a bivariate GARCH-in-mean VAR model for India in order to study the impact of macroeconomic uncertainties on the real economy. Our model is an augmented version of a bivariate quarterly VAR model comprising of real GDP growth (or growth rates of its subcomponents) and any one of the following variables – the real oil price growth, the real exchange rate growth, the inflation rate or the real gold price growth. The estimated model is thus a structural bivariate VAR model suitably modified to accommodate GARCH-in-mean errors. Formally we have,

$$Ay_t = C + B_1 y_{t-1} + B_2 y_{t-2} + \cdots + B_p y_{t-p} + D(L) H_t^{\frac{1}{2}} + \epsilon_t, \qquad (1)$$

where dim(A) = dim(B_i) = (2 x 2), $\varepsilon_t | \varphi_{t-1} \sim iid\ N(0, H_t)$, $H_t^{\frac{1}{2}}$ is diagonal, $D(L)$ is a matrix polynomial in lag operator, and φ_{t-1} is the information set at time t – 1. We identify the system by imposing a sufficient number of exclusion restrictions on matrix A, and assuming zero contemporaneous correlation in the structural disturbances, ε_t. Under the latter assumption, the conditional variance matrix H_t is diagonal and thus its general GARCH specification can be represented as follows:

$$diag(H_t) = C_v + \sum_{j=1}^{J} F_j\ diag\left(\epsilon_{t-j}\epsilon'_{t-j}\right) + \sum_{i=1}^{I} G_i\ diag(H_{t-i}), \qquad (2)$$

where the *diag* operator extracts the diagonal from a square matrix. We also impose an additional restriction that the conditional variances of each of the variables in y_t depend only on their own past squared errors and their own past conditional variances. This assumption makes the parameter matrices F_j and G_i also to be diagonal. Equation (2) is then estimated with $J = I = 1$. Following Elder and Serletis (2010) and in order to ensure positive definiteness of H_t and covariance stationarity of ε_t, we also impose the following restrictions: C_v is element-wise

[8] See Appendix Table 3 for a summary of the unit root tests.

positive, F_j and G_i are element-wise non-negative, and the eigenvalues of ($F_j + G_i$) are less than one in modulus.

Then the bivariate GARCH-in-mean VAR model comprising of equations (1) and (2) are estimated using Full Information Maximum Likelihood (FIML) method. The procedure maximizes the log likelihood function $\sum_{t=1}^{T} l_t$ with respect to the structural parameters *A*, *C*, B_1, B_2, …, B_p, *D*, C_v, F_j and G_i, where

$$l_t = -\frac{N}{2}\ln(2\pi) + \frac{1}{2}\ln(|A|^2) - \frac{1}{2}\ln(|H|_t) - \frac{1}{2}(\epsilon_t' H_t^{-1}\epsilon_t).$$

Under the standard regularity conditions, the FIML estimates are asymptotically normal and efficient. Following Elder (2003) and Elder and Serletis (2010), we calculate the impulse response functions and the corresponding confidence bands. Our baseline bivariate VAR specification allows for real GDP growth (or growth rates of its subcomponents) to respond to contemporaneous innovations in the other relevant variable. However, we ensure that our results are results are robust to other specifications. We use quarterly data with four lags, thus reducing our usable sample by one full year.

4. Empirical Results

Table 1 shows the estimates of variance functions of the different bivariate GARCH-in-mean VAR models involving real GDP growth as a variable. In all the estimated functions the lagged variance term is significant, indicating persistent behavior. Moreover, the coefficients of the lagged squared errors are not significant in the volatility processes of real GDP, real exchange rate and real gold price. Table 2 lists the effects of various uncertainty measures on the real Indian economy. The main coefficients of interest are the effects of the different measures of uncertainty on the real GDP growth of India. In order to ensure robustness of our results, we run several bivariate GARCH-in-mean VAR models with different subcomponents of output growth, such as the real private consumption expenditure growth, the real government expenditure growth and the real gross capital formation growth as one of the covariates. We further ensure that our results listed in Table 2 are robust to alternative structural orderings of the GARCH-in-

Table 1

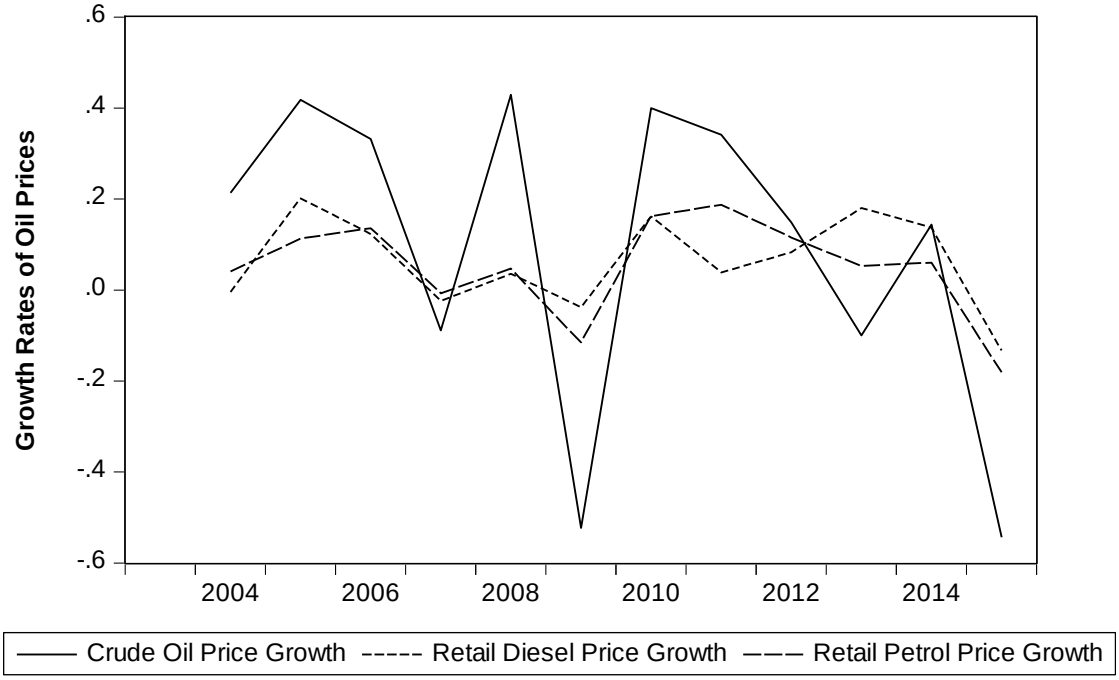
Variance function estimates for sets of bivariate GARCH-in-mean VAR models.

Equation set	Conditional variance	Constant	$\epsilon_i(t-1)^2$	$H_{i,i}(t-1)$
Real oil price growth	$H_{1,1}(t)$	0.005*	0.417***	0.468***
Real GDP growth	$H_{2,2}(t)$	0.0001***	0.00	0.760***
Real exchange rate growth	$H_{1,1}(t)$	0.0002***	0.00	0.762***
Real GDP growth	$H_{2,2}(t)$	0.0001***	0.00	0.791***
CPI inflation rate	$H_{1,1}(t)$	0.00002	0.582***	0.404**
Real GDP growth	$H_{2,2}(t)$	0.0001***	0.00	0.772***
WPI inflation rate	$H_{1,1}(t)$	0.00001	0.156*	0.801***
Real GDP growth	$H_{2,2}(t)$	0.0001***	0.00	0.782***
Real gold price growth	$H_{1,1}(t)$	0.001*	0.096	0.668***
Real GDP growth	$H_{2,2}(t)$	0.0001***	0.00	0.775***

Notes: These are the FIML estimates of C_v, F_j and G_i. Every row in the table represents an equation from the corresponding bivariate GARCH-in-mean VAR model. A value of 0.00 implies that the nonnegativity constraint is binding for that coefficient.
*Significant at 10% level.
**Significant at 5% level.
***Significant at 1% level.

mean VAR variables, where we allow for real oil price growth, real exchange rate growth, inflation rate or real gold price growth to respond to contemporaneous innovations in the real GDP growth (or growth rates of its subcomponents). It is clear from our results that oil price uncertainty has no significant effect on the real economy of India. This could be due to the prudent management of the impact of oil prices by the Indian government by way of adjusting the excise duties on petrol and diesel. Thus by maintaining the price paid at the gas stations within a tight band, the government may be able to effective shield the Indian economy from oil price shocks.

In order to bolster this point we plot the annual growth rates of prices per liter at the retail level for petrol and diesel along with the per liter crude oil price growth rates in Figure 0. The



Note: Retail oil prices are the averages of Delhi, Mumbai, Kolkata and Chennai prices on April 01 of the year.
Source: Indian Oil Corporation Limited.

Figure 0: Annual Growth Rates of Crude and Retail Oil Prices in India

stark differences in the volatilities of the international crude oil price growth and the retail petrol and diesel price growth rates make the India government's oil price management quite evident.

We also observe insignificant impact of real exchange rate uncertainty on real GDP and its subcomponents. The RBI, as a matter of policy, does not have any explicit or implicit rupee-dollar exchange rate target. However, the stated RBI policy also points to the fact that the central bank regularly intervenes in the rupee-dollar exchange market to control excessive volatility of the exchange rate. The RBI thus manages the rupee-dollar exchange rate volatility and prevents it to cross a critical threshold beyond which its effect is felt on the real economy. Our result indeed conforms to the general finding of a threshold effect uncovered by Serven (2003) for a set of developing economies, where the real exchange rate uncertainty seems to matter for the real economy only when it exceeds a certain critical level.

The literature on the effect of inflation uncertainty on output growth is mixed. Similar to the result obtained by Fountas (2010), our estimation with Indian data suggests that neither the

Table 2

Sources of uncertainty and the real economy.

Measures of real economy	Measures of uncertainty
	Oil price uncertainty
Real GDP growth	0.045
Real private consumption expenditure growth	0.077
Real government expenditure growth	0.318
Real gross capital formation growth	-0.06
	Exchange rate uncertainty
Real GDP growth	0.014
Real private consumption expenditure growth	-0.32*
Real government expenditure growth	5.405
Real gross capital formation growth	0.047
	CPI inflation uncertainty
Real GDP growth	-0.17
Real private consumption expenditure growth	-0.21
Real government expenditure growth	2.43**
Real gross capital formation growth	0.547
	WPI inflation uncertainty
Real GDP growth	0.405
Real private consumption expenditure growth	-2.34***
Real government expenditure growth	-4.25
Real gross capital formation growth	-7.84***
	Gold price uncertainty
Real GDP growth	1.157***
Real private consumption expenditure growth	-0.07
Real government expenditure growth	-3.47
Real gross capital formation growth	-0.03

Notes: These are the FIML estimates of $D(L)$ for each conditional standard deviation measure that is paired in a bivariate GARCH-in-mean model with every variable represented by each row.
*Significant at 10% level.
**Significant at 5% level.
***Significant at 1% level.

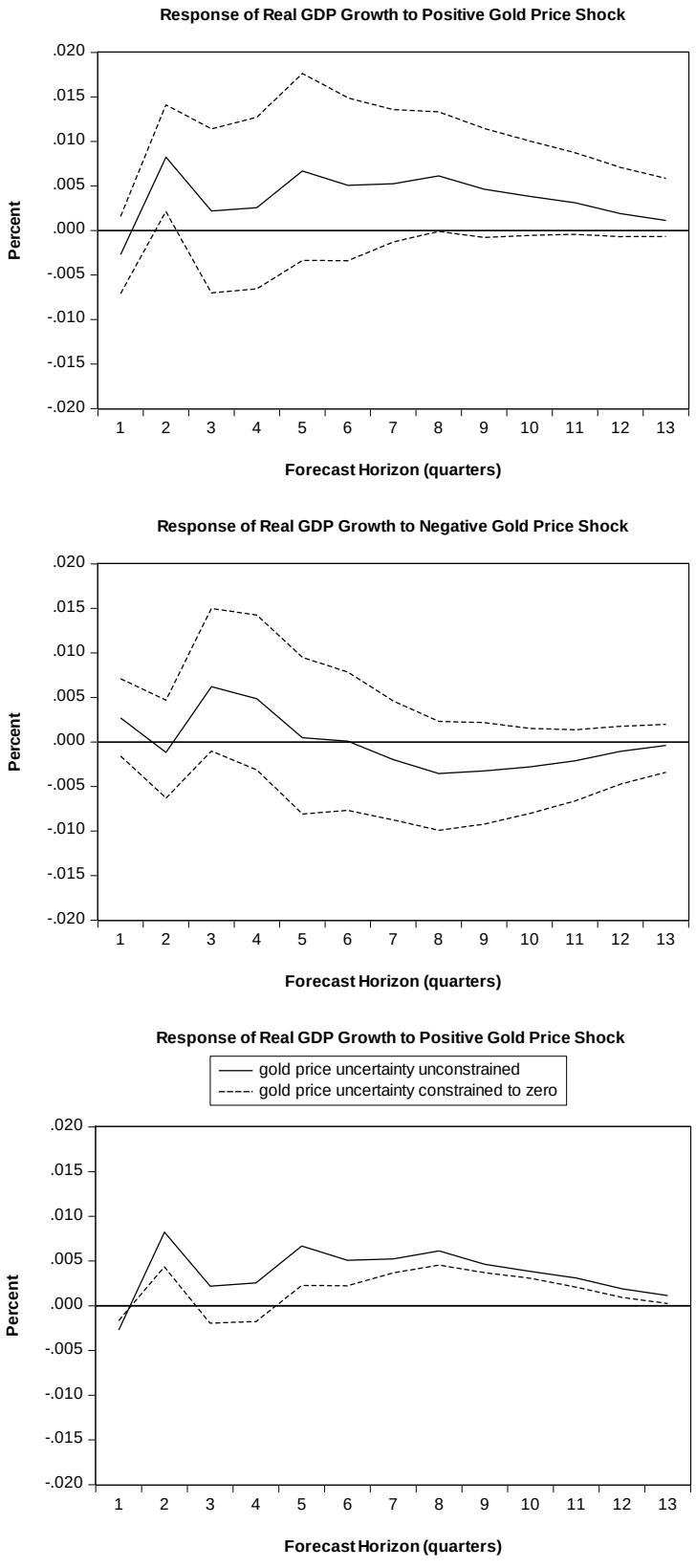


Figure 1. Impulse Responses of Real GDP Growth to Real Gold Price Shocks

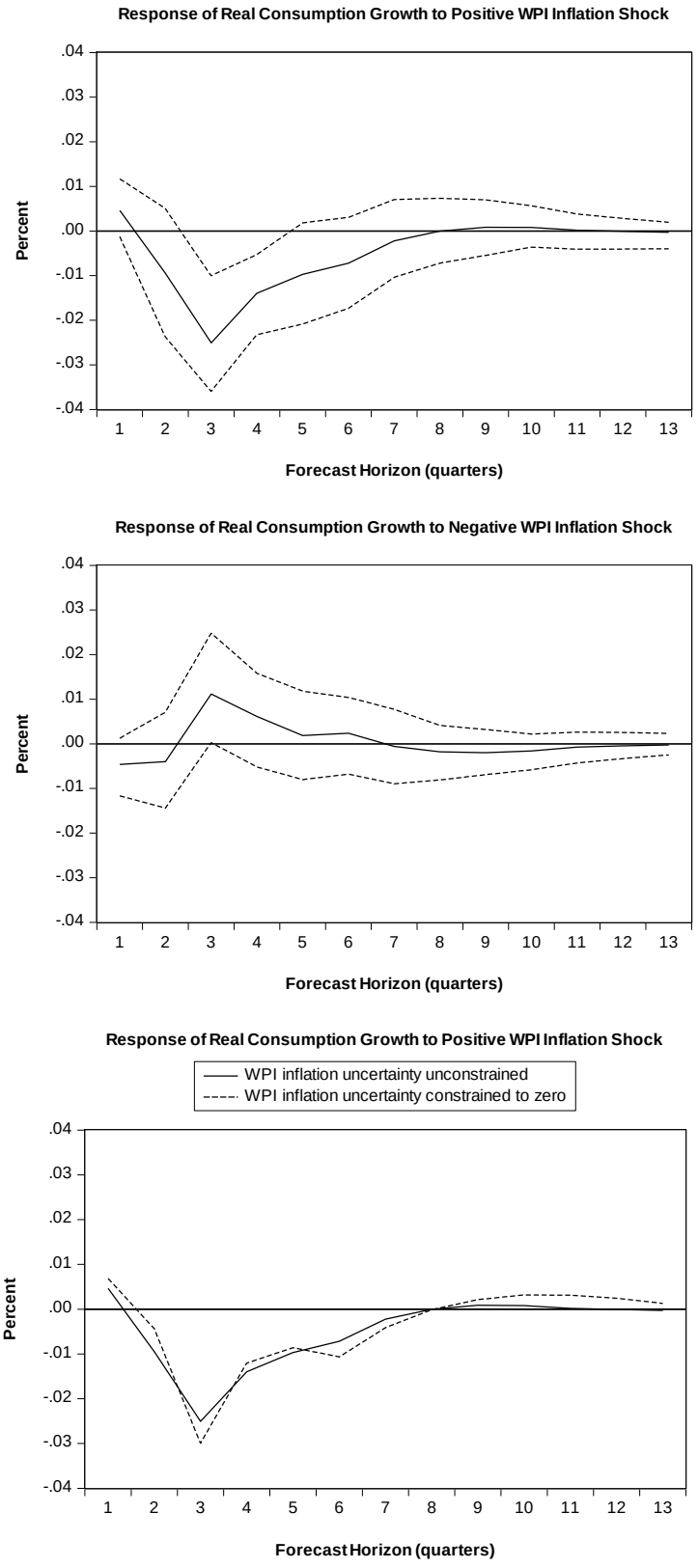


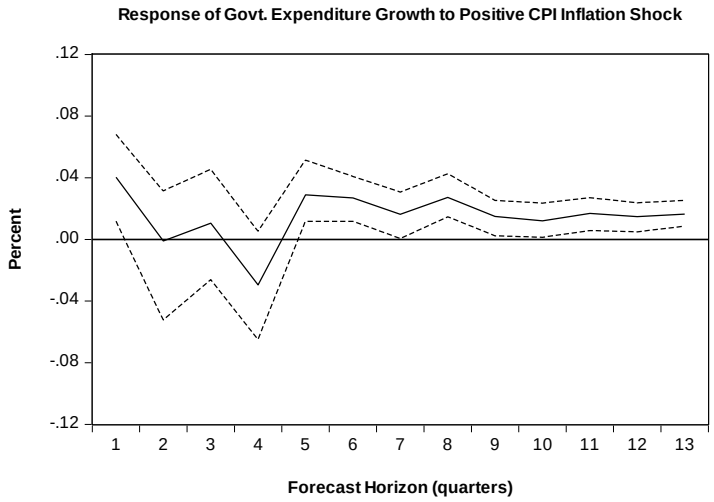
Figure 2. Impulse Responses of Real Consumption Growth to WPI Inflation Shocks

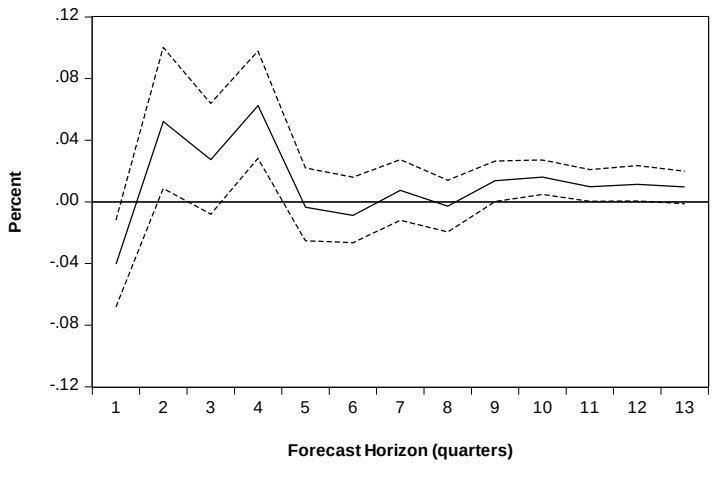
CPI-based inflation uncertainty measure nor the WPI-based inflation uncertainty measure has any significant effect on real GDP growth. However, we find that WPI inflation uncertainty significantly depresses private consumption expenditure growth and the growth rate of gross capital formation for the Indian economy. As Dotsey and Sarte (2000) suggest, this can be explained by a rise in precautionary savings by economic agents in response to higher inflation uncertainty that gets fed into the economy by way of higher government expenditure, thus neutralizing the negative effects on real GDP growth arising due a fall in private consumption expenditure growth and the growth rate of gross capital formation. Indeed, we find empirical evidence of an increase in government expenditure in response to higher CPI inflation uncertainty in our sample, which, to some extent, helps explain the lack of any output growth impact after a rise in inflation uncertainty for the Indian economy.

Finally, we find that real gold price uncertainty has a significant positive influence on the real GDP growth of India. Increased uncertainty in real gold prices is likely to discourage gold investment (as theories of investment under uncertainty and real options would predict), which in turn may induce Indian households to either boost consumption expenditure or to invest in residential real estate and other forms of collateralizable productive assets such as capital machinery. This is likely to have a positive impact on real GDP growth. Also by discouraging household savings in the form of gold, gold price uncertainty may lead to higher bank deposits and a resulting increase in government expenditure – another contributor to output growth.

However, we could not find significant effects of gold price uncertainty on either private consumption expenditure growth or government expenditure growth or on the growth rate of gross capital formation for India.

Next we consider the bivariate GARCH-in-mean VAR models in which there is a significant role of our uncertainty measures and try to assess the dynamic responses of real GDP or its relevant subcomponents after a shock in the other variable. Figures 1 to 4 plot the associated simulated impulse responses. The magnitude of the shock is unconditional one standard deviation of the variable for which the estimated uncertainty measure has a significant impact on real GDP or its relevant subcomponents. We also consider a shock of the same magnitude and calculate the comparable impulse responses for a standard homoscedastic VAR.





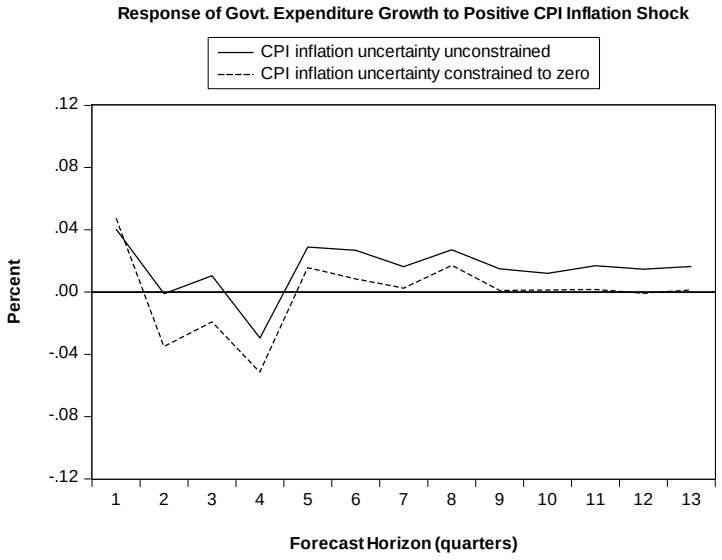


Figure 3. Impulse Responses of Govt. Expenditure Growth to CPI Inflation Shocks

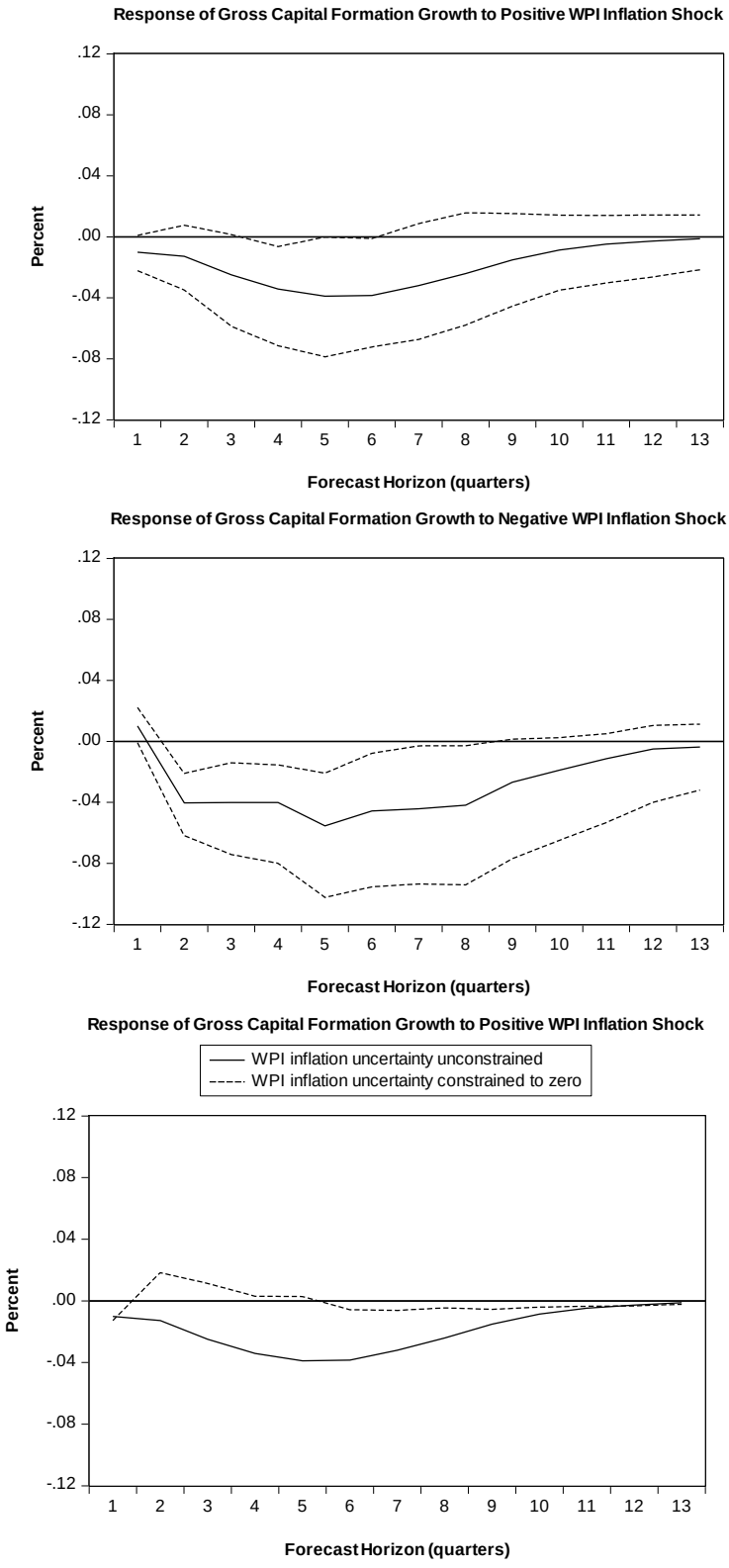


Figure 4. Impulse Responses of Gross Capital Formation Growth to WPI Inflation Shocks

We choose both positive and negative shocks of the same magnitude and plot the corresponding impulse response functions in order to investigate whether the responses to shocks are symmetric or asymmetric. We plot one-standard error bands around the impulse response functions.

In the first panel of Figure 1, the impulse response function, which accounts for the effects of gold price uncertainty, indicates how a positive gold price shock increases real GDP growth by about 80 basis points immediately after one quarter. However, this positive impact lacks persistence as the longer horizon estimates are within the one standard error band around zero.

The second panel of Figure 1 reports the real GDP response to a negative gold price shock. However, the GDP growth impact for a negative shock is not statistically significant for any quarter within the forecast horizon. Hence, the model responses to positive and negative shocks are not symmetric.

In the last panel of Figure 1, we compare the response of real GDP growth to a positive gold price shock with a GARCH-in-mean VAR model where the coefficient of gold price uncertainty in the real GDP growth equation is restricted to zero. In order aid the comparison, we suppress the error bands from the impulse response functions. When gold price uncertainty is accounted for, the real GDP growth response is positive and more pronounced than when the effect of gold price uncertainty is suppressed. This implies that when a feedback from the conditional standard deviation of gold price changes is allowed to influence output growth, its response to a positive gold price shock is amplified.

Similarly, the impulse response function in the first panel of Figure 2 shows that a positive WPI inflation shock reduces real consumption growth in the second quarter by about 250 basis points. This negative impact is again not persistent as the longer horizon estimates are within the one standard error band around zero.

The effect of real consumption growth following a negative WPI inflation shock, which is shown in the second panel of Figure 2, is not statistically significant for the entire forecast horizon. This again makes the model responses to positive and negative shocks to be asymmetric. Moreover, in the last panel of Figure 2 there is no clear evidence of amplification of the response of real consumption growth when a feedback from the conditional standard deviation of WPI inflation changes is allowed to influence real consumption growth.

The impulse response function in the first panel of Figure 3 shows that following a positive CPI inflation shock there is a delayed increase in government expenditure growth in the fourth quarter by about 290 basis points. This positive impact is also observed to be relatively persistent for the remainder of the forecast horizon. On the other hand, a negative CPI inflation shock increases government expenditure growth immediately in the first quarter and again in the third quarter by as much as 625 basis points. However, these initial increases lack persistence. Here again we observe that the model responses to positive and negative shocks are not symmetric. Our model estimates show that the estimated uncertainty effect is so large that it causes government expenditure growth to increase in response to a negative CPI inflation shock. This may be due to the fact that an unexpected fall in inflation often precedes a general economic slowdown, which may prompt the government to ready an expansionary fiscal expenditure package in order to provide some immediate remedy.

Similarly, the last panel of Figure 3 shows that when CPI inflation uncertainty is accounted for, the response of real government expenditure growth is positive and the tendency to remain positive is more pronounced than when the effect of CPI inflation uncertainty is suppressed.

Finally, the first panel of Figure 4 shows that a positive WPI inflation shock leads to a one-shot reduction in real gross capital formation growth by about 340 basis points in the third quarter. Next when we plot the response of real gross capital formation growth to a negative WPI inflation shock in the second panel of Figure 4, we observe an immediate 400 basis points fall in gross capital formation growth in the first quarter. Moreover, this fall in capital formation growth rate persists up until the seventh quarter. Hence, the model responses to positive and negative shocks are also not symmetric. As before, we argue that an unexpected fall in inflation often precedes a general economic slowdown that may be the cause behind a persistent deceleration of real gross capital formation growth observed in the data.

In the last panel of Figure 4, we observe that when WPI inflation uncertainty is accounted for, the response in real gross capital formation growth is negative and more pronounced than when the effect of WPI inflation uncertainty is suppressed. From this we can infer that when a feedback from the conditional standard deviation of WPI inflation changes is allowed to

influence real capital formation growth, its response to a positive WPI inflation shock is amplified.

5. Conclusion

As one of the major emerging economies of the world today, India needs to grapple with many forms of uncertainty. Theories of investment under uncertainty and real options predict that oil price uncertainty tends to depress investment and consumption in an economy. Moreover, for a capital importing emerging economy such as India, uncertainty around real exchange rates also may adversely affect domestic capital formation. Given the socio-economic realities and the deficiencies in penetration of formal financial institutions in India, gold has become one of the major investment vehicles of choice for the Indian households. However, over-investment in gold may have adverse consequence for the real economy as it may be responsible for driving away resources from productive capital. Moreover, several authors including Friedman (1977) envisaged a potential link between high inflation uncertainty and lower output growth. It is often argued that higher inflation uncertainty may make it harder to extract information from the price system and thus may reduce economic efficiency and raise unemployment, at least in the short run. In this paper, we focus on the uncertainty about the path of macroeconomic variables such as inflation, real exchange rate, real gold price and real oil price. Our measure of uncertainty is the standard deviation of the one-step-ahead forecast error. Using a bivariate GARCH-in-mean VAR model for India, we estimate the interrelationships of our macroeconomic uncertainty measures and the real economy.

As expected, our empirical results indicate that gold price uncertainty has a significant positive influence on the real GDP growth of India. Although our results are robust to alternative structural orderings of our GARCH-in-mean VAR variables, we could not find significant effects of gold price uncertainty on either private consumption expenditure growth or government expenditure growth or on the growth rate of gross capital formation for India. We also observe higher WPI inflation uncertainty to significantly dampen growth rates of private consumption expenditure and gross capital formation; however, we could not reveal an empirical link between WPI inflation uncertainty and India's output growth. This is particularly interesting as we find no such negative influence on the real economy when we consider CPI inflation uncertainty instead.

Indeed CPI inflation uncertainty is observed to boost government expenditure in our sample, as envisaged by Dotsey and Sarte (2000). Moreover, we find that the Indian economy is not particularly vulnerable to real exchange rate or oil price uncertainties.

The impulse response functions of the various GARCH-in-mean VAR models estimated in our paper also reveal interesting facts regarding the degree of influence of the different measures of uncertainty on the real economy. We find that accounting for gold price uncertainty in the model makes the effect of gold price shocks on output growth to be more pronounced. However, such a clear-cut pattern is not observed in the dynamic response of real consumption expenditure growth after one standard deviation positive WPI inflation shock. On the other hand, we find that allowing WPI inflation uncertainty to directly influence gross capital formation growth exacerbates the deceleration of capital formation for the Indian economy. Moreover, government expenditure grows more robustly following a positive CPI inflation shock if we do not restrict the coefficient of CPI inflation uncertainty in the real government expenditure growth equation in the bivariate GARCH-in-mean VAR model to zero. Finally, all the reported impulse response functions suggest that the real effects of the various uncertainty shocks are asymmetric, in the sense that the effect of a positive shock are different from that of a negative shock.

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Appendix

Table 3: Unit Root Tests

Variable	ADF[a]	Philips-Perron[a]	KPSS[b]
CPI Inflation	-2.42	-2.68*	0.32
WPI Inflation	-4.37***	-2.53	0.13
Real GDP Growth	-3.85***	-3.95***	0.19
Real Private Consumption Growth	-7.95***	-7.97***	0.30
Real Government Expenditure Growth	-8.65***	-8.65***	0.09
Real Gross Capital Formation Growth	-2.87*	-2.88**	0.17
Real Exchange Rate Growth	-5.67***	-3.58***	0.04
Real Gold Price Growth	-3.35**	-2.81*	0.26
Real Oil Price Growth	-3.92***	-2.77*	0.31

[a] H_0 is presence of unit root; [b] H_0 is stationarity.
*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.

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