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Oil price dynamics, macro-finance interactions and the role of financial speculation

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Abstract

What is the role of financial speculation in determining the real oil price? We find that while macroeconomic shocks have been the major upward driver of the real oil price since the mid 1980s, financial shocks have also sizably contributed since early 2000s, and at a much larger extent since mid 2000s. Despite financial shocks contributed with 44% out of the 65% real oil price increase over the period 2004-2010, the *third oil price shock* was a *macro-financial* episode: macroeconomic shocks actually largely accounted for the 2007-2008 oil price swing. While we then find support to the demand side view of real oil price determination, we also find a much larger role for financial shocks than previously noted in the literature.

Keywords: Oil price, financial speculation, macro-finance interface, international business cycle, factor vector autoregressive models.
JEL classification: C22; E32; G12

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1 Introduction

After about two decades of stability, both nominal and real oil prices have been increasing since 2003 (US$ 30 per barrel), with unprecedented volatility in 2008, as nominal oil prices peaked up at US$ 140 in July, to bottom down at US$ 40 in December; oil prices have mostly been increasing thereafter, achieving a new peak in April 2011 (US$ 110), quoting about US$ 100 at the time of writing.

Recent oil price trends, hikes and volatility have indeed revived the debate on the factors contributing to oil price determination, and two main explanations for the *third oil price shock* have so far been proposed in the literature: firstly, increasing oil demand, due to rapid growth in emerging countries and stable OECD oil consumption (Kilian, 2008, 2009a,b) or to expansionary monetary policies (Frankel, 2007; Calvo, 2008; Kilian, 2010), in the face of stagnant oil production; secondly, increased speculation in the oil futures markets since mid 2000s (Davidson, 2008; Krugman, 2008, 2009).

While strong empirical support for the economic growth hypothesis has been found in the literature (Kilian and Murphy, 2010; Kilian and Hicks, 2011; Hamilton 2009a,b, Baumeister and Perssman, 2008; Dvir and Rogoff, 2010), the empirical evidence on the effects of financial speculation is not clear-cut.

The narrative evidence on the contribution of financial speculation to recent oil price dynamics is based on the steady increase in the market share of non hedging open interest positions in the US commodity futures and option markets. Since 2002 the Working's T index for the oil futures market has been increasing at an average 2% annual rate. Moreover, while historically the oil futures market has been in general *backwardation* over the 1980s and 1990s, since 2005 a *contango* condition has prevailed: the increased presence of non-commercial investors, seeking portfolio diversification in the oil futures market, might have indeed lead to a reversal in the receipt of the premium, i.e. from arbitrageurs to oil producers, rather than the other way around, as it would be theoretically expected (Hamilton and Wu, 2011). This might also be indicative of a structural shift in inventories management, as contango (backwardation) is in general associated with a high (low) level of inventories, which may indeed be induced by speculative behavior (Gorton et al., 2008). Alquist and Kilian (2010), within the framework of a fully endogenous model for the oil spot and futures price and inventories, actually document that the twelve-month oil futures spread ($future_t^{12} - spot_t$) is strictly related to precautionary/speculative oil demand shocks; yet, the latter linkage would have undergone structural change since 2004, feature which may be related to the increased financialization of the oil market.

There are few *fundamental* financial transmission mechanisms which can be posited to explain the transmission of liquidity shocks to the real oil price: firstly, excess liquidity may lead to an increase in the demand for oil as a financial asset through a portfolio rebalancing mechanism; secondly, a contraction in the real interest rate may lead to a portfolio shift from bonds to (perceived) more profitable assets, i.e. oil and other commodities, housing-related securities and stocks (Frankel, 2007; Calvo, 2008); thirdly, by lowering the cost of holding inventories for traders and slowing down the rate of extraction for producers (Hotelling, 1931); fourthly, as the real oil price may be measured as the net present value of the expected future stream of convenience yields (Pindyck, 1993), a contraction in the real interest rate would lead to lower discounting and therefore a higher real oil price; fifthly, according to a Dornbusch-type monetarist overshooting mechanism a monetary expansion would drive the real interest rate down and the real oil price up, over its equilibrium value, as much as it is largely considered overvalued and there are expectations of future depreciation offsetting the lower real interest rate (Frankel, 2007); finally, as oil is valuated in US$, a generalized depreciation of the US$ might lead to a proportional increase in the real oil price, as OPEC might manage the oil supply in order to maintain unchanged the purchasing power of oil.

The empirical evidence in favor of the excess liquidity channel is weak. For instance, Barsky and Killian (2002, 2004) and Kilian (2010) point to a positive linkage between liquidity conditions and the real oil price over the 1970s. Similarly Thomas et al. (2010) and Frankel and Rose (2010), yet finding little evidence of a direct role for liquidity and the real interest rates in explaining oil price dynamics, beyond any effect exercised through real activity and inflation, as in Kilian and Barsky (2002). Moreover, the impact of liquidity on the real oil price would only be transitory, and therefore unlikely to account for the 2008 episode (Erceg et al., 2011).

The presence of heterogeneous agents in the oil futures market is a crucial condition for financial speculation to be destabilizing. In fact, while arbitrageurs, by trading on the basis of information about fundamentals, contribute to price discovery, noise traders would create drifts in the price process. Albeit heterogeneous behavior in the oil futures market has actually been documented in various papers (Vansteenkiste, 2011; Reitz and Slopek, 2008; ter-Ellen and Zwinkles, 2010; Ciffarelli and Paladino, 2010), the empirical evidence on the effects of financial speculation in the oil futures market is controversial.

Few studies, based on U.S. Commodity Futures Trading Commission (CFTC) daily data, would suggest that speculation in the oil futures market, since mid 2000s, would have not been destabilizing. For instance, there would not be any evidence of Granger causality from trading positions to futures oil prices, but actually some support to the view that oil prices lead trading positions; also, both hedging and non-hedging traders in the oil futures market would feature herding behavior (Buyuksahin and Harris, 2009); moreover, herding behavior by hedge funds, by being countercyclical, would have not been destabilizing (Boyd et al., 2009). Also, financial speculation would have contributed to stabilizing oil futures price volatility (Brunetti et al., 2010) and increased oil futures market liquidity (Buyuksahin et al., 2008). Differently, using weekly CFTC data, Singleton (2011) finds that the thirteen-week change in the imputed positions of index investors and in the managed-money spread positions would predict weekly oil futures price returns since 2006. Frankel and Rose (2010), using annual (non CFTC) data, also find some supporting evidence that herding behavior by financial speculators may have contributed to the 2008 price hike.

Moreover, within the framework of structural vector autoregressive models, Kilian and Murphy (2010) find evidence against any role of financial speculation in the recent oil price episode, while according to Juvenal and Petrella (2011) and Lombardi and Van Robays (2011), speculative (non fundamental) financial shocks might account for 15% of the real oil price increase between 2004 and 2008 and have determined a 10% overshooting in the real oil price between 2007:8 and 2008:6, respectively.

In the light of the contrasting empirical evidence, the current paper then aims at assessing the role of financial speculation in the recent oil price episode, providing original contributions under different perspectives.

Firstly, large-scale modeling of the oil market-macro-finance interface is implemented, considering macro-financial data for fifty countries, including OECD and emerging economies, and a detailed description of the oil market and oil futures market conditions. Single country macro-financial data are employed to estimate the *unobserved* factors driving the global business and financial cycle; additional *observed* US financial factors, proxying for expectations about future fundamentals and economic/financial fragility conditions are also considered: in particular, the US fiscal and trade deficit to GDP ratios, stock market S&P500 volatility, the size and value Fama and French (1993) factors, the Carhart (1997) momentum factor, the Pastor and Stambaugh (1997) liquidity factor, the Adrian, Etula and Muir (2011) leverage factor; the real IMF non-energy commodities price index, real gold prices and the Bagliano and Morana (2012) economic/financial fragility index are also included in the information set.

The careful and large-scale modelling of the oil market macro-finance interface surely is an important novelty of our study, as we are unaware of previous contributions seeking such an in depth understanding of macro-financial interactions within the oil market. While Kilian and Murphy (2010), by including inventories in their model, do allow for a financial oil demand component and, indirectly, for the effect of future fundamentals on oil demand, our contribution, by conditioning on risk factors, is the first attempt to *directly* measuring their effects. By including measures of excess speculation, our study also aims at disentangling the fundamental and non fundamental components of financial oil demand, which are left indistinct in Kilian and Murphy (2010). We do find that without a careful description of the *financial side*, *shocks* and *transmission mechanisms* which are important to the understanding of the working of the oil market would go neglected.

Secondly, the proposed modelling approach leads not only to confirm previous evidence, but also to important new insights on the determination of the real oil price: while we confirm that, at least since the mid-1980s, macroeconomic shocks were the major upward driver of the real oil price, we also find a sizable contribution of oil market supply side and financial shocks since early 2000s. In general, macroeconomic and financial shocks had a stabilizing effect on nominal oil price volatility, while oil market supply side shocks were destabilizing. The contribution of financial shocks to real oil price fluctuations was particularly remarkable since mid-2000s: out of the 65% real oil price increase over the 2004 through 2010 period, 44% is related to fundamental (33%) and non fundamental (11%) financial shocks; differently, macroeconomic and oil market supply side shocks contributed with a 5% and 3% increase, respectively. Yet, despite the large contribution of financial shocks, the third oil price shock was a *macro-finance* episode: macroeconomic shocks accounted for 58% out of the 68% real oil price run up over the 2007(2)-2008 (2) period, and financial shocks for 6% in 2007(4); moreover, the -67% and -31% contractions in 2008(4) and 2009(1) are also largely accounted for by macroeconomic shocks (-40% and -26%), yet with financial shocks (-14% and -7%) also sizably contributing; the 54% real oil price increase over the 2009(2) through 2009(4) period is finally equally accounted for by macroeconomic (21%) and financial (20%) shocks.

Hence, while our results are consistent with the demand side view of the real oil price determination, we do also find a larger role for financial shocks than previously noted in the literature.

After this introduction, the paper is organized as follows. In Section 2 the econometric methodology is introduced, while in Section 3 the data are presented. Then, in Section 4 specification and estimation issues are discussed, while in Section 5, 6 and 7 the empirical results are presented. Finally, conclusions are drawn in Section 8.

2 The econometric model

The econometric model is described by two blocks of equations. The former refers to the *observed* ($\mathbf{F}_{2,t}$) and *unobserved* ($\mathbf{F}_{1,t}$) global macro-financial factors and oil market demand and supply side variables ($\mathbf{O}_t$), collected in the $r \times 1$ vector $\mathbf{F}_t = \left[\mathbf{F}'_{1,t}\ \mathbf{F}'_{2,t}\ \mathbf{O}'_t\right]'$, while the latter to q macro-financial variables for m countries ($n = m \times q$ equations in total). The joint dynamics of the "global" macro-finance-oil market interface (the global economy thereafter) and the "local" macro-finance interface are then modelled by means of the following reduced form dynamic factor model

$$
\begin{aligned}
(\mathbf{I} - \mathbf{P}(L))(\mathbf{F}_t - \boldsymbol{\kappa}_t) &= \boldsymbol{\eta}_t & (1)\\
\boldsymbol{\eta}_t &\sim i.i.d.(\mathbf{0}, \boldsymbol{\Sigma}_\eta) & (2)\\
(\mathbf{I} - \mathbf{C}(L))\left((\mathbf{Z}_t - \boldsymbol{\mu}_t) - \boldsymbol{\Lambda}\left(\mathbf{F}_t - \boldsymbol{\kappa}_t\right)\right) &= \mathbf{v}_t & (3)\\
\mathbf{v}_t &\sim i.i.d.(\mathbf{0}, \boldsymbol{\Sigma}_v). & (4)
\end{aligned}
$$

The model is cast in a weakly stationary representation, as $(\mathbf{F}_t - \boldsymbol{\kappa}_t), (\mathbf{Z}_t - \boldsymbol{\mu}_t) \sim I(0)$, where $\boldsymbol{\mu}_t$ and $\boldsymbol{\kappa}_t$ are $n \times 1$ and $r \times 1$ vectors of deterministic components, respectively, with $r \leq n$, including an intercept term, and, possibly, linear or non linear trends components.

Global dynamics are described by the stationary finite order polynomial matrix in the lag operator $\mathbf{P}(L)$, $\mathbf{P}(L) \equiv \mathbf{P}_1 L + \mathbf{P}_2 L^2 + ... + \mathbf{P}_p L^p$, where $\mathbf{P}_j$, $j = 1, .., p$, is a square matrix of coefficients of order r, and $\boldsymbol{\eta}_t$ is a $r \times 1$ vector of i.i.d. reduced form shocks driving the $\mathbf{F}_t$ factors. The contemporaneous effects of the global factors on each country variables in $\mathbf{Z}_t$ are measured by the loading coefficients collected in the $n \times r$ matrix $\boldsymbol{\Lambda} = \left[\boldsymbol{\Lambda}'_{F_1}\ \boldsymbol{\Lambda}'_{F_2}\ \boldsymbol{\Lambda}'_O\right]'$.

Finally, $\mathbf{v}_t \sim i.i.d.(\mathbf{0}, \boldsymbol{\Sigma}_v)$ is the $n \times 1$ vector of reduced-form idiosyncratic (i.e. country-specific) disturbances, with $E\left[\eta_{jt} v_{is}\right] = 0$ for all i, j, t, s, and $\mathbf{C}(L)$ is a finite order stationary block (own country) diagonal polynomial matrix in the lag operator, $\mathbf{C}(L) \equiv \mathbf{C}_1 L + \mathbf{C}_2 L^2 + ... + \mathbf{C}_c L^c$, where $\mathbf{C}_j$, $j = 0, .., c$, is a square matrix of coefficients of order n, partitioned as

$$
\underset{n \times n}{\mathbf{C}_j} = \begin{bmatrix} \underset{q \times q}{\mathbf{C}_{j,11}} & \mathbf{0} & ... & \mathbf{0} \\ \mathbf{0} & \underset{q \times q}{\mathbf{C}_{j,22}} & ... & \mathbf{0} \\ \vdots & ... & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & ... & \underset{q \times q}{\mathbf{C}_{j,mm}} \end{bmatrix}. \qquad (5)
$$

The specification of the model in (1)-(3) embeds a set of important assumptions on the structure of global and local linkages: (i) global shocks

($\boldsymbol{\eta}_t$) affect both the global and local economy through the polynomial matrix $\mathbf{P}(L)$ and the factor loading matrix $\boldsymbol{\Lambda}$; (*ii*) country-specific disturbances ($\mathbf{v}_t$) do not affect global factor dynamics, limiting their impact only to the country of origin ($\mathbf{C}(L)$ is assumed to be block (own-country) diagonal).

By substituting (1) into (3), the reduced form vector autoregressive (VAR) representation of the dynamic factor model can be written as

$$(\mathbf{I} - \mathbf{A}(L))\,(\mathbf{Y}_t - \boldsymbol{\gamma}_t) = \boldsymbol{\varepsilon}_t \tag{6}$$

where $\mathbf{Y}_t = [\mathbf{F}_t'\ \mathbf{Z}_t']'$, $\boldsymbol{\gamma}_t = [\boldsymbol{\kappa}_t'\ \boldsymbol{\mu}_t']'$,

$$\mathbf{A}(L) = \begin{pmatrix} \mathbf{P}(L) & \mathbf{0} \\ [\boldsymbol{\Lambda}\mathbf{P}(L) - \mathbf{C}(L)\boldsymbol{\Lambda}] & \mathbf{C}(L) \end{pmatrix},$$

$$\boldsymbol{\varepsilon}_t \equiv \begin{bmatrix} \boldsymbol{\varepsilon}_{1,t} \\ \boldsymbol{\varepsilon}_{2,t} \end{bmatrix} = \begin{bmatrix} \mathbf{I} \\ \boldsymbol{\Lambda} \end{bmatrix} [\boldsymbol{\eta}_t] + \begin{bmatrix} \mathbf{0} \\ \mathbf{v}_t \end{bmatrix},$$

with variance-covariance matrix

$$E\left[\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t'\right] = \boldsymbol{\Sigma}_{\varepsilon} = \begin{pmatrix} \boldsymbol{\Sigma}_{\eta} & \boldsymbol{\Sigma}_{\eta}\boldsymbol{\Lambda}' \\ \boldsymbol{\Lambda}\,\boldsymbol{\Sigma}_{\eta} & \boldsymbol{\Lambda}\,\boldsymbol{\Sigma}_{\eta}\boldsymbol{\Lambda}' + \boldsymbol{\Sigma}_{v} \end{pmatrix}.$$

The structural vector moving average representation for the global model in (1) can then be written as

$$(\mathbf{F}_t - \boldsymbol{\kappa}_t) = \mathbf{H}_F(L)\mathbf{K}^{-1}\boldsymbol{\xi}_t, \tag{7}$$

where $\boldsymbol{\xi}_t$ is the vector of the r structural shocks driving the common factors in $\mathbf{F}_t$, i.e. $\boldsymbol{\xi}_t = \mathbf{K}\,\boldsymbol{\eta}_t$, $\mathbf{K}$ is a $r \times r$ invertible matrix, and

$$\mathbf{H}(L) \equiv \begin{pmatrix} \mathbf{H}_F(L) & \mathbf{0} \\ \mathbf{H}_{FZ}(L) & \mathbf{H}_Z(L) \end{pmatrix} \equiv (\mathbf{I} - \mathbf{A}(L))^{-1}.$$

By assumption the structural factor shocks are orthogonal and have unit variance, so that $E\left[\boldsymbol{\xi}_t \boldsymbol{\xi}_t'\right] = \mathbf{K}\,\boldsymbol{\Sigma}_{\eta}\,\mathbf{K}' = \mathbf{I}_r$. To achieve exact identification of the structural disturbances, additional $r(r-1)/2$ restrictions need to be imposed. Since $\boldsymbol{\eta}_t = \mathbf{K}^{-1}\boldsymbol{\xi}_t$, imposing exclusion restrictions on the contemporaneous impact matrix amounts to imposing zero restrictions on the elements of $\mathbf{K}^{-1}$, for which a lower-triangular structure is assumed. Operationally, $\mathbf{K}^{-1}$ (with the $r(r-1)/2$ zero restrictions necessary for exact identification imposed) is estimated by the Choleski decomposition of the factor innovation variance-covariance matrix $\boldsymbol{\Sigma}_{\eta}$, i.e. $\hat{\mathbf{K}}^{-1} = chol(\hat{\boldsymbol{\Sigma}}_{\eta})$. Forecast error variance and historical decompositions can then be obtained by means of standard formulas.

Consistent and asymptotically Normal estimation of the two-block specification in (1) and (3) is obtained by means of the procedures proposed in Morana (2011a,b), also shown to yield accurate estimation in small samples (see the Monte Carlo results reported in Morana, 2011a,b). Following the thick modelling strategy of Granger and Jeon (2004), median estimates of the parameters of interest, impulse responses, forecast error variance and historical decompositions, as well as their confidence intervals, are obtained by means of simulation. See the Appendix for a detailed account of the estimation procedure and the econometric methodology more in general.

3 The data

We use seasonally adjusted quarterly macroeconomic time series data for 31 advanced economies (Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Taiwan, United Kingdom), 5 advanced emerging economies (Brazil, Hungary, Mexico, Poland, South Africa), and 14 secondary emerging economies (Argentina, Chile, China, Colombia, India, Indonesia, Malaysia, Morocco, Pakistan, Peru, Philippines, Russia, Thailand, Turkey), for a total of 50 countries. The (main) data source is IMF *International Financial Statistics*[1]

Concerning the block of equations in (3), for each of the 50 countries, apart from some exceptions, 17 macroeconomic variables are employed, namely *real GDP*, *private consumption* and *investment* growth, *public expenditure to GDP ratio* growth, *nominal bilateral US$ exchange rate* (value of 1 US$ in units of country currency) returns, *CPI inflation rate*, *M2 or M3 to GDP ratio* growth, *nominal M2/M3* growth, *civilian employment* growth, *unemployment rate* changes, *real wages* growth, *real stock prices* returns, *real housing prices* returns, *real short and long term interest rates*, *real effective exchange rate* returns, *bank loans to the private sector to GDP ratio* growth. A total of over 800 equations is then considered in block (3). For OECD countries the macro-financial sample extends from 1980:1 through 2010:3, while for non OECD countries only from 1995:1 through 2010:3. Different samples are therefore employed in estimation.

Concerning the block of equations in (1), a total of 33 variables are considered in the vector $\mathbf{F}_t$.

[1] Other data sources employed are FRED2 (Federal Reserve Bank of St. Louis); OECD and BIS (unofficial) house price data sets, and International Energy Agency (IEA-OECD) data sets.

Firstly, 12 variables are included in the vector of (global) observed factors $\mathbf{F}_{2,t}$, i.e. the Bagliano and Morana (2011) *US economic/financial fragility* index (FRA) in differences, the Fama and French (1993) *size* and *value* factors (SMB, HML), the Carhart (1997) *momentum* factor (MOM), the Pastor and Stambaugh (1997) *stocks' liquidity* factor (PSL), the S&P 500 stock return *volatility* in differences (FV), computed from an asymmetric GARCH model, the real *gold* price (GD) return, real IMF *non-energy commodities* price index returns (M), the *US fiscal* (Fd) and *trade deficit* (Td) *to GDP ratios* in differences, the Adrian, Etula and Muir (2011) *leverage* factor (LEV). The sample for the observed macro-financial factors extends from 1980:1 through 2010:3.

Secondly, 10 additional variables, concerning global oil demand and supply conditions have been included in the vector $\mathbf{O}_t$, namely *world oil reserves* growth (R), net *world oil production changes* (increase: Pp, decrease: Pm)[2], *OECD oil refinery margins* growth (RM), *world oil consumption* (C) growth, *OECD oil inventories* rate of growth (INV), *real WTI oil price* (OP) return, *nominal WTI oil price volatility* in differences (OV), computed from a GARCH model, the twelve-month *futures basis*, i.e. the ratio of the nominal twelve-month futures-spot spread over the nominal spot oil price (FB), and the growth rate of the oil futures market *Working* (1960)'s-T index (WT). The sample for the latter oil market variables extends from 1986:1 through 2010:3.

Thirdly, 11 variables have been collected in the vector of (global) unobserved factors $\mathbf{F}_{1,t}$; the latter are estimated using (3), as detailed in the Appendix. In particular, a first order own diagonal dynamic structure, as suggested by the BIC information criterion, was employed[3] and twelve unobserved global macro-financial factors were extracted from subsets of homogeneous variable, i.e. a *real activity* factor (Y) from the real GDP, private consumption and investment growth series; a *fiscal stance* factor from the public expenditure to GDP ratio growth series (G); a global bilateral *US\$ exchange rate* index from the various bilateral exchange rates against the US\$ returns (X); a *nominal* (*core inflation*) factor (N) from the inflation rate and the nominal money growth, short and long term interest rate series; an *excess liquidity* index (L) from the M3(M2) to GDP ratio and the private loans to GDP ratio growth series; an *employment* factor (E) from the civilian employment growth series; an *unemployment rate* factor (U) from

[2] See Hamilton (1996), albeit for an application to the oil price.

[3] $\hat{\mathbf{F}}_{1,t}$ has been obtained by conditioning with respect to $\mathbf{F}_{2,t}$ and only a subset of the variables considered in $\mathbf{O}_t$, i.e. the real oil price and the real non-energy commodities price index, which are avavilable since 1980:1. The other oil market variables are availble only since 1986:1.

the unemployment rate in changes series; a *real wage* factor (W) from the real wage growth series; a *real stock market return* factor (F) from the real stock market price index return series; a *real housing return* factor (H) from the real housing price index return series; a *real short term rate* factor (SR) from the real short term interest rate series; a *term spread factor* (TS) from the term spread series.[4]

4 The global oil market-macro-finance interface model: specification and estimation

The global model for the oil market macro-finance interface in (1) counts 33 endogenous variables, collected in the vector $\mathbf{F}_t = \left[\mathbf{F}'_{1,t}\ \mathbf{F}'_{2,t}\ \mathbf{O}'_t\right]'$. For PC-VAR estimation 12 principal components of $\mathbf{F}_t$, jointly accounting for 80% of total variance, and three lags were selected, according to Monte Carlo results (Morana, 2011b) and specification tests. Hence, 36 parameters were estimated for each of the 33 equations in the model. Note that a symmetric VAR model would have required the estimation of 99 parameters for each of the 33 equations, which would have been unfeasible given the sample size available.

The identification of the structural shocks has been performed by means of the Choleski decomposition strategy described in the methodological section. The Choleski identification approach implies a recursive structural model, which ordering is assumed as follows: reserves, net oil production changes (negative and positive), refinery margins, employment and the unemployment rate, real activity, the fiscal stance, the US fiscal and trade deficit to GDP ratios, the nominal factor, real wages, oil consumption, excess liquidity, the real short term rate and term spread, real housing prices, the US$ exchange rate index, stock market volatility, the size and value Fama-French factors, the Carhart momentum factor, the Pastor-Stambaugh liquidity factor, the Adrian-Etula-Muir leverage factor, the Working-T speculative index, the futures market basis, oil inventories, the real oil price, nominal oil price volatility, the real non-energy commodities price index, real stock market prices, real gold prices and the Bagliano-Morana economic/financial fragility index.

As a caveat it should be recalled that the identified shocks may be sensitive to the ordering of the variables, requiring therefore economic motivations.

[4]Detailed results on PCA and unit root testing are not included for reasons of space, but are available from the author upon request. Further details on data construction can also be found in the working paper version of this article. See Morana (2011c).

The selected ordering is then based on the following rationale concerning the working of the oil market:

• the oil market supply side is constrained by geophysical conditions, reacting therefore with (at least one quarter) delay to macro-financial conditions;

• oil consumption is contemporaneously determined by the state of the world business cycle;

• inventories are contemporaneously affected by oil market demand and supply side conditions, as well as fundamental and non fundamental financial factors;

• the real oil price and nominal oil price volatility are contemporaneously determined by oil market supply side, flow and financial oil demand conditions, and inventories; they also react with delay to additional fundamental financial factors.

Moreover, concerning macro-financial interactions, it is assumed that:

• real activity, over the business cycle, is determined by labor market conditions, through a short-run production function;

• the fiscal/trade stance contemporaneously adjust to business cycle conditions;

• aggregate demand then feedbacks with delay to aggregate supply, and prices adjust according to their interaction;

• real wages contemporaneously react to aggregate demand and supply developments, and prices as well;

• the liquidity stance, set (by central banks) according to the state of the business cycle, contemporaneously determines the real short-term interest rate, also impacting on asset prices and financial risk;

• liquidity, consistent with a leaning-against-the-wind strategy followed by central banks, may then respond to asset prices and financial risk developments only with (at least one-quarter) delay.

Three main sets of structural shocks are then identified by means of the assumed recursive structure, i.e. oil market supply side, macroeconomic and financial shocks, in addition to two *other* shocks, related to the real oil price and nominal oil price volatility, and two *preference* shocks, related to oil consumption and inventories. The recursive structure implies that oil market supply side variables are *relatively* exogenous to macroeconomic and financial shocks, and that macroeconomic (and oil consumption) variables are relatively exogenous to financial factors. Differently, inventories, the real oil price and nominal oil price volatility are endogenous relatively to oil market supply side, macroeconomic and (most of the) financial variables. Structural macroeconomic shocks are therefore contemporaneously orthogonal to structural oil market supply side shocks; similarly, structural financial shocks are contemporaneously orthogonal to structural oil market supply side and macroeconomic shocks. Within each set of shocks, the same reasoning applies, i.e. for any two variables in the ordering, the leading one is relatively exogenous to the one which follows.

As the implied recursive structural model is exactly identified, the assumed (weak exogeneity) restrictions cannot be tested. Yet, pairwise LM weak exogeneity testing can always be carried out to gauge further evidence on data properties. A joint test, based on the Bonferroni bounds principle, carried out using the 528 possible bivariate tests, implied by the recursive structure, which can be computed out of the 33 variables, would not reject, even at the 20% significance level, the weak exogeneity null hypothesis.[5] While this result cannot be taken as a validation for the set of restrictions at the system level, it however suggests that the implied pair wise recursive structure would not be rejected by the data.

Concerning the block of physical oil market variables, eight structural shocks can then be identified, i.e. an *oil reserves* shock, *net positive* and *negative production* shocks, a *refinery margins* shock, *oil consumption* and *inventories preferences* shocks, and *other real oil price* and *nominal oil price volatility* shocks.

The interpretation of the *own equation* shocks in terms of reserves, net production and refinery margins shocks is clear-cut, each of the latter accounting for about 100% of the own variable fluctuations at the impact (see below for details). The interpretation of the oil consumption and inventories own shocks in terms of preferences shocks, depends on the former being net of the contemporaneous effect of the macroeconomic variables driving flow oil demand, and the latter also of the effect of the (financial) variables driving financial oil demand; hence, the latter shocks captures changes in oil consumption and inventories which are unrelated to macroeconomic and financial fundamentals. Similarly for the real oil price and nominal oil price volatility own shocks, to which we do not attach an economic interpretation, and which are simply referred to as *other* real oil price and nominal oil price volatility shocks. Supporting evidence is also provided by the impulse response analysis (see below for details).

Moreover, concerning the block of macroeconomic variables, eight structural shocks can be identified, i.e. a *labor supply* shock, a (*negative*) labor demand shock, an *aggregate demand* shock, a *fiscal stance* shock, *US fiscal* and *trade deficit* shocks, a *core inflation* shock and a *productivity* shock.

The interpretation of the shocks is grounded on economic reasoning and

[5] The value of the test is 0.005 to be compared with a 20% critical value equal to 0.0004. Details are available upon request from the author.

correspondence in FEVD and impulse response properties.[6] For instance, consistent with economic theory, a positive labor supply shock (upward shift in the labor supply schedule) would induce a negative long-term correlation between employment (1.3%) and the real wage (-1.3%), while a positive correlation is induced by a (negative) labor demand shock (downward shift in the labor demand schedule; -0.10%, employment, short-term; -0.33%, real wage, long-term); the labor supply and demand shock also account for 90% of employment and unemployment rate fluctuations in the very short-term, respectively.

A positive aggregate demand shock (upward shift in the aggregate demand schedule) induces a permanent positive correlation in aggregate activity (0.29%) and the price level (0.02%), while a negative correlation is induced by the productivity shock (rightward shift in the aggregate supply schedule) (0.7%, real activity, long-term; -0.01%, price level, short-term); while the aggregate demand shock accounts for 80% of real activity fluctuations in the very short-term, impacting on real activity more strongly in the very short-term (0.67%) than in the long-term, the productivity shock is the largest contributor to real activity long-term fluctuations (20%), affecting real activity more in the long-term than in the short-term (0.3%).

The core/expected inflation shock (upward shift in the short-term Phillips curve) accounts for 60% of nominal factor fluctuations in the very short-term, inducing a positive short-term correlation between the nominal factor (0.05%, long-term) and the unemployment rate (0.19%, short-term).

Due to the ordering, fiscal stance and US fiscal and trade deficit shocks are orthogonal to global business cycle shocks (aggregate demand, labor demand and supply shocks). Therefore, they reflect growing global imbalances, unrelated to fundamental business cycle developments; a negative impact on real activity can be noted in all cases (-0.5%, fiscal stance; -0.23%, US fiscal deficit; -0.4%, US trade deficit); also, they account for 58%, 85%, and 80% of fluctuations in the own variable in the very short-term.

Finally, concerning the block of financial variables, seventeen structural shocks can be identified. The shocks can be collected into two groups, i.e. fundamental and non fundamental shocks; fundamental shocks can then be further decomposed into three groups, i.e. liquidity and interest rates, risk factors and portfolio shocks. Among the fundamental financial shocks, the *excess liquidity* shock, *risk-free* rate and *term spread* shocks belong to the former group; *risk aversion*, *size*, *value*, *leverage*, *stocks' liquidity*, *momen-*

[6] Results concerning the structural interpretation of macroeconomic and fundamental financial shocks are not reported for reasons of space. A full set of results is however available upon request from the author.

tum, and *fragility index* shocks belong to the middle group; *real stock market, housing, gold,* and *non energy commodity index* prices shocks belong to the latter group; an *US$ exchange rate index* shock could also be included in the latter category. Among the non-fundamental shocks, two oil futures market speculative shocks are considered, i.e. *Working's-T* and *futures basis* shock.

The excess liquidity shock accounts for 35% of excess liquidity fluctuations in the very short-term and leads to a permanent contraction in the real short-term interest rate (-0.07%), as well as in the real long-term interest rate (-0.03%, implied by the 0.04% increase in the term spread following the shock). Being net of the contemporaneous effect of (oil market supply side and) macroeconomic and liquidity shocks, the risk-free rate shock may be interpreted in terms of a short-term bond risk premium shock. The latter accounts for 30% of short-term real interest rate fluctuations in the very short-term. Being also net of the contemporaneous effect of the risk-free rate shock, the term spread shock is related to unexpected changes to the long-term rates, i.e. to revision in expectations about future business cycle conditions; it accounts for 64% of term spread fluctuations in the very short-term.

The risk aversion, size, value, leverage, stocks' liquidity, and momentum factor shocks account for 60%, 54%, 56%, 35%, 51% and 54% of stock market volatility, size, value, momentum, stocks' liquidity and leverage factors fluctuations, respectively, in the very short-term. Being contemporaneously orthogonal to (oil market supply side and) macroeconomic, liquidity and interest rates shocks, the risk factors shocks measure revisions in market expectations about future fundamentals. Moreover, the economic and financial fragility index shock accounts for 15% of the economic and financial fragility index fluctuations in the very short-term, and, being orthogonal to all the other shocks considered in the model, it then bears the interpretation of *residual* fragility shock.

In addition, being net of the contemporaneous effect of (oil market and) macroeconomic, liquidity and interest rates, and risk factors shocks - apart from housing prices and the exchange rate index-, the real stock market, housing, gold, and non energy commodity index prices shocks bear the interpretation of preference/portfolio shocks; the latter account for 21%, 68%, 24% and 38% of very short-term fluctuations in the corresponding variables, respectively. Similarly the US$ exchange rate shock, accounting for 50% of the US$ exchange rate index fluctuations in the very short-term.

Finally, the oil futures market speculative shocks, i.e. the Working's-T and futures basis shocks account for 55% (each) of Working's-T and futures basis fluctuations in the very short-term, respectively. Their interpretation in terms of oil futures market speculative shocks follows from their positive impact on both the oil futures and spot price, also affecting inventories at various horizons, in addition to being orthogonal to the set of macroeconomic and financial shocks driving flow and fundamental financial oil demand.

5 Forecast error variance decomposition

Median forecast error variance decompositions have been computed up to a horizon of ten years (40 quarters). Results for the oil market variables are reported in Table 1, for selected horizons; for expository purposes, we denote as very short-term the horizon within 2 quarters, short-term the horizon between 1 and 2 years, medium-term the horizon between three and five years, and long-term the 10-year horizon. Rather than focusing on the contribution of each structural shock, results are discussed with reference to various categories of shocks, distinguishing among oil market supply side shocks (SUP: reserves, net negative and positive production, refinery margins), oil consumption preferences shocks (C), inventories preferences shocks (INV), macroeconomic shocks (MAC: labor supply and demand, aggregate demand, fiscal stance, US fiscal and trade deficit, core inflation and productivity), fundamental financial shocks (FIN: excess liquidity, risk-free rate, term spread, real housing prices, risk aversion, size, value, momentum, stocks' liquidity and leverage factors, real non-energy commodity price index, real stock prices, real gold prices, economic and financial fragility index, (other) nominal oil price volatility), US$ exchange rate index shocks (X), speculative/non fundamental financial shocks (SPC: Working's-T index, futures basis), (other) real oil price shocks (OP). In both cases the contribution of the own shock (OWN) is isolated from the overall contribution: for instance, with reference to oil reserves, the SUP category would not include the reserves variable, whose contribution is reported under the OWN category.[7]

5.1 Oil consumption and production

According to the results of the forecast error variance decomposition, oil consumption and production would be similarly *exogenous* in the very short-term, yet similarly *endogenous* already in the short-term. In fact, the own shock would account for about 80% of oil consumption fluctuations in the very short-term and 60% at longer horizons; similarly for net oil production changes, i.e. 70% and 90% for negative and positive changes, respectively, in the very short-term, and about 50% in both cases since the two-year horizon.

[7] A full set of results is available upon request from the author.

Macroeconomic shocks would sizably contribute to oil consumption fluctuations already in the very short-term (20% within 1-quarter), as well as in the medium- to long-term (16%); similarly for financial shocks (12%). Moreover, net oil supply contractions would be more affected by macroeconomic (20% since the 1-year horizon) than financial shocks (up to 18%), and the other way around for net oil supply increases (10% and up to 30%, respectively).

Overall, the sizable proportion of oil production and consumption variability accounted for by the own shocks, also in the medium- to long-term, would be consistent with the presence of geophysical constraint in the former case, and rigidities in oil consumption patterns, small, and declining over time, income and price elasticities, and low substitutability among energy sources, in the latter case.

Even stronger endogeneity is shown by both reserves and refinery margins in the short-term. For instance, the own shock accounts for 40% and 20% of fluctuations at the two- and five-year horizon, respectively, for both variables; macroeconomic and financial shocks jointly explain 50% of reserves fluctuations since the two-year horizon, while (other) oil market supply side shocks up to 20% in the medium- to long-term; similarly for refinery margins fluctuations, i.e. 20% and 40% (each) at the two-year horizon and in the medium- to long-term, respectively. The evidence is then consistent with the view that macro-financial developments may create incentives for oil producers in engaging in reserves discovery activities and investment, as well as that refinery margins are tuned according to the state of the business and financial cycle.

5.2 Oil inventories and futures market variables

Also inventories would be strongly endogenous, the own shock accounting for only 40% of fluctuations in the very short-term and 20% in the long-term. Both oil market supply side (12% in the medium- to long-term) and oil consumption (10% in the short-term) shocks, as well as macroeconomic (20% to 30%) and fundamental (20% to 25%) and non fundamental (4% to 7%) financial shocks, would sizably contribute to inventories fluctuations. In particular, the relevance of financial shocks for inventories fluctuations is consistent with the existence of a financial demand for oil, as the latter would influence the real oil price through inventories.

Both the Working's-T (WT) and futures basis (FB) would be fairly endogenous as well, the own shock accounting for about 50% of fluctuations in the very short-term in both cases; 40% and 20% in the short- and long-term, respectively, for WT; 20% and 15% for FB. Fundamental financial shocks would yield a sizable contribution to fluctuations in both variables in the very short-term (20%), while macroeconomic shocks in the short- to long-term (20% to 40% for WT; 30% for FB); a sizable contribution is also yield by oil market supply side shocks (up to 16%; long-term). Once accounted for the common fundamental information, residual fluctuations in FB and WT appear to be strongly unrelated; the proportion of FB variance explained by the WT shock is not larger than 0.3%, and the other way around. The two variables would therefore convey complementary information concerning the role of excess speculation in the oil futures market, justifying their joint inclusion in the model.

5.3 Real oil price and nominal oil price volatility

Strong endogeneity is also shown by the real oil price at any horizon, the own shock accounting for 20% of fluctuations in the very short-term, and for no more than 10% at any other horizon; similarly for nominal oil price volatility (30% in the very short-term; 15% in the long-term). Macroeconomic and fundamental financial shocks would jointly account for the bulk of real oil price fluctuations at any horizon (70% in the very short-term; 60% in the long-term), with macroeconomic shock yielding a larger contribution than financial shocks (up to 50% and 25%, respectively, short-term; 40% and 20%, respectively, medium- to long-term). The contribution of macroeconomic and fundamental financial shocks to nominal oil price volatility fluctuations is also sizable, and larger for financial than macroeconomic shocks in the long-term (15% in the short-term; 30% and 5%, respectively, in the long-term); macro-financial shocks would then jointly account for 25% of nominal oil price volatility fluctuations in the very short-term; 45% and 35% in the short- and long-term, respectively.

Among fundamental financial shocks, risk factors shocks (up to 30%; not reported) would be the main determinant of nominal oil price volatility fluctuations, while liquidity and interest rates shocks (up to 15%; not reported) would matter most for the real oil price; risk factors (10%; not reported) and portfolio (up to 10%) shocks would also yield a sizable contribution to real oil price fluctuations. Moreover, among macroeconomic shocks, aggregate demand (up to 20%; not reported), US trade deficit and productivity shocks (up to 14% each; not reported) would matter most for the real oil price, while labor supply shocks for nominal oil price volatility (up to 7%; not reported).

Also, non fundamental financial shocks would yield a larger contribution to real oil price fluctuations in the medium- to long-term (5%) than in the short-term, and the other way around for nominal oil price volatility (5% in the very short-term); a larger role for oil market supply side shocks is also found for nominal oil price volatility than the real oil price (15% to 30%

and 5% to 10%, respectively); similarly for US$ exchange rate shocks (up to 10% and 5%, respectively) and inventory shocks (up to 5%, respectively); conversely, oil consumption shocks would more sizably contribute to real oil price than nominal oil price volatility fluctuations (up to 10% and 5%, respectively).

Finally, real oil price and nominal oil price volatility own shocks negligibly account for each other fluctuations (1%; not reported).

6 Impulse response analysis

Concerning the transmission mechanisms of the structural shocks, the impulse response analysis is reported in Figures 1-2 for the real oil price and in Tables 2-4 for all the oil market variables, over selected horizons, as for the forecast error variance decomposition analysis. In all cases median cumulated responses have been computed with 90% significance bands.[8] In the tables significant figures at the 10% level, are shown in bold.

6.1 Oil market shocks

Oil market supply side shocks Firstly, a (unitary and permanent) positive *reserves* shock would lead to a sizable short-term contraction in the real oil price (-1%; Table 3, Panel C). A temporary negative effect can also be noted on the futures basis, strongly declining within two quarters (-1.9%, Table 4, Panel B), consistent with the market expecting lower real oil prices in the future. Both nominal oil price volatility (-0.75%, Table 4, Panel C) and excess speculation (Working's-T, -0.34%, Table 5, Panel A) would be permanently dampened.

Secondly, a *negative net production* shock (downward shift in the flow oil supply) would lead to a short-term increase in the real oil price (3.3%) and nominal oil price volatility (0.7%), yet to a long-term contraction in nominal oil price volatility (-1%). The futures basis also increases in the very short-term only (0.63%), consistent with expected higher oil prices and weaker fundamentals in the future. A permanent negative impact on excess speculation (Working's-T index) can finally be noted (-0.6%). Note also that, in the expectation of future oil supply shortfalls, inventories (0.3%) and refinery margins (0.82%) are permanently increased for precautionary reasons.

[8] Non cumulated responses are only reported for the futures basis and the stocks' liquidity and leverage factors.

Differently, a *positive net production* shock (upward shift in the flow oil supply) would lead to a contraction in the real oil price in the short-term (-1.9%), but to a permanent increase in nominal oil price volatility (1.3%). The futures basis increases in the short-term (1.1%), consistent with expected stronger future flow oil demand. Inventories and oil consumption are also increased in the short-term (0.18% and 0.09%, respectively), stimulated by the reduction in the real oil price. A transitory negative impact on excess speculation can finally be noted (-0.15%).

Thirdly, a positive *refinery margins* shock would lead to a permanent contraction in the real oil price, which is already sizable in the short-term (-2% within 2 quarters; -1.4% at the 10-year horizon), consistent with a shift in the production mix favoring (relatively less expensive) medium and heavy sour crudes. The futures basis then contracts at the outset (-1.1%), while excess speculation increases in the short-term (0.17%). The impact on nominal oil price volatility is also permanent and sizable (0.5%).

Oil market demand side shocks Fourthly, concerning the effects of oil consumption and inventories preferences shocks, a positive *oil consumption* shock would lead to a permanent increase in the real oil price (3.3%), yet dampening nominal oil price volatility (-0.39%). The futures basis increases in the very short-term (1.2%), consistent with the expectation of stronger demand also in the future, while excess speculation (Working's-T) in the short-term (0.13%). The shock also permanently increases oil production and refinery margins (0.14% and 0.28%), while inventories are drawn down in the short-term (-0.3%) in order to smooth consumption. Differently, a positive *inventories* shock would lead to a permanent contraction in the real oil price (-2.3% in the short-term; -0.93% in the long-term), dampening nominal oil price volatility (-0.56%) and stimulating oil consumption in the short-term (0.07%). The futures price contracts less than the spot price in the short-term, fully adjusting in the medium- to long-term, and therefore leading to a temporary increase in the futures basis (1.3%); refinery margins would also permanently contract (-0.1%).

Other real oil price and nominal oil price volatility shocks Consistent with oil being traded as a financial asset, a positive risk-return relationship can be noted, as a positive *other nominal oil price volatility* shock would lead to a permanent increase in the real oil price (1.1%). The level of the oil price would also matter for oil price uncertainty, as a positive *other real oil price* shock would lead to a permanent increase in nominal oil price volatility (0.21%). Hence, a bidirectional linkage can be found for the real oil price level and nominal oil price volatility.

Moreover, positive real oil price and nominal oil price shocks would lead to an increase in the futures price, smaller than for the spot price for the former shock and larger for the latter one, in the short-term. Hence, a temporary contraction (-0.44%) and a temporary increase (0.3%) in the futures basis are observed, respectively. Excess speculation would also be permanently increased by the real oil price shock (Working's-T, 0.06%), while dampened in the short-term by the nominal oil price volatility shock (Working's-T, -0.14%). Finally, the real oil price shock would lead to a short- to medium-term contraction in oil consumption (-0.03%) and a short-term drawing down in inventories (-0.05%) to smooth oil consumption; refinery margins permanently decrease (-0.05%), consistent with the contraction in oil demand.

6.2 Macroeconomic shocks

Business cycle and productivity shocks Firstly, the evidence is consistent with the view that macroeconomic fundamentals determine the real oil price by shifting flow oil demand according to the state of the business cycle; in fact, positive *labor supply*, *aggregate demand*, and *labor demand*[9] shocks would all exercise a sizable, positive impact on the real oil price at various horizons.

The strongest effect is shown by the aggregate demand shock at all horizons, leading to real oil price overshooting (6.6% very short-term; 3.6% long-term); differently, the impact of the labor supply (employment) shock builds gradually over time (0.86% very short-term; 2.3% long-term), while the effects of the labor demand shock would fade away in the medium-term (2.13% very short-term; 0.63% medium-term). Coherently, oil consumption increases, particularly in the short-term (0.13%, 0.21% and 0.11%, respectively); moreover, inventories are drawn down (-0.30%) and refinery margins increased (0.14%), in order to smooth consumption.

An improvement in economic conditions would also lead to the expectation of a higher real oil price in the future, as revealed by the futures basis permanently increasing following the labor supply (0.3%) and demand (0.16%) shocks, as well as the aggregate demand (0.32%; medium-term) shocks; excess speculation in the oil futures market would be dampened by the two former shocks (-0.23% and -0.26%), yet increased by the latter one (0.13%).

Secondly, a positive *productivity* shock would also increase oil consumption (0.2% very short-term; 0.15% long-term), and refinery margins (0.44%

[9] In the impulse response tables, figures correspond to the effects of a negative labor demand shock; signs should then be reversed in order to gauge the effects of a positive shock.

long-term). The negative impact on the real oil price (-3.8% very short-term; -2.1% long-term) may be explained through a mechanism involving financial oil demand, as the productivity shock would lead to a long-term liquidity contraction (-0.5%; not reported) and a long-term increase in the real short-term interest rate (0.11%; not reported), both determining a contraction in the real oil price (see below for details). The increase in refinery margins triggered by the shock might also contribute to the real oil price contraction.

Thirdly, in general, business cycle shocks would exercise a dampening effect on nominal oil price volatility, which is permanent for the labor demand (-0.46%) and productivity (-0.29%) shocks and transitory for the aggregate demand shock (-0.35%); differently, a destabilizing effect can be noted for the labor supply shock (0.48%).

Fourthly, the evidence is also consistent with the view that the oil supply is managed according to the state of the business cycle. In fact, positive labor supply (0.11%) and aggregate demand (0.17%) shocks would lead to an increase in oil production, i.e. to an upward shift in the flow oil supply function; yet, only aggregate demand shocks would leave permanent effects on oil production (0.12%).

Other macroeconomic shocks Fifthly, a worsening in global economic conditions, as signaled by positive *core inflation* (N), *fiscal stance* (G) and *US fiscal deficit* (Fd) shocks, would lead to a contraction in oil consumption and production, most sizable in the short-term (-0.13% and -0.02%, N; -0.05% and -0.18%, G; -0.14% and -0.09%, Fd), and to a permanent contraction in the real oil price (-1.7%, -1.8% and -1.2%, respectively); as a positive *US trade deficit* shock would lead to a long-term contraction in the real interest rate (-0.04%; not reported), its positive impact on the real oil price may then be explained through a financial oil demand effect (see below for details), as well as the short-term contraction in refinery margins triggered by the shock (-0.08%). Finally, mixed transitory effects can be found for nominal oil price volatility, increasing following the US fiscal deficit (0.59%) and core inflation (0.12%) shocks, and contracting following the fiscal stance (-0.12%) and US trade deficit (-0.18%) shocks.

6.3 Financial shocks

Excess liquidity and interest rate shocks Firstly, a positive *excess liquidity* shock would lead to a permanent contraction in the real short-term interest rate (-0.07%; not reported) and increase in the real oil price (2.3%); a short-term increase in the oil futures basis (1.5%) and contraction in nominal oil price volatility (-0.21%) can also be noted; coherently, inventories permanently increase (0.22% in the short-term; 0.09% in the long-term) and refinery margins contract (-0.1%). A long-term dampening effect on excess speculation (Working's-T, -0.86%) and oil consumption (-0.07%) is also found.

The above linkage between excess liquidity, the real interest rate, inventories, and the real oil price is then fully consistent with various mechanisms implying the existence of a fundamental financial demand for oil; for instance, a contraction in the real interest rate might lead to a higher real oil price by lowering the cost of holding inventories for traders and slowing down the rate of extraction for producers, as well as through lower discounting of the expected future stream of convenience yields; also, some evidence of overshooting in the real oil price, reminiscent of the Dornbusch-type monetarist mechanism, can be noted: in fact, following the excess liquidity shock, the real oil price would overshoot its long-term value after one quarter (3%; not reported), then undershoot it within one-year (1.5%), to overshoot it again within two years (2.6%), finally stabilizing after five years (2.3%)[10]; moreover, excess liquidity may lead to an increase in the demand for oil as a financial asset through a portfolio rebalancing/diversification mechanism: following the excess liquidity shock real commodity prices increase (2.3% oil; 2.2% gold and 1.1% non energy commodities; not reported), while real stock and housing prices contract (-0.09% and -0.56%, respectively; not reported).

An inverse relationship between the real interest rate and the real oil price can also be noted, as a positive *risk-free rate* shock would lead to a permanent contraction in the real oil price (-0.67%), as well as in the futures price, the basis being only increased in the short-term (1%); consistent with Hotelling (1931), an increase in oil production in the short- to medium-term can also be noted (0.03%), as well as a permanent increase in reserves (0.38%); while nominal oil price volatility is left unaffected, oil inventories (0.11%) and consumption increase (0.12%, short-term) in response to the lower real oil price.

Asset prices (portfolio) shocks Secondly, a similar pattern can be detected concerning the effects of the *portfolio* shocks; in fact, positive *real stock market*, *housing*, *non energy commodities* and *gold* price shocks would lead to a permanent increase in the real oil price (1.1%, 2.3%, 0.32% and 1.3%, respectively), the futures basis being also increased in the short-term (0.14%, 1.1%, 0.36% and 0.57%, respectively); an increase in excess specula-

[10]Note that the above dynamics are not strictly comparable with what predicted by the monetarist mechanism, as the latter refers to the effect of a temporary increase in liquidity, while the identified liquidity shock is a permanent one.

tion (Working's-T), following the real housing and stock market price shocks (0.06%, 0.11%), as well as a permanent building up of inventories, apart from the stock market shock (0.16%, 0.04% and 0.08%), can also be noted. The above interactions are then consistent with an asset price channel and the existence of a fundamental financial demand for oil. Interestingly, only the real gold price shock would lead to a permanent increase in nominal oil price volatility (0.21%).

Thirdly, a positive US$ exchange rate index shock (depreciation shock) would lead to a permanent increase in the real oil price (2.5%), nominal oil price volatility (1.1%), excess speculation (Working's-T, 0.27%), and in the futures basis (0.45%; short- to medium-term only). Refinery margins also permanently contract (-0.2%), while inventories, albeit drawn down in the short-term (-0.18%) to smooth consumption, do increase in the long-term (0.14%). A US$ depreciation would then lead to a higher real oil price by contracting refinery margins and stimulating excess speculation in the futures market.

Risk factors shocks Fourthly, a worsening in economic and financial stability conditions, as measured by positive *risk aversion*, *value* and *leverage* factor shocks, and negative *size*, *stocks' liquidity*, *momentum* and *term spread*[11] shocks[12], would lead to a contraction in the real oil price: in the short-term following the risk aversion and value factor shocks (-0.97% and -1.18%, respectively), as well as in the long-term following the size, momentum, stocks' liquidity, leverage and term spread shocks (-0.93%, -0.55%, -0.65%, -2.2%, -0.48%, respectively).

A reduction in the futures basis (-0.27% to -1.2%) and in excess financial speculation (Working's-T; -0.12% to -0.59%, apart from the leverage and term spread shocks) can also be noted at various horizons.

The effects on oil price volatility and inventories are mixed. In fact, volatility would be dampened by the value, momentum, and stocks' liquidity shocks (-1.2%, -0.91%, -0.27%), yet stimulated by the risk aversion, size,

[11] In the impulse response tables, figures correspond to the effects of a positive term spread shock; signs should then be reversed in order to gauge the effects of a negative shock.

[12] During economic downturn, small firms are more strongly affected than large firms (negative size shock), investors shift from growth to value stocks (*flight to quality;* positive value shock), stock returns are in general negative (negative momentum shock), uncertainty and risk aversion increase (positive risk aversion shock), portfolio are rebalanced favoring (safer) bonds over stocks (negative stocks' liquidity shock), credit and liquidity conditions worsen (positive fragility shock), monetary policy is accommodative (negative term spread shock); moreover, the higher is the leverage and the lower the resilience of the financial system (positive leverage shock).

leverage and term spread shocks (0.32%, 0.25%, 0.34%, 0.31%); also, inventories would be drawn down following risk aversion, momentum, leverage and term spread shocks (-0.1% to -0.37%), yet accumulated following size, value and stocks' liquidity shocks (0.08% to 0.3%).

Differently, a positive *fragility* shock would lead to a short-term increase in the real oil price (0.22%) and the futures basis (0.24%) and to a permanent increase in oil price volatility (0.09%).

Overall, the effects of risk factors shocks on the real oil price can be explained through a liquidity effect: in fact, excess liquidity would increase following the positive fragility shock (0.11%; not reported), therefore contributing to increasing the real oil price; also, following positive value and leverage shocks, as well as negative momentum and size shocks, excess liquidity would decrease (-0.49%, -0.31%, -0.14%, -0.72%; not reported), therefore leading to a contraction in the real oil price; differently, positive risk aversion and negative stocks' liquidity shocks would lead to an increase in liquidity (0.30%, 0.09%; not reported) and therefore in the real oil price. Moreover, the negative effect of the term spread shock on the real oil price can be related to decreased oil consumption (-0.11% short-term; -0.05% long-term), production (-0.07% short-term; -0.02% long-term) and inventories (-0.1%), as triggered by the shock, and therefore to flow oil demand and supply interactions, in the expectation of a worsening in economic conditions.

Oil futures market speculative shocks Following positive *Working's-T* and *futures basis* shocks, the real oil price would increase 0.3% in the very short-term, and 0.6% and 2.4%, respectively, in the long-term; the impact on the futures basis is also positive, yet transitory (0.08% and 4.4%, respectively); the impact on nominal oil price volatility would also be permanent, yet negative (-0.2% and -0.1%, respectively), pointing to a significant *liquidity effect* associated with non fundamental financial shocks in the oil futures market. Moreover, while a permanent accumulation of inventories can be noted following a positive Working's-T shock (0.2%), a contraction can be observed following a positive futures basis shock (-0.15%): the latter finding may be related to consumption smoothing as, following the sizable real oil price increase triggered by the futures basis shock, oil consumption contracts also in the long-term (-0.03%).

Interestingly, the futures basis shock would permanently and negatively affect also oil production (-0.03%) and refinery margins (-0.07%). Hence, non fundamental financial shocks may lead to a higher real oil price, also without affecting (above ground and offshore) inventories: this would entail a downward shift in the flow oil supply schedule, possibly in the expectation of a downward shift in flow oil demand, triggered by the higher real oil price, and a shift in the production mix in favor of (relatively more expensive) light crudes, still in the expectation of a future slow down in demand and less binding margins. The downward shift in the flow oil supply schedule is also consistent with an *oil in the ground* type of policy, i.e. the underground accumulation of inventories by oil producers, through slowing down the extraction rate.

7 Historical decomposition: the oil price-macro-finance interface

In order to gauge the effects of various categories shocks on the level of the real oil price and nominal oil price volatility, as for the forecast error variance decomposition analysis, in Figures 3-4 the cumulative historical decomposition (net of base prediction) for the real oil price growth rate and nominal oil price volatility changes, over the period 1986:4 through 2010:3, is reported. To facilitate visual inspection, the initial value is set equal to zero in all cases and a spline smoother is also plotted in the graphs.

A shown in Figure 3, macroeconomic shocks were the major upward driver of the real oil price over the whole period investigated; financial shocks sizably contributed to increasing the real oil price since early 2000s as well, and even more since mid 2000s, fundamental dominating non fundamental financial shocks; inventories shocks and *other* real oil price shocks contributed as well, albeit at a smaller extent; similarly US$ exchange rate and oil market supply side shocks since early 2000s. Differently, the oil consumption preferences shock was a downward driver of the real oil price over the whole period investigated, consistent with a substitution pattern favoring other energy sources.

Moreover, as shown in Figure 4, oil market supply side shocks were the major upward driver of nominal oil price volatility; oil consumption and inventories shocks also yield a minor contribution to increasing nominal oil price volatility over the whole period considered, and similarly US$ exchange rate shocks since mid 2000s. Macroeconomic and fundamental financial shocks, as well as nominal oil price volatility shocks, contributed to stabilizing the nominal oil price over the whole period investigated, as well as non fundamental financial shocks since mid 2000s. While the stabilizing contribution of financial shocks can be understood in terms of a liquidity effect, the Great Moderation phenomenon, and the progressive disinflation achieved by improved US monetary policy management over the period considered, may explain the dampening effect of macroeconomic shocks on nominal oil price volatility. Finally, the smaller contribution of oil market supply side shocks to real oil price fluctuations since early 2000s (Figure 3), yet the positive contribution to nominal oil price volatility (Figure 4), may be understood as a US CPI price index effect.[13]

Moreover, in Figure 5 and 6 the decomposition of the financial component for both variables, relatively to the sub categories of liquidity and interest rate shocks (MP: excess liquidity, risk-free rate, term spread), portfolio allocation shocks (PA: real housing, stocks, gold, and non energy commodity index prices) and risk factors shocks (RF: risk aversion, size, value, momentum, stocks' liquidity, leverage and fragility factors) is plotted. In the latter plots, the non fundamental and fundamental financial components are also contrasted for both series.

As shown in Figure 5, among the fundamental financial shocks, portfolio allocation shocks were the main upward driver of the real oil price, particularly since mid 2000s; also liquidity and interest rate shocks contributed to increasing the real oil price, particularly over the 1990s and since mid 2000s; while risk factor shocks, in general, contributed to decreasing the real oil price over the sample investigated, a sizable positive impact can however be noted in 2006 and 2007.

Also, as shown in Figure 6, liquidity and interest rate shocks contributed to decreasing nominal oil price volatility over the sample investigated; differently, the evidence for portfolio allocation and risk factors shocks is not clear-cut.

Risk factors shocks were also the main determinant of the fundamental financial component for both the real oil price and nominal oil price volatility; also liquidity/interest rate shocks and portfolio allocation shocks sizably contributed to determining the fundamental financial component, and the former more than the latter for the real oil price. Finally, the dominance of the fundamental over the non fundamental financial component is a clear-cut finding for both the real oil price and nominal oil price volatility.

The third oil price shock episode The 2007-2009 oil price episode surely stands out for both the very high nominal oil price level (US$ 140, July 2008), comparable in real terms with the second oil price shock, and volatility (100 US$ drop within 5 months; US$ 40, December 2008). As reported in Table 5, over the period 2004:1 through 2010:3, the real oil price increased 65%; of the latter, 44% is jointly accounted by fundamental (33%) and non

[13] If o is the log real oil price and p log US CPI, the variance of the log nominal oil price $(p + o)$ is $V_{p+o} = V_p + V_o + 2Cov(p, o)$. Hence, when V_o contracts, V_{p+o} may increase, decrease or remain unchanged, depending on changes occurring in V_p and $Cov(p, o)$.

fundamental (11%) financial shocks; macroeconomic and oil market supply side shocks contributed with a 5% and 3% increase, respectively; finally, 13% is jointly accounted by inventories (3%), *other* real oil price and oil consumption (5.5% each), and US$ exchange rate (-1%) shocks. Over the same period, nominal oil price volatility cumulatively increased 1%, as the result of fundamental (-4%) and non fundamental (-3%) financial shocks, macroeconomic (-4%), oil consumption (-2%) and other nominal oil price volatility (-4%) shocks dampening the destabilizing effects of oil market supply side (14%), inventories (1%), and US$ exchange rate (2%) shocks.

Despite the large contribution of financial shocks to the real oil price increase since 2004, it would be inaccurate describing the *third oil price shock* as a purely "financial" episode. As shown in Table 5, the 2007-2008 episode is a macro-finance episode, with macroeconomic factors actually playing a larger role than financial factors.

In fact, the 2007(2) through 2008 (2) real oil price run up (68%) is largely accounted for by macroeconomic shocks. Indeed macroeconomic shock accounted for 6% out of the 9% increase in 2007(2), 7% out of the 15% increase in 2007(3), 14% out of the 17% increase in 2007(4), 14% out of the 6% increase in 2008(1) and 17% out of the 21% increase in 2008(2), i.e. 58% out of the 68% overall real oil price increase. The contribution of fundamental and non fundamental financial shocks to the real oil price increase was positive (6%) in 2007(4), yet negative in 2007(2) and 2008(1) (-4% and -3%, respectively).

Moreover, while the -7% real oil price drop in 2008(3) is accounted for by oil market supply side (-4%) and real oil price idiosyncratic shocks (-7%), the -67% contraction in 2008(4) is jointly accounted for by macroeconomic (-40%) and financial (-14%) shocks, yet with the former largely dominating the latter; similarly for the -31% real oil price contraction in 2009(1) (-26% and -7%, respectively). Over the 2009(2) through 2009(4) period, macroeconomic (21%) and financial (20%) shocks however equally contributed to the 54% real oil price increase.[14]

8 Conclusions

What is the role of financial speculation in the determination of the real oil price? In the light of the contrasting empirical evidence available in

[14] See the working paper version of this article (Morana, 2011c) and Morana (2012) for a macro-finance interface perspective on the first and second Persian Gulf War and the East-Asia crisis oil price episodes.

the literature, the current paper then aims at assessing the contribution of macro-financial interactions to recent oil price dynamics.

The careful and large-scale modelling of the oil market macro-finance interface surely is an important novelty of our study, as we are unaware of previous contributions seeking such an in depth understanding of macro-financial interactions within the oil market. While Kilian and Murphy (2010), by including inventories in their model, do allow for a financial oil demand component and, indirectly, for the effect of future fundamentals on oil demand, our contribution, by conditioning on risk factors, is the first attempt to *directly* measuring their effects. By including measures of excess speculation, our study also aims at disentangling the fundamental and non fundamental components of financial oil demand, which are left indistinct in Kilian and Murphy (2010). We do find that without a careful description of the *financial side*, *shocks* and *transmission mechanisms* which are important to the understanding of the working of the oil market would go neglected.

Secondly, the proposed modelling approach leads not only to confirm previous evidence, but also to important new insights on the determination of the real oil price: while we confirm that, at least since the mid-1980s, macroeconomic shocks were the major upward driver of the real oil price, we also find a sizable contribution of oil market supply side and financial shocks since early 2000s. The contribution of financial shocks to real oil price fluctuations was particularly remarkable since mid-2000s: out of the 65% real oil price increase over the period 2004 through 2010, 44% is related to fundamental (33%) and non fundamental (11%) financial shocks; differently, macroeconomic and oil market supply side shocks contributed with a 5% and 3% increase, respectively. Yet, despite the large contribution of financial shocks, the third oil price shock was a *macro-finance* episode: macroeconomic shocks accounted for 58% out of the 68% real oil price run up over the 2007(2)-2008 (2) period, while financial shocks for 6% in 2007(4); moreover, the -67% and -31% contractions in 2008(4) and 2009(1) are also largely accounted for by macroeconomic shocks (-40% and -26%), yet with financial shocks (-14% and -7%) also sizably contributing; the 54% real oil price increase over the 2009(2) through 2009(4) period is finally equally accounted for by macroeconomic (21%) and financial (20%) shocks.

Hence, while our results are consistent with the demand side view of the real oil price determination, we do also find a larger role for financial shocks than previously noted in the literature. We ascribe the above important findings to the careful modelling of the oil market-macro-finance interface undertaken in this study. In a broader perspective, recent dramatic macroeconomic episodes have reminded of the somewhat forgotten macro-finance interface in macroeconomic analysis; the paper also contributes to this issue, pointing to the importance of better integrating financial shocks and transmission mechanisms within the modelling of oil price and macroeconomic dynamics. Our contribution then provides empirical facts on the oil market-macro-finance interface, as well as methodological insights suitable for more general applications.

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9 Appendix: Estimation of the econometric model

The two-block specification is estimated by means of a two-stage approach.

Firstly, consistent and asymptotically Normal estimation the set of equations in (3) is obtained following the iterative procedure proposed in Morana (2011a); the latter bears the interpretation of QML estimation performed by means of the EM algorithm:

• An initial estimate of the r_1 unobserved common factors in $\mathbf{F}_{1,t}$ is obtained through the application of Principal Components Analysis (PCA) to subsets of homogeneous cross-country data $\mathbf{Z}_i = \{\mathbf{Z}_{i,1}, ..., \mathbf{Z}_{i,T}\}$, $i = 1, ..., r_1$, $r_1 \leq q$;[15] then, an initial estimate of the polynomial matrix $\mathbf{C}(L)$ and the factor loading matrix $\mathbf{\Lambda}$ is obtained by means of OLS estimation of the equation system in (3). This is performed by first regressing $\hat{\mathbf{F}}_t$ on $\boldsymbol{\kappa}_t$ to obtain $\hat{\boldsymbol{\kappa}}_t$; then the actual series $\mathbf{Z}_t$ are regressed on $\boldsymbol{\mu}_t$ and $\hat{\mathbf{F}}_t - \hat{\boldsymbol{\kappa}}_t$ to obtain $\hat{\mathbf{\Lambda}}$ and $\hat{\boldsymbol{\mu}}_t$; $\hat{\mathbf{C}}(L)$ is then obtained by means of OLS estimation of the VAR model for the gap variables $\mathbf{Z}_t - \hat{\boldsymbol{\mu}}_t - \hat{\mathbf{\Lambda}}\left(\hat{\mathbf{F}}_t - \hat{\boldsymbol{\kappa}}_t\right)$ in (3).

• In the E-step the unobserved factors $(\mathbf{F}_{1,t})$ are estimated, given the observed data and the current estimate of model parameters, by means of principal components analysis (PCA), i.e. a new estimate of the unobserved common factors in $\mathbf{F}_{1,t}$ is obtained by means of PCA applied to the filtered variables $\mathbf{Z}_t^* = \mathbf{Z}_t - \left[\mathbf{I} - \hat{\mathbf{C}}(L)\right]\hat{\mathbf{\Lambda}}_*\left(\hat{\mathbf{F}}_{*,t} - \hat{\boldsymbol{\kappa}}_{*,t}\right)$, with $\hat{\mathbf{F}}_{*,t} = \left[\mathbf{F}'_{2,t}\ \mathbf{O}'_t\right]'$, $\hat{\mathbf{\Lambda}}_* = \left[\hat{\mathbf{\Lambda}}'_{F_2}\ \hat{\mathbf{\Lambda}}'_O\right]'$ and $\hat{\boldsymbol{\kappa}}_{*,t} = \left[\hat{\boldsymbol{\kappa}}'_{F_2,t}\ \hat{\boldsymbol{\kappa}}'_{O,t}\right]'$.

• In the M-step the likelihood function is maximized (OLS estimation of the $C(L)$ matrix is performed) under the assumption that the unobserved factors are known, conditioning on their E-step estimate, i.e. conditional on the new unobserved common factors, a new estimate of the polynomial matrix $\mathbf{C}(L)$ and the factor loading matrix $\mathbf{\Lambda}$ is attained as described in the initialization step. Convergence to the one-step QML estimate is ensured, as the value of the likelihood function is increased at each step.

Secondly, consistent and asymptotically Normal estimation of the set of equations in (1) is performed by means of PC-VAR estimation (Morana, 2011b), treating the consistently estimated factors as they were actually observed. The latter is achieved in the following steps:

• PCA is applied to $\mathbf{x}_t \equiv \hat{\mathbf{F}}_t - \hat{\boldsymbol{\kappa}}_t$ and the first s PCs, $\hat{\mathbf{f}}_t$, are computed;

• the dynamic vector regression

[15] For instance, a stock return global factor can be estimated by means of the application of PCA to the vector of cross-country stock return data, and so on.

$$\begin{aligned} \mathbf{x}_t &= \mathbf{D}(L)\hat{\mathbf{f}}_t + \boldsymbol{\varsigma}_t \\ \boldsymbol{\varsigma}_t &\sim I.I.D.\left(\mathbf{0}, \boldsymbol{\Sigma}_{\varsigma}\right), \end{aligned} \tag{8}$$

where $\mathbf{D}(L) \equiv \mathbf{D}_1 L + \mathbf{D}_2 L^2 + ... + \mathbf{D}_p L^p$ features all the roots outside the unit circle, is estimated by OLS to obtain $\hat{\mathbf{D}}(L)$;

• the (implied OLS) estimate of the VAR parameters in (1) is then obtained by solving

$$\hat{\mathbf{P}}(L)_{PCVAR} = \hat{\mathbf{D}}(L)\hat{\boldsymbol{\Xi}}_s',$$

where $\hat{\boldsymbol{\Xi}}_s$ is the matrix of the eigenvectors associated with the first s ordered eigenvalues of $\hat{\boldsymbol{\Sigma}}$ ($\boldsymbol{\Sigma} = E\left[\mathbf{x}_t\mathbf{x}_t'\right]$).

See Morana (2011a,b) for additional details concerning the estimation procedure.

Table 1: forecast error variance decomposition, contributions of subsets of structural shock

World oil reserves

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
2	6.8	0.7	0.3	13.2	0.0	6.1	0.6	0.2	72.1
4	9.3	0.4	0.1	23.9	0.7	9.9	0.3	0.1	55.4
6	9.8	0.9	0.1	30.0	1.1	12.7	0.2	0.1	45.1
8	10.8	1.7	0.1	32.8	1.4	14.5	0.2	0.2	38.3
12	13.1	3.0	0.2	34.1	1.2	17.0	0.1	0.4	30.9
20	16.7	3.7	0.3	34.2	0.8	17.5	0.1	0.6	26.2
40	21.2	3.7	0.2	33.8	0.5	15.4	0.1	0.6	24.5

Oil net production decreases

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	97.0
2	3.4	0.6	0.5	15.3	0.8	7.7	1.0	0.0	70.7
4	2.7	0.6	0.4	21.9	0.5	14.3	0.9	0.1	58.6
6	2.1	0.8	0.4	22.8	0.5	17.7	1.2	0.1	54.5
8	1.8	0.8	0.4	22.6	0.4	17.6	1.7	0.2	54.4
12	1.6	1.2	0.5	22.8	0.4	17.9	1.9	0.2	53.5
20	1.3	1.1	0.6	23.4	0.4	17.9	2.2	0.3	52.7
40	1.2	0.8	0.8	23.6	0.3	17.5	2.7	0.4	52.7

Oil net production increases

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.9
2	0.9	0.4	0.0	3.8	1.0	3.2	0.1	0.0	90.6
4	1.0	0.9	0.6	8.6	1.1	11.8	0.6	0.1	75.3
6	2.5	2.2	1.3	11.1	1.2	19.1	0.8	0.2	61.6
8	3.3	3.7	1.5	11.7	1.1	24.5	0.7	0.2	53.3
12	3.3	5.6	1.3	12.4	1.0	28.8	0.6	0.1	46.8
20	2.9	6.5	1.4	12.1	0.9	30.2	0.5	0.1	45.4
40	2.5	6.7	1.8	11.3	1.0	30.1	0.6	0.1	45.9

Refinery margins

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	99.1
2	2.2	3.9	0.0	7.1	0.1	6.5	0.2	0.3	79.6
4	7.6	12.8	0.1	8.8	0.3	13.3	0.2	0.2	56.6
6	13.8	12.5	0.2	10.2	0.9	16.9	0.1	0.2	45.0
8	19.0	10.6	0.3	13.4	1.3	17.0	0.2	0.2	38.0
12	26.0	8.4	0.3	17.3	1.4	17.0	0.1	0.2	29.2
20	31.1	5.2	0.4	20.5	1.3	17.9	0.2	0.1	23.3
40	36.1	3.8	0.4	22.1	1.2	17.2	0.2	0.1	19.0

Oil consumption

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	3.7	82.6	0.0	13.7	0.0	0.0	0.0	0.0	82.6
2	6.3	66.0	0.7	19.3	0.1	7.3	0.2	0.1	66.0
4	5.8	58.8	0.5	22.0	0.3	12.3	0.3	0.1	58.8
6	6.0	56.3	0.5	22.0	0.6	14.3	0.3	0.1	56.3
8	6.0	55.9	0.5	21.1	0.7	15.4	0.3	0.1	55.9
12	5.8	57.0	0.4	19.4	1.0	16.0	0.3	0.1	57.0
20	6.0	60.1	0.3	17.3	1.3	14.5	0.3	0.1	60.1
40	6.5	63.1	0.2	15.7	1.6	12.4	0.4	0.1	63.1

Inventories

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	2.1	5.7	37.0	21.2	4.7	25.0	4.2	0.0	37.0
2	1.8	10.2	31.2	28.9	3.1	21.2	3.4	0.1	31.2
4	3.0	9.7	31.9	26.7	2.1	22.6	3.9	0.1	31.9
6	4.5	8.5	30.8	27.4	1.6	23.0	4.1	0.1	30.8
8	4.9	8.3	29.0	28.8	1.6	22.4	4.9	0.1	29.0
12	7.9	6.1	25.5	30.4	2.1	21.9	5.9	0.1	25.5
20	10.2	3.7	23.3	31.9	2.3	22.2	6.2	0.1	23.3
40	12.4	2.0	22.2	32.8	2.2	21.7	6.6	0.1	22.2

Oil price

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	7.9	0.0	2.3	44.2	1.9	25.7	0.3	17.7	17.7
2	10.9	3.8	2.5	49.4	3.2	17.2	3.2	9.9	9.9
4	9.1	4.7	3.1	46.9	4.3	17.7	3.3	10.8	10.8
6	7.7	5.8	3.2	43.8	4.6	19.9	3.7	11.3	11.3
8	6.8	7.2	2.8	41.8	5.0	21.0	4.4	10.9	10.9
12	6.0	8.4	2.1	41.0	5.1	22.2	5.0	10.1	10.1
20	5.1	9.9	1.7	39.4	5.4	22.8	5.7	10.0	10.0
40	4.3	10.8	1.4	38.6	5.9	22.9	6.2	9.9	9.9

Oil price volatility

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	20.8	4.6	5.9	10.7	7.3	13.6	6.4	1.5	29.2
2	15.9	2.8	5.3	16.0	3.8	27.5	3.3	0.9	24.6
4	20.0	2.1	4.3	11.9	5.4	34.0	2.2	0.5	19.6
6	22.3	1.9	3.9	9.7	7.3	34.7	1.9	0.5	17.8
8	24.0	1.9	3.7	8.9	8.3	33.7	1.7	0.4	17.5
12	26.7	1.8	3.5	7.8	8.4	32.2	1.4	0.4	17.6
20	29.3	1.7	3.4	6.4	9.8	31.2	1.1	0.4	16.7
40	31.6	1.6	3.3	5.7	10.8	30.1	0.8	0.4	15.6

Working's T index

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	5.5	0.2	0.0	14.8	7.0	19.6	0.0	0.0	52.9
2	5.4	2.4	0.3	21.5	2.9	21.2	0.3	0.3	45.8
4	5.4	2.1	0.2	24.2	3.0	22.5	0.2	0.2	42.1
6	5.5	1.5	0.1	27.8	3.1	23.2	0.1	0.2	38.5
8	5.6	1.3	0.1	30.2	3.0	22.5	0.1	0.1	36.9
12	6.5	1.0	0.1	34.0	2.8	21.6	0.1	0.1	33.8
20	8.6	0.5	0.2	39.5	2.6	20.3	0.0	0.1	28.2
40	12.0	0.3	0.3	42.7	2.6	19.0	0.0	0.1	22.9

Futures basis

	SUP	C	INV	MAC	X	FIN	SPC	OP	OWN
0	5.7	3.7	0.0	17.2	0.0	19.0	0.2	0.0	54.2
2	13.3	7.5	4.9	32.2	0.8	18.8	0.3	1.2	21.1
4	17.1	7.2	4.9	32.8	0.7	19.1	0.3	1.1	16.8
6	16.9	6.7	4.5	32.5	0.8	22.4	0.3	1.0	14.9
8	17.0	6.7	4.3	33.0	1.0	22.4	0.3	1.0	14.3
12	17.5	6.6	4.3	32.2	1.7	22.9	0.3	1.0	13.5
20	16.9	6.7	4.1	32.1	1.9	24.1	0.3	1.0	13.0
40	16.9	6.7	4.1	32.0	1.9	24.2	0.3	1.0	12.9

The table reports the forecast error variance decomposition for world oil reserves, net oil production changes, refinery margins, oil consumption, inventories, the real oil price, the nominal oil price volatility, the Working's T index, and the futures basis, at selected horizons (impact (0) and 2 to 40 quarters), relatively to subsets of structural shocks (net of the contribution of the own shock) : oil supply shocks (SUP, reserves, net production changes, refinery margins, oil consumption shocks (C), inventories shocks (INV), macroeconomic shocks (MAC: labor supply and demand, aggregate demand, fiscal stance, US fiscal and trade deficit, core inflation, productivity), US$ exchange rate index shocks (X), fundamental financial shocks (FIN: excess liquidity, risk-free rate, term spread, real housing prices, risk aversion, size, value, momentum, liquidity and leverage factors, real commodity prices, real stock prices, economic and financial fragility index, nominal oil price volatility), financial speculation (SPC: Working-T index, futures basis), the real oil price (OP), and the own shock (OWN). For instance, for world oil reserves, the SUP subset is net of the contribution of the reserves own shock, which is reported under the OWN category.

Table 2: impulse response analysis, world oil reserves, production and refineries margins; responses to each structural shock

Panel A: world oil reserves

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**0.39**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	**0.79**	**0.20**	**0.21**	**0.10**	**0.07**	**-0.08**	0.03	-0.02	**0.09**	**-0.21**	**0.05**	**0.32**	**-0.09**	**0.04**	**-0.02**	0.00	**0.16**
4	**1.00**	**0.38**	**0.25**	**0.17**	**0.08**	**-0.24**	0.00	**-0.08**	**0.28**	**-0.44**	0.03	**0.59**	**0.08**	0.05	**0.09**	**0.06**	**0.36**
6	**1.20**	**0.55**	**0.22**	**0.24**	0.07	**-0.38**	0.03	**-0.15**	**0.42**	**-0.64**	0.00	**0.80**	**0.26**	0.01	**0.18**	**0.13**	**0.53**
8	**1.29**	**0.79**	0.14	**0.26**	0.13	**-0.52**	0.09	**-0.26**	**0.51**	**-0.75**	-0.03	**0.92**	**0.42**	-0.01	**0.28**	**0.18**	**0.66**
12	**1.43**	**1.10**	0.00	**0.26**	0.13	**-0.61**	0.05	**-0.38**	**0.66**	**-0.88**	-0.06	**1.12**	**0.59**	-0.07	**0.43**	**0.26**	**0.77**
20	**1.53**	**1.44**	-0.19	**0.27**	-0.09	**-0.66**	0.02	**-0.33**	**0.77**	**-0.87**	0.02	**1.21**	**0.64**	-0.11	**0.41**	**0.23**	**0.67**
40	**1.66**	**1.65**	-0.29	**0.35**	-0.19	**-0.70**	0.03	**-0.31**	**0.83**	**-0.92**	0.08	**1.34**	**0.66**	-0.14	**0.38**	**0.21**	**0.66**

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.02	**0.04**	**-0.15**	0.01	**0.06**	0.00	**-0.03**	**-0.02**	**-0.07**	**-0.05**	**0.04**	**0.13**	**-0.03**	**-0.04**	**-0.06**	**0.01**
4	**0.16**	**0.21**	**-0.17**	-0.01	**0.08**	**-0.14**	**-0.10**	0.01	**-0.07**	-0.02	**-0.03**	**0.16**	-0.02	**-0.06**	0.02	**0.03**
6	**0.24**	**0.35**	**-0.11**	0.01	**0.05**	**-0.26**	**-0.18**	0.02	**-0.06**	0.01	**-0.09**	**0.15**	0.01	**-0.08**	**0.06**	**0.03**
8	**0.31**	**0.43**	-0.03	0.07	0.01	**-0.36**	**-0.24**	0.03	-0.06	0.07	**-0.15**	**0.12**	0.04	**-0.07**	**0.12**	**0.03**
12	**0.26**	**0.56**	0.08	**0.21**	**-0.09**	**-0.50**	**-0.34**	0.02	-0.04	**0.15**	**-0.23**	0.05	0.06	**-0.08**	**0.15**	0.03
20	0.17	**0.56**	-0.05	**0.37**	**-0.11**	**-0.56**	**-0.30**	0.01	-0.04	**0.16**	**-0.26**	-0.05	0.07	**-0.15**	0.12	0.01
40	0.13	**0.53**	-0.15	**0.44**	-0.11	**-0.57**	**-0.27**	0.01	-0.07	0.15	**-0.27**	-0.08	0.07	**-0.19**	0.08	-0.01

Panel B: oil production

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**-0.02**	**-0.21**	**0.40**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	**-0.03**	**-0.17**	**0.41**	**0.00**	**0.07**	-0.01	**0.03**	**-0.03**	**-0.09**	0.00	**0.01**	**-0.04**	**0.03**	0.00	**0.01**	**-0.05**	0.01
4	**0.03**	**-0.15**	**0.42**	0.02	**0.07**	-0.01	**0.17**	**-0.03**	**-0.05**	0.00	0.00	**-0.08**	**0.07**	**-0.04**	0.00	**0.02**	**0.07**
6	**0.12**	**-0.15**	**0.41**	**0.05**	**0.11**	0.00	**0.17**	**-0.04**	**0.04**	0.00	**-0.02**	**-0.03**	**0.14**	**-0.06**	0.02	**0.06**	**0.12**
8	**0.17**	**-0.15**	**0.42**	0.03	**0.08**	-0.01	**0.14**	**-0.05**	**0.06**	0.00	**-0.02**	**0.04**	**0.19**	**-0.05**	**0.03**	**0.07**	**0.12**
12	**0.08**	**-0.13**	**0.36**	0.01	**0.05**	**-0.01**	**0.12**	**-0.03**	**0.03**	0.01	**-0.01**	**-0.02**	**0.19**	**-0.05**	**0.03**	**0.06**	**0.09**
20	**0.05**	**-0.14**	**0.35**	0.02	0.01	0.00	**0.11**	**-0.02**	**0.01**	**0.05**	0.00	**-0.07**	**0.13**	**-0.05**	**-0.03**	**0.01**	**0.02**
40	**0.06**	**-0.13**	**0.36**	0.02	0.03	0.00	**0.12**	**-0.02**	**0.01**	0.04	-0.01	**-0.04**	**0.14**	**-0.05**	**-0.02**	**0.02**	**0.04**

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	**0.02**	**-0.02**	**0.04**	**0.00**	0.00	**-0.01**	0.01	0.00	**-0.02**	0.00	**0.01**	**-0.02**	0.00	**0.02**	0.00	**0.01**
4	**0.07**	**0.09**	**0.15**	**0.00**	**-0.04**	0.00	**-0.01**	0.00	**-0.02**	0.00	**0.03**	**0.04**	0.00	**0.01**	**-0.02**	**0.01**
6	**0.06**	**0.20**	**0.14**	**0.00**	**-0.03**	0.00	**-0.02**	0.00	**-0.04**	-0.01	**0.03**	**0.10**	0.00	**0.02**	**-0.03**	**0.03**
8	**0.07**	**0.31**	**0.12**	**0.00**	**-0.02**	**-0.02**	**-0.02**	0.01	**-0.04**	-0.02	0.01	**0.09**	0.00	0.01	**-0.02**	**0.03**
12	**0.05**	**0.26**	**0.13**	**0.00**	**-0.02**	**-0.01**	**-0.01**	0.01	**-0.03**	-0.01	0.00	**0.02**	0.00	0.01	**-0.02**	**0.02**
20	**0.04**	**0.18**	**0.07**	**0.00**	**-0.02**	**0.00**	0.00	0.01	**-0.03**	-0.02	**0.01**	**0.02**	0.00	0.00	**-0.03**	**0.01**
40	**0.05**	**0.20**	**0.09**	**0.00**	**-0.02**	**-0.01**	0.00	0.01	**-0.03**	-0.02	**0.01**	**0.03**	0.00	0.00	**-0.03**	**0.02**

Panel B: refinery margins

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	-0.01	**0.02**	**0.02**	**0.32**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	**0.09**	0.03	0.01	**0.43**	**-0.05**	0.01	**0.09**	**-0.04**	**-0.12**	**-0.06**	**-0.03**	**0.02**	**0.15**	**-0.09**	0.01	-0.02	**0.05**
4	**0.18**	**0.18**	**-0.04**	**0.40**	**-0.08**	0.01	**0.14**	**-0.08**	**-0.06**	-0.04	0.01	**0.08**	**0.29**	**-0.16**	**0.04**	0.01	**0.04**
6	**0.25**	**0.26**	**-0.09**	**0.46**	**-0.17**	-0.01	**0.09**	**-0.10**	**0.08**	**-0.08**	0.00	**0.18**	**0.26**	**-0.24**	**0.04**	**0.06**	0.03
8	**0.33**	**0.36**	**-0.14**	**0.50**	**-0.29**	0.01	0.04	**-0.07**	**0.12**	-0.05	0.00	**0.28**	**0.28**	**-0.24**	0.02	**0.04**	-0.01
12	**0.32**	**0.54**	**-0.27**	**0.54**	**-0.45**	-0.03	0.06	0.03	**0.14**	-0.02	**0.10**	**0.24**	**0.27**	**-0.24**	**-0.05**	-0.02	**-0.11**
20	**0.42**	**0.65**	**-0.35**	**0.64**	**-0.56**	-0.04	0.07	**0.10**	**0.17**	-0.04	**0.17**	**0.32**	**0.24**	**-0.26**	**-0.12**	**-0.07**	**-0.15**
40	**0.53**	**0.82**	**-0.43**	**0.68**	**-0.61**	-0.08	0.07	0.08	**0.24**	-0.09	**0.19**	**0.44**	**0.28**	**-0.29**	**-0.10**	-0.07	**-0.13**

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.02	-0.02	**0.06**	**0.03**	**-0.05**	**-0.04**	**-0.03**	**0.03**	-0.01	0.00	**-0.03**	**-0.07**	**0.04**	0.00	0.00	**-0.03**
4	**-0.05**	0.03	**0.11**	**0.11**	**-0.12**	**-0.03**	**-0.09**	0.01	0.01	**-0.04**	**-0.02**	**-0.09**	**0.03**	0.00	**-0.06**	**-0.04**
6	**-0.12**	**0.09**	**0.08**	**0.14**	**-0.11**	**-0.05**	**-0.08**	0.00	**-0.03**	**-0.05**	**-0.03**	**-0.07**	-0.01	**-0.04**	**-0.09**	**-0.03**
8	**-0.14**	**0.14**	**-0.07**	**0.17**	**-0.08**	**-0.11**	**-0.07**	0.01	**-0.04**	**-0.06**	**-0.04**	**-0.10**	-0.02	**-0.09**	**-0.10**	**-0.04**
12	**-0.15**	0.04	**-0.18**	**0.24**	**-0.08**	**-0.10**	0.01	0.01	**-0.03**	**-0.07**	**-0.05**	**-0.19**	0.01	**-0.13**	**-0.11**	**-0.06**
20	**-0.16**	-0.04	**-0.32**	**0.27**	-0.04	**-0.09**	**0.08**	0.03	**-0.06**	**-0.11**	**-0.03**	**-0.20**	0.01	**-0.18**	**-0.15**	**-0.08**
40	**-0.20**	-0.02	**-0.36**	**0.34**	**-0.06**	**-0.12**	0.07	0.03	**-0.07**	**-0.10**	**-0.05**	**-0.23**	0.01	**-0.20**	**-0.16**	**-0.09**

The table reports impulse responses for oil reserves (Panel A), oil production (Panel B) and refineries margins (Panel C), at selected horizons (impact (0) and 2 to 40 quarters), relatively to the various structural shocks: reserves (R), net negative production (Pm), net positive production (Pp), refinery margins (RM), labor supply (E), labor demand (U), aggregate demand (Y), fiscal stance (G), US fiscal deficit (Fd), US trade deficit (Td), core inflation (N), productivity (W), oil consumption (C), excess liquidity (L), risk-free rate (S), term spread (TS), real housing prices, (H), US$ exchange rate index (X), risk aversion (FV), size factor (SMB), value factor (HML), momentum factor (MOM), stocks' liquidity factor (PSL), leverage factor (LEV), Working-T index (WT), futures basis (FB), inventories (INV), real oil price (OP), nominal oil price volatility (OV), non-energy commodity price index (M), real stock prices (F), real gold price (GD), economic and financial fragility index (FRA). Figures in bold denote statistical significance at the 10% level.

Table 3: impulse response analysis, oil consumption, inventories and oil price; responses to each structural shock

Panel A: oil consumption

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**0.04**	**-0.09**	**0.06**	-0.01	**0.07**	**-0.11**	**0.13**	0.00	-0.01	**0.11**	-0.02	**0.05**	**0.54**	0.00	0.00	0.00	0.00
2	**0.09**	-0.04	**0.07**	-0.04	**0.21**	**-0.09**	**0.13**	**-0.06**	**-0.14**	0.00	**-0.06**	**0.05**	**0.45**	**0.04**	**0.04**	0.03	**0.07**
4	**0.15**	**-0.06**	**0.08**	-0.03	**0.20**	**-0.09**	**0.12**	**-0.16**	**-0.05**	-0.02	**-0.12**	**0.14**	**0.53**	**-0.06**	**0.09**	**0.11**	**0.11**
6	**0.17**	-0.05	**0.09**	-0.06	**0.21**	**-0.10**	**0.10**	**-0.18**	0.00	0.00	**-0.12**	**0.20**	**0.58**	**-0.04**	**0.12**	**0.09**	**0.12**
8	**0.17**	0.00	0.06	-0.05	**0.14**	**-0.09**	**0.10**	**-0.16**	-0.03	0.04	**-0.13**	**0.17**	**0.59**	**-0.06**	**0.09**	**0.10**	**0.09**
12	**0.15**	0.06	0.00	-0.03	**0.08**	**-0.08**	**0.10**	**-0.13**	-0.01	**0.08**	**-0.11**	**0.14**	**0.57**	**-0.07**	**0.06**	**0.09**	0.04
20	**0.14**	0.04	-0.02	-0.01	0.04	**-0.06**	**0.10**	**-0.07**	-0.03	**0.10**	**-0.07**	**0.12**	**0.53**	**-0.06**	0.01	**0.04**	-0.01
40	**0.17**	0.07	-0.02	0.00	0.05	**-0.07**	**0.10**	**-0.09**	-0.02	**0.08**	**-0.08**	**0.15**	**0.55**	**-0.07**	0.02	**0.05**	0.01

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	-0.02	**-0.05**	**0.13**	**0.06**	**-0.05**	-0.01	**-0.06**	**-0.03**	-0.02	**0.07**	0.00	0.02	**0.03**	**0.04**	0.01	-0.01
4	**-0.07**	**0.10**	**0.20**	**0.08**	**-0.08**	**-0.05**	**-0.13**	**-0.04**	**-0.04**	**0.06**	**-0.02**	**0.04**	-0.01	**0.03**	-0.01	0.00
6	**-0.08**	**0.13**	**0.16**	**0.10**	**-0.08**	**-0.07**	**-0.14**	**-0.04**	**-0.02**	**0.06**	**-0.03**	**0.03**	-0.01	**0.03**	-0.01	0.01
8	**-0.08**	**0.17**	**0.15**	**0.09**	**-0.08**	**-0.09**	**-0.15**	**-0.04**	-0.02	**0.05**	**-0.03**	0.01	-0.01	0.01	0.00	0.00
12	**-0.10**	0.14	**0.11**	**0.12**	**-0.08**	**-0.08**	**-0.11**	**-0.04**	-0.02	0.04	**-0.03**	-0.01	-0.01	-0.01	-0.02	0.00
20	**-0.09**	**0.07**	0.04	**0.11**	**-0.05**	**-0.05**	**-0.07**	-0.03	**-0.03**	0.02	-0.01	-0.01	-0.01	-0.02	-0.03	**-0.01**
40	**-0.10**	**0.09**	0.04	**0.12**	**-0.06**	**-0.06**	**-0.08**	-0.03	**-0.03**	0.02	-0.01	-0.01	-0.01	**-0.02**	-0.03	**-0.01**

Panel B: inventories

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**0.05**	-0.01	**0.06**	-0.10	0.00	**-0.23**	**-0.24**	**-0.05**	**0.17**	-0.02	**-0.04**	**0.06**	**-0.20**	**0.09**	**0.15**	**0.15**	0.01
2	0.03	-0.03	**0.08**	-0.03	0.04	**-0.35**	**-0.30**	**-0.06**	**0.27**	**-0.11**	-0.04	**0.21**	**-0.30**	**0.17**	**0.17**	**0.13**	**0.08**
4	0.03	0.05	**0.18**	**-0.08**	-0.04	**-0.30**	**-0.23**	**0.11**	**0.14**	**-0.07**	0.07	0.01	**-0.27**	**0.22**	**0.08**	0.04	-0.01
6	0.02	**0.16**	**0.18**	-0.03	-0.04	**-0.39**	**-0.12**	**0.10**	**0.22**	**-0.07**	**0.06**	**-0.08**	**-0.22**	**0.13**	**0.05**	**0.09**	0.02
8	**0.15**	**0.13**	**0.14**	0.05	-0.03	**-0.39**	**-0.09**	**0.09**	**0.29**	**-0.11**	0.02	-0.01	**-0.21**	**0.10**	0.03	**0.09**	**0.09**
12	**0.21**	**0.27**	**0.15**	0.05	-0.01	**-0.44**	**-0.09**	0.04	**0.31**	**-0.13**	-0.02	0.08	-0.06	**0.11**	**0.09**	**0.08**	**0.16**
20	**0.20**	**0.30**	**0.10**	0.02	0.02	**-0.45**	**-0.10**	-0.01	**0.32**	**-0.14**	-0.04	0.08	-0.04	**0.09**	**0.14**	**0.11**	**0.18**
40	**0.20**	**0.31**	**0.09**	0.03	0.00	**-0.44**	**-0.09**	0.01	**0.31**	**-0.13**	-0.03	0.06	-0.06	**0.09**	**0.11**	**0.10**	**0.16**

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA
0	**-0.18**	**-0.21**	**0.07**	**0.10**	0.00	**-0.18**	**-0.18**	**0.13**	**-0.11**	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00
2	**-0.10**	**-0.22**	**-0.08**	0.03	**0.10**	**-0.23**	**-0.10**	**0.15**	**-0.13**	**0.58**	**-0.05**	0.02	0.01	**-0.03**	**0.08**	**0.03**
4	-0.05	**-0.37**	**-0.07**	**0.08**	**0.06**	**-0.18**	**-0.07**	**0.16**	**-0.10**	**0.51**	0.01	**-0.04**	**0.05**	-0.01	**0.05**	**-0.02**
6	0.04	**-0.29**	0.02	0.02	**0.06**	**-0.18**	**-0.09**	**0.16**	**-0.13**	**0.45**	0.02	0.00	**0.05**	-0.01	**0.06**	-0.01
8	**0.12**	**-0.23**	-0.02	-0.01	**0.10**	**-0.20**	**-0.11**	**0.19**	**-0.18**	**0.39**	**0.05**	**0.07**	**0.03**	**-0.03**	0.04	0.00
12	**0.17**	**-0.13**	-0.04	-0.03	**0.10**	**-0.28**	**-0.15**	**0.22**	**-0.15**	**0.42**	0.00	**0.04**	**0.04**	**-0.03**	**0.08**	0.00
20	**0.14**	**-0.10**	0.03	0.02	**0.06**	**-0.30**	**-0.18**	**0.20**	**-0.14**	**0.45**	-0.01	0.03	**0.04**	-0.02	**0.08**	0.00
40	**0.14**	**-0.13**	0.01	0.02	**0.07**	**-0.29**	**-0.17**	**0.20**	**-0.15**	**0.44**	-0.01	0.03	**0.04**	-0.02	**0.08**	0.00

Panel C: real oil price

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**-0.92**	**1.59**	**-0.96**	**-1.44**	**-0.41**	**-1.00**	**3.13**	**0.90**	**-0.72**	**3.33**	**0.86**	**-3.29**	0.16	**1.43**	**-2.59**	**-1.93**	**-0.87**
2	**-1.03**	**3.26**	0.34	**-2.07**	**0.86**	**-2.13**	**6.57**	**-0.86**	**-1.44**	**4.04**	0.17	**-3.84**	**2.79**	**2.42**	**-3.09**	**0.51**	**0.73**
4	-0.05	0.73	**-1.85**	-0.25	**1.46**	-0.08	**4.26**	**-1.22**	-0.63	**2.79**	**-1.33**	**-1.94**	**3.12**	**1.48**	**-1.75**	0.36	**1.89**
6	0.73	-0.04	0.00	-0.55	**1.86**	-0.04	**3.12**	**-1.47**	**-0.89**	**2.02**	**-1.51**	-0.36	**2.91**	**2.16**	**-1.05**	0.14	**2.40**
8	-0.61	0.80	0.26	**-1.25**	**2.05**	-0.40	**3.16**	**-1.94**	**-1.38**	**2.38**	**-1.82**	**-1.06**	**3.54**	**2.58**	-0.51	0.27	**2.32**
12	-0.74	0.38	-0.16	**-1.39**	**2.61**	-0.61	**3.70**	**-2.23**	**-1.30**	**1.76**	**-1.74**	**-1.76**	**3.24**	**2.03**	-0.37	**0.83**	**2.61**
20	-0.91	0.38	-0.23	**-1.36**	**2.03**	**-0.63**	**3.63**	**-1.73**	**-1.12**	**2.21**	**-1.55**	**-2.00**	**3.33**	**2.21**	**-0.72**	**0.50**	**2.24**
40	-0.98	-0.01	0.03	**-1.42**	**2.27**	-0.54	**3.58**	**-1.80**	**-1.23**	**2.24**	**-1.67**	**-2.05**	**3.27**	**2.26**	**-0.67**	**0.48**	**2.32**

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA
0	**1.23**	**-0.97**	**-1.98**	**1.03**	**1.04**	**0.32**	0.13	**0.36**	**0.30**	**-1.35**	**3.73**	0.00	0.00	0.00	0.00	0.00
2	**2.62**	-0.25	-0.09	**0.65**	0.16	**1.48**	**-1.84**	-0.22	**2.60**	**-1.98**	**3.69**	0.21	**0.79**	**0.61**	**0.97**	-0.11
4	**2.58**	-0.10	-0.15	**-1.18**	**1.17**	**1.60**	**-1.71**	**0.78**	**2.00**	**-2.32**	**3.63**	**1.79**	-0.13	**0.82**	**0.51**	0.13
6	**2.31**	0.40	**-0.81**	**-1.10**	**1.36**	**0.87**	**-1.92**	**0.75**	**2.05**	**-1.56**	**3.24**	**1.75**	-0.13	**0.75**	**0.78**	**0.22**
8	**2.30**	0.17	-0.05	**-0.59**	**0.89**	0.47	**-2.00**	**0.73**	**2.67**	**-0.66**	**2.64**	**0.83**	**0.34**	**0.98**	**1.52**	**0.17**
12	**2.15**	0.03	**1.66**	-0.13	0.23	**0.72**	**-2.40**	**0.48**	**2.34**	**-0.71**	**2.86**	**1.06**	**0.36**	**1.27**	**1.28**	0.14
20	**2.48**	0.08	**0.90**	-0.29	0.48	**0.63**	**-2.12**	**0.59**	**2.42**	**-0.93**	**2.92**	**0.92**	**0.37**	**1.07**	**1.33**	0.11
40	**2.54**	0.15	**0.93**	-0.46	**0.55**	**0.65**	**-2.16**	**0.59**	**2.39**	**-0.93**	**2.95**	**1.05**	**0.32**	**1.14**	**1.34**	0.15

The table reports impulse responses for oil consumption (Panel A), inventories (Panel B) and the real oil price (Panel C) at selected horizons (impact (0) and 2 to 40 quarters), relatively to the various structural shocks: reserves (R), net negative production (Pm), net positive production (Pp), refinery margins (RM), labor supply (E), labor demand (U), aggregate demand (Y), fiscal stance (G), US fiscal deficit (Fd), US trade deficit (Td), core inflation (N), productivity (W), oil consumption (C), excess liquidity (L), risk-free rate (S), term spread (TS), real housing prices, (H), US$ exchange rate index (X), risk aversion (FV), size factor (SMB), value factor (HML), momentum factor (MOM), stocks' liquidity factor (PSL), leverage factor (LEV), Working-T index (WT), futures basis (FB), inventories (INV), real oil price (OP), nominal oil price volatility (OV), non-energy commodity price index (M), real stock prices (F), real gold price (GD), economic and financial fragility index (FRA). Figures in bold denote statistical significance at the 10% level.

Table 4: impulse response analysis, Working's-T, futures basis, and volatility responses to each structural shock

Panel A: Working's-T

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**0.11**	-0.04	**-0.11**	**0.17**	-0.01	**0.05**	-0.02	0.03	**-0.20**	**0.12**	**-0.08**	**-0.29**	**-0.04**	**-0.12**	-0.03	**-0.07**	**0.06**
2	0.07	**-0.11**	-0.01	0.04	**-0.23**	**0.16**	**-0.09**	**0.09**	**-0.40**	**0.16**	-0.05	**-0.34**	**0.15**	**-0.20**	0.02	0.00	**-0.07**
4	**-0.09**	**-0.21**	**-0.13**	**0.16**	-0.01	-0.01	**0.13**	**-0.07**	**-0.20**	**0.13**	-0.05	**-0.47**	**0.08**	**-0.35**	0.04	**0.07**	0.02
6	-0.05	**-0.19**	**-0.15**	**0.15**	0.05	**0.13**	**0.12**	-0.07	**-0.44**	**0.16**	**-0.15**	**-0.54**	**0.13**	**-0.33**	0.04	0.02	0.04
8	-0.08	**-0.21**	**-0.14**	**0.12**	0.01	**0.16**	**0.10**	-0.03	**-0.40**	**0.28**	**-0.15**	**-0.59**	**0.13**	**-0.32**	0.00	-0.02	-0.02
12	**-0.18**	**-0.34**	**-0.13**	0.11	-0.03	**0.19**	**0.10**	0.00	**-0.45**	**0.33**	**-0.15**	**-0.68**	0.06	**-0.32**	-0.05	-0.02	**-0.08**
20	**-0.27**	**-0.49**	-0.08	0.10	0.00	**0.25**	**0.11**	0.06	**-0.52**	**0.40**	**-0.15**	**-0.81**	0.00	**-0.29**	**-0.10**	-0.07	**-0.13**
40	**-0.34**	**-0.61**	-0.02	0.07	0.08	**0.26**	0.11	0.04	**-0.57**	**0.42**	**-0.19**	**-0.86**	-0.01	**-0.28**	-0.08	-0.05	-0.11

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA	
0	**0.26**	**-0.14**	**-0.15**	**-0.33**	**0.12**	0.02	**0.05**	**0.72**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2	**0.14**	0.04	**-0.05**	**-0.35**	0.02	-0.01	**-0.03**	**0.68**	**0.08**	0.01	**-0.05**	**-0.14**	0.00	0.00	-0.01	-0.01	
4	**0.17**	**-0.08**	**0.20**	**-0.36**	-0.01	**0.10**	0.01	**0.68**	-0.01	0.01	**-0.03**	**-0.06**	-0.02	**0.05**	-0.03	**0.02**	
6	**0.22**	-0.06	**0.21**	**-0.44**	0.01	**0.08**	-0.03	**0.71**	0.00	-0.01	-0.02	**-0.05**	-0.01	**0.08**	-0.02	0.01	
8	**0.21**	-0.04	**0.15**	**-0.43**	0.03	**0.08**	-0.02	**0.72**	0.00	-0.05	0.01	**-0.05**	-0.02	**0.07**	-0.04	0.01	
12	**0.22**	-0.06	**0.14**	**-0.46**	0.04	**0.09**	0.01	**0.72**	-0.01	-0.05	0.02	**-0.06**	-0.02	**0.06**	-0.03	0.00	
20	**0.25**	**-0.12**	**0.13**	**-0.54**	**0.08**	**0.15**	0.05	**0.73**	-0.01	**-0.09**	**0.06**	-0.03	-0.02	**0.08**	-0.04	0.01	
40	**0.27**	-0.11	**0.19**	**-0.59**	0.07	**0.16**	0.03	**0.73**	0.00	-0.09	**0.06**	0.00	-0.03	**0.11**	-0.03	0.01	

Panel B: futures basis

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**0.65**	**0.63**	-0.17	**-1.09**	**-0.70**	**1.01**	**-0.62**	**-0.44**	**-1.47**	-0.17	**1.30**	**-0.24**	**1.15**	**1.51**	**0.86**	**0.38**	**1.14**
2	**-1.90**	**-1.96**	-0.14	**-0.31**	0.20	**0.72**	**-3.05**	**0.40**	**0.93**	**-0.63**	**-0.46**	**0.24**	**-2.09**	**0.89**	**1.04**	-0.08	**-0.27**
4	**-0.59**	**-0.64**	**1.14**	-0.22	**-0.57**	**0.38**	**-1.32**	**0.33**	**-0.29**	**-0.71**	**-0.23**	-0.06	**-0.83**	**0.52**	**0.39**	0.18	**-0.20**
6	**-1.03**	-0.09	**0.35**	**-0.39**	0.00	**-0.36**	0.06	**0.61**	-0.05	0.02	**0.53**	**-0.93**	**-0.37**	**0.71**	**-0.18**	**-0.25**	**-0.29**
8	-0.15	**-0.77**	**0.34**	0.08	0.22	**-0.20**	**0.32**	**0.38**	-0.12	-0.52	**0.23**	**-0.68**	**-0.62**	0.02	**-0.25**	-0.02	0.09
12	**0.31**	-0.19	**0.25**	0.08	**0.24**	**-0.16**	**0.17**	0.02	**0.12**	**-0.20**	-0.05	0.15	**0.30**	0.09	0.02	-0.05	**0.36**
20	-0.05	-0.02	0.08	**-0.13**	**0.12**	0.01	**-0.07**	**-0.16**	0.02	0.01	**-0.11**	0.03	**0.10**	-0.02	**0.15**	**0.08**	0.07
40	-0.01	**-0.04**	**0.03**	-0.01	**0.03**	0.00	0.00	**-0.01**	-0.01	0.00	**-0.02**	-0.01	0.01	0.00	**0.01**	0.01	**0.02**

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA	
0	-0.02	0.07	**0.89**	**-0.14**	-0.07	**0.71**	**-0.94**	**0.24**	**4.36**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
2	**-0.46**	**-0.83**	-0.23	**-0.27**	**0.57**	**-0.24**	**0.86**	**0.24**	-0.06	**1.26**	**-0.44**	**0.30**	**-0.25**	**0.12**	**0.57**	**0.24**	
4	**-0.23**	**-0.52**	**0.30**	**0.74**	**-0.30**	**-0.52**	0.06	-0.04	**0.19**	**0.90**	**-0.41**	**-0.49**	**0.31**	-0.02	**0.50**	**-0.16**	
6	**0.37**	**-1.16**	0.10	**0.34**	**-0.13**	**0.25**	**0.46**	0.01	**0.35**	**0.24**	0.01	**-0.35**	**0.36**	**0.14**	**0.33**	**-0.12**	
8	**0.42**	**-0.45**	**0.52**	0.01	-0.09	**0.18**	0.07	-0.05	**-0.26**	-0.12	**0.23**	**0.20**	**0.11**	**0.11**	-0.01	**-0.05**	
12	**0.45**	**0.21**	-0.03	**-0.26**	**0.11**	-0.07	**-0.11**	**0.10**	0.00	**-0.17**	0.05	**0.21**	0.00	0.04	0.05	0.02	
20	-0.06	**0.18**	**0.18**	0.01	**-0.06**	**-0.08**	**-0.11**	-0.02	0.03	**0.08**	**-0.06**	0.00	-0.02	**0.04**	**0.04**	**0.03**	
40	0.01	0.01	**0.03**	**-0.02**	0.00	0.00	**-0.01**	0.00	0.00	0.00	0.00	**0.01**	0.00	**0.01**	**0.01**	**0.00**	

Panel C: nominal oil price volatility

	R	Pm	Pp	RM	E	U	Y	G	Fd	Td	N	W	C	L	SR	TS	H
0	**-0.13**	**0.74**	**0.32**	**0.16**	**0.37**	**0.30**	0.02	**-0.12**	**0.27**	**-0.12**	**0.12**	**0.09**	**-0.39**	0.05	0.03	**-0.26**	0.01
2	-0.03	0.14	**0.82**	**0.65**	0.00	**0.52**	**-0.35**	-0.07	**0.59**	**-0.18**	0.00	**0.60**	**-0.42**	**-0.21**	0.06	**-0.10**	0.02
4	**-0.39**	**-0.40**	**1.18**	**0.48**	0.15	**0.33**	**-0.12**	0.02	**0.23**	0.05	0.06	**0.32**	**-0.29**	0.08	-0.02	**-0.42**	-0.02
6	**-0.65**	**-0.52**	**1.05**	**0.51**	**0.42**	**0.27**	**0.26**	0.00	**-0.18**	-0.07	0.07	**-0.16**	**-0.29**	0.08	-0.06	**-0.38**	0.09
8	**-0.55**	**-0.65**	**1.00**	**0.58**	**0.46**	**0.37**	0.12	-0.06	0.04	-0.23	-0.01	-0.08	**-0.37**	-0.04	0.02	**-0.24**	**0.16**
12	**-0.52**	**-0.79**	**1.24**	**0.55**	**0.38**	**0.44**	-0.06	-0.04	0.13	-0.09	-0.12	0.07	**-0.35**	0.04	0.04	**-0.28**	0.14
20	**-0.64**	**-0.85**	**1.18**	**0.59**	**0.38**	**0.46**	0.03	0.05	0.03	-0.03	-0.11	-0.18	**-0.38**	0.02	-0.05	**-0.31**	0.10
40	**-0.75**	**-1.02**	**1.26**	**0.52**	**0.48**	**0.46**	0.07	0.03	-0.03	0.00	-0.15	**-0.29**	**-0.39**	0.04	-0.04	**-0.31**	0.13

	X	FV	SMB	HML	MOM	PSL	LEV	WT	FB	INV	OP	OV	M	F	GD	FRA	
0	**0.49**	-0.02	**-0.10**	**-0.28**	**0.51**	**0.09**	**0.16**	**-0.43**	**-0.15**	**-0.44**	**0.22**	**0.98**	0.00	0.00	0.00	0.00	
2	**0.46**	**0.32**	**-0.54**	**-1.05**	**0.94**	**0.25**	**0.31**	**-0.31**	**-0.21**	**-0.61**	**0.18**	**1.28**	**-0.27**	**-0.12**	**-0.07**	**0.14**	
4	**0.74**	0.11	**-0.74**	**-1.00**	**0.96**	0.11	**0.44**	**-0.25**	**-0.10**	**-0.46**	**0.10**	**1.00**	**-0.08**	**-0.09**	**0.14**	**0.09**	
6	**0.96**	-0.22	**-0.25**	**-1.06**	**0.83**	**0.26**	**0.41**	**-0.26**	-0.05	**-0.42**	**0.12**	**0.95**	0.06	**0.06**	**0.23**	**0.05**	
8	**0.86**	-0.18	-0.04	**-1.05**	**0.79**	**0.34**	**0.33**	**-0.27**	**-0.13**	**-0.50**	**0.18**	**1.14**	-0.03	**0.09**	**0.13**	**0.07**	
12	**0.89**	0.04	**-0.31**	**-1.11**	**0.91**	**0.20**	**0.33**	**-0.23**	**-0.10**	**-0.50**	**0.15**	**1.17**	**-0.07**	0.03	**0.17**	**0.09**	
20	**1.01**	-0.04	**-0.25**	**-1.18**	**0.92**	**0.24**	**0.36**	**-0.20**	**-0.12**	**-0.56**	**0.19**	**1.17**	-0.05	0.05	**0.19**	**0.08**	
40	**1.06**	-0.03	-0.14	**-1.24**	**0.91**	**0.27**	**0.34**	**-0.20**	**-0.11**	**-0.56**	**0.21**	**1.19**	-0.04	0.09	**0.21**	**0.09**	

The table reports impulse responses for Working-T index (Panel A), futures basis (Panel B) and nominal oil price volatility (Panel C) at selected horizons (impact (0) and 2 to 40 quarters), relatively to the various structural shocks: reserves (R), net negative production (Pm), net positive production (Pp), refinery margins (RM), labor supply (E), labor demand (U), aggregate demand (Y), fiscal stance (G), US fiscal deficit (Fd), US trade deficit (Td), core inflation (N), productivity (W), oil consumption (C), excess liquidity (L), risk-free rate (S), term spread (TS), real housing prices, (H), US$ exchange rate index (X), risk aversion (FV), size factor (SMB), value factor (HML), momentum factor (MOM), stocks' liquidity factor (PSL), leverage factor (LEV), Working-T index (WT), futures basis (FB), inventories (INV), real oil price (OP), nominal oil price volatility (OV), non-energy commodity price index (M), real stock prices (F), real gold price (GD), economic and financial fragility index (FRA). Figures in bold denote statistical significance at the 10% level.

Table 5: real oil price and nominal oil price volatility (net of base prediction), historical decomposition (2004-2010), contribution of various categories of shocks.

	Panel A: real oil price									Panel B: nominal oil price volatility									
	SUP	**C**	**INV**	**MAC**	**X**	**FIN**	**SPC**	**OWN**	**WTI**	**SUP**	**C**	**INV**	**MAC**	**X**	**FIN**	**SPC**	**OP**	**OWN**	**WTIv**
04(1)	-2.6	2.1	-1.6	5.5	-0.8	15.6	-5.2	-2.0	**11.1**	1.2	-0.2	-0.5	-1.7	0.4	-0.9	-0.4	-0.1	-0.4	**-2.5**
04(2)	-2.0	2.7	-0.6	7.1	-2.0	-6.0	4.6	2.9	**6.7**	1.5	-0.1	0.5	-1.8	-0.6	-1.9	0.3	0.1	0.7	**-1.1**
04(3)	1.6	-0.1	0.8	0.1	-2.9	7.8	2.7	2.9	**12.9**	2.2	-0.9	0.5	0.3	-0.3	-0.5	0.2	0.3	0.2	**2.0**
04(4)	5.0	6.1	-2.6	-2.6	1.1	6.0	0.9	-5.3	**8.8**	0.4	-0.2	-0.6	0.2	0.8	1.9	-0.2	-0.2	0.3	**2.4**
05(1)	2.4	-0.6	-1.3	-1.7	1.6	-1.8	-0.4	3.7	**2.0**	-0.5	-0.1	0.0	1.4	-0.5	0.4	-0.8	0.0	1.7	**1.6**
05(2)	-2.2	-2.7	1.3	0.5	-1.5	3.6	2.6	3.2	**4.9**	0.8	0.4	-0.6	1.1	-0.8	-1.3	-0.8	0.2	0.1	**-0.9**
05(3)	-0.4	-1.1	-0.1	20.0	-2.2	-6.1	0.6	5.3	**15.8**	1.2	1.0	0.1	-2.0	-0.1	1.2	-0.1	0.4	-1.3	**0.5**
05(4)	-0.9	-5.5	-0.7	11.1	-1.3	-9.1	2.1	-1.5	**-5.8**	0.7	0.1	-0.4	-0.7	-0.1	0.0	-1.0	-0.3	-1.1	**-2.8**
06(1)	-0.9	-0.4	1.4	3.1	-1.0	6.9	-6.3	1.6	**4.5**	0.9	-0.2	0.5	-0.7	0.4	-1.2	1.2	-0.2	-1.6	**-0.8**
06(2)	0.5	2.9	2.9	-14.1	1.0	22.1	1.3	-7.9	**8.7**	0.4	0.3	0.9	0.2	0.1	-1.1	0.8	-0.4	-1.2	**0.0**
06(3)	2.0	-4.4	0.9	-18.8	1.0	11.5	5.8	1.1	**-0.9**	0.5	-0.5	0.0	1.5	-0.3	-3.9	0.0	0.1	0.4	**-2.1**
06(4)	4.4	0.2	-1.6	-20.2	-1.0	3.6	-4.3	3.3	**-15.5**	0.3	0.5	-0.3	3.1	-0.4	-1.1	0.3	0.2	-0.8	**1.7**
07(1)	1.1	-1.9	3.8	-2.4	2.0	-9.5	1.2	1.3	**-4.6**	0.2	-0.1	0.5	0.2	1.1	0.1	-0.3	0.2	0.1	**2.0**
07(2)	0.0	-2.2	2.4	6.3	4.3	-7.3	3.2	2.4	**9.1**	0.3	-0.6	0.3	-2.3	0.3	-0.2	0.0	0.2	1.6	**-0.3**
07(3)	-2.0	5.7	-0.7	6.9	0.9	4.1	-3.9	3.5	**14.6**	0.8	0.3	0.2	-2.0	-0.5	0.3	0.1	0.0	-0.1	**-0.9**
07(4)	-0.3	-1.0	-2.6	13.5	2.0	12.1	-6.1	-0.4	**17.3**	0.9	-0.5	-0.8	-1.3	1.8	2.1	-0.9	0.0	-0.2	**1.0**
08(1)	2.2	2.0	-3.0	14.0	1.8	0.2	-3.2	-7.6	**6.3**	0.5	0.5	-0.5	-1.3	0.0	1.3	0.6	-0.5	-2.1	**-1.6**
08(2)	1.4	-0.6	-0.9	16.7	1.4	-4.1	4.4	3.0	**21.1**	0.1	-0.1	0.2	-1.1	1.1	2.6	-0.2	0.0	-1.8	**0.7**
08(3)	-3.6	-0.5	0.9	1.8	1.3	-1.1	1.9	-7.2	**-6.5**	0.5	0.6	0.3	-1.9	0.3	1.7	-0.5	-0.3	-0.5	**0.1**
08(4)	-2.1	-3.5	-2.0	-39.3	-2.6	-11.1	-2.5	-4.5	**-67.4**	2.5	-0.1	0.0	4.6	-0.9	2.7	0.0	0.0	1.4	**10.1**
09(1)	7.2	0.7	-0.9	-26.3	-2.7	-6.9	-0.3	-1.5	**-30.6**	-0.2	-0.1	0.2	4.1	1.0	0.6	0.0	0.1	0.6	**6.2**
09(2)	2.8	2.9	1.4	6.1	0.0	12.4	4.3	1.3	**31.3**	-1.3	-0.4	0.1	2.6	-0.6	-2.4	0.1	0.2	0.7	**-1.0**
09(3)	0.0	0.0	2.5	9.9	0.4	-1.6	1.2	0.1	**12.6**	-1.6	-0.1	0.5	0.4	0.0	-1.7	-0.1	0.3	0.1	**-2.3**
09(4)	-2.5	0.3	0.1	4.6	0.7	3.5	0.1	3.6	**10.5**	-0.2	0.1	-0.3	-3.0	0.0	-1.4	0.1	0.0	0.5	**-4.2**
10(1)	-0.6	-1.1	-1.1	3.5	-1.2	-1.8	2.3	2.8	**2.7**	-0.2	0.2	-0.3	-3.9	-0.9	-0.3	0.1	0.0	0.8	**-4.4**
10(2)	-3.2	-0.5	2.3	6.2	-2.3	-7.3	0.9	2.1	**-1.9**	1.0	-0.7	0.7	-0.4	0.1	-0.9	-0.3	0.0	-1.0	**-1.5**
10(3)	-4.3	6.0	1.8	-6.5	1.3	-2.7	2.7	-0.9	**-2.6**	1.1	-0.6	0.2	0.7	0.4	0.0	-1.2	-0.2	-1.3	**-0.9**
TOT	**3.2**	**5.5**	**3.1**	**5.1**	**-0.8**	**32.9**	**10.5**	**5.5**	**65.0**	**13.8**	**-1.5**	**1.3**	**-3.7**	**1.8**	**-3.8**	**-2.9**	**0.3**	**-4.3**	**1.1**

The table reports the historical decomposition (net of base prediction) for the real oil price growth rate and nominal oil price volatility in changes over the period 2005-1010, relatively to subsets of structural shocks (net of the contribution of the own shock) : oil supply shocks (SUP, reserves, net production changes, refinery margins), oil consumption shocks (C), inventories shocks (INV), macroeconomic shocks (MAC: labor supply and demand, aggregate demand, fiscal stance, US fiscal and trade deficit, core inflation, productivity), US$ exchange rate index shocks (X), fundamental financial shocks (FIN: excess liquidity, risk-free rate, term spread, real housing prices, risk aversion, size, value, momentum, liquidity and leverage factors, real commodity prices, real stock prices, economic and financial fragility index, nominal oil price volatility), financial speculation (SPC: Working-T index, futures basis), the real oil price (OP), and the own shock (OWN). WTI denotes the actual real oil price growth rate and WTIv the actual nominal oil price volatility in changes (both net of base prediction); TOT denotes the cumulative contribution over the 2004:1 through 2010:3 period.

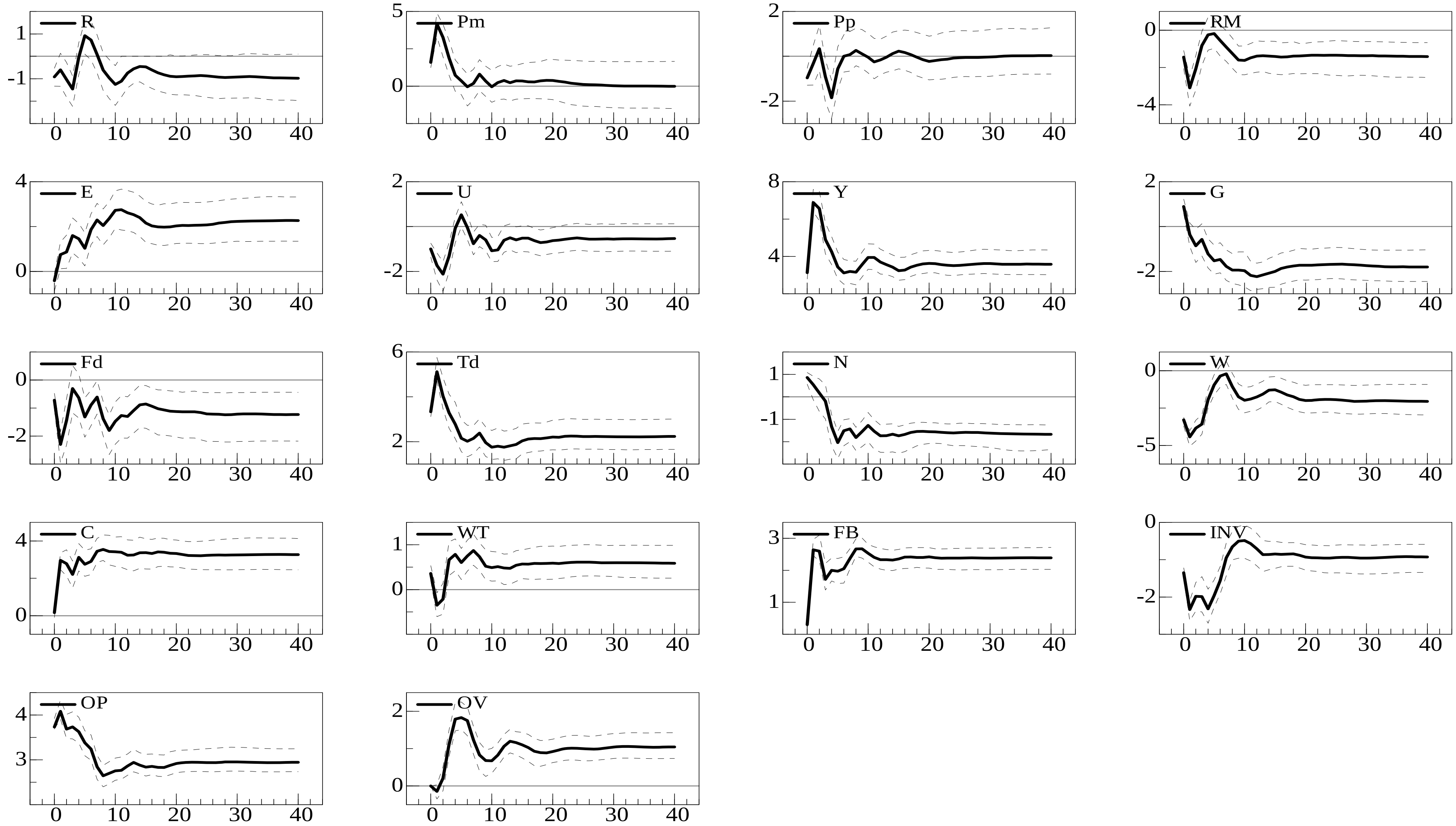

Figure 1: Impulse responses for the real oil price to various structural shocks (median and 95% confidence interval): reserves (R), net negative production (Pm), net positive production (Pp), refinery margins (RM), labor supply (E), labor demand (U), aggregate demand (Y), fiscal stance (G), US fiscal deficit (Fd), US trade deficit (Td), core inflation (N), productivity (W), oil consumption (C), Working-T index (WT), futures basis (FB), inventories (INV), real oil price (OP), nominal oil price volatility (OV).

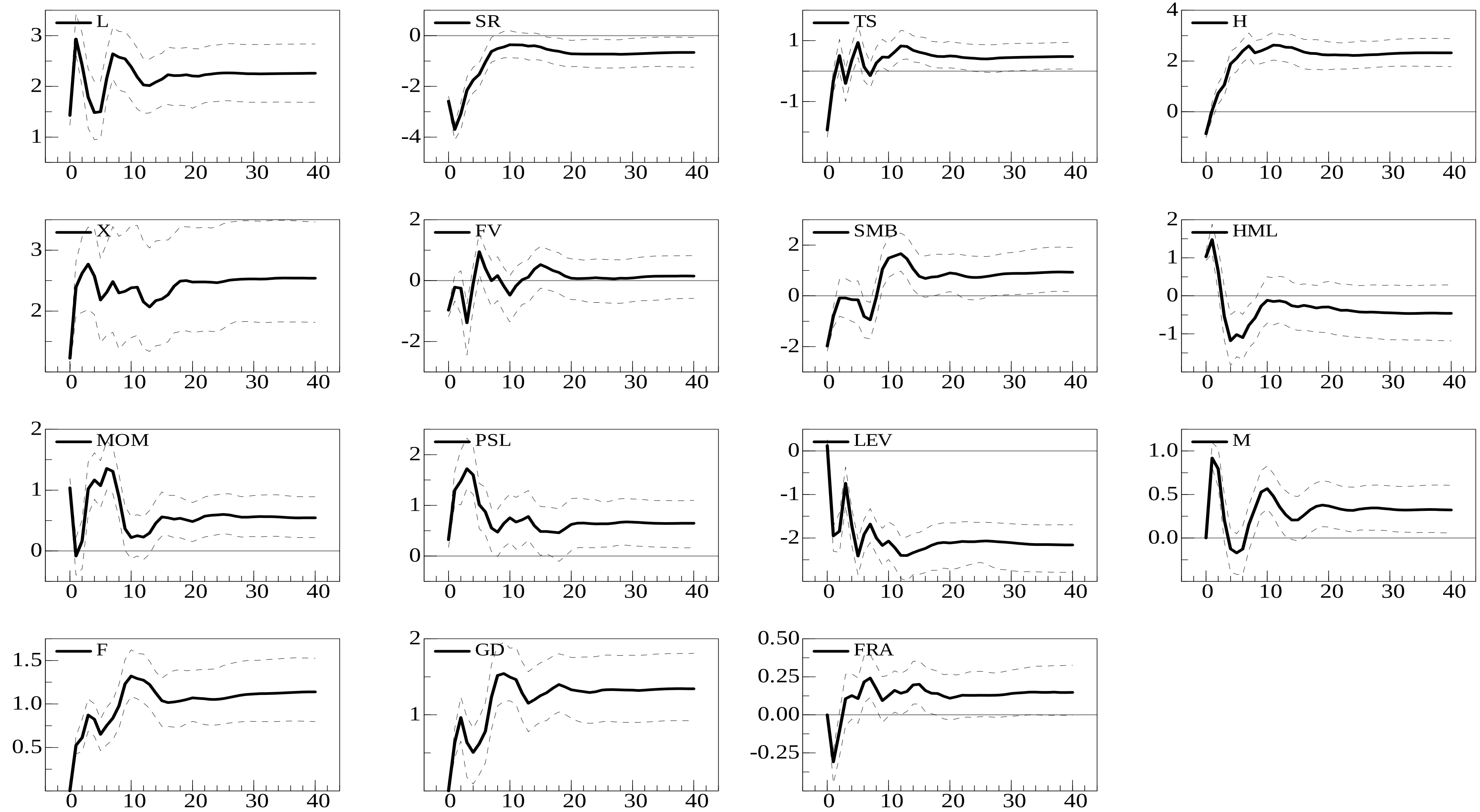

Figure 2: Impulse responses for the real oil price to various structural shocks (median and 95% confidence interval): excess liquidity (L), risk-free rate (S), term spread (TS), housing price, (H), US$ exchange rate index (X), risk aversion (FV), size factor (SMB), value factor (HML), momentum factor (MOM), stocks' liquidity factor (PSL), leverage factor (LEV), non-energy commodity price index (M), stock prices (F), gold price (GD), fragility (FRA).

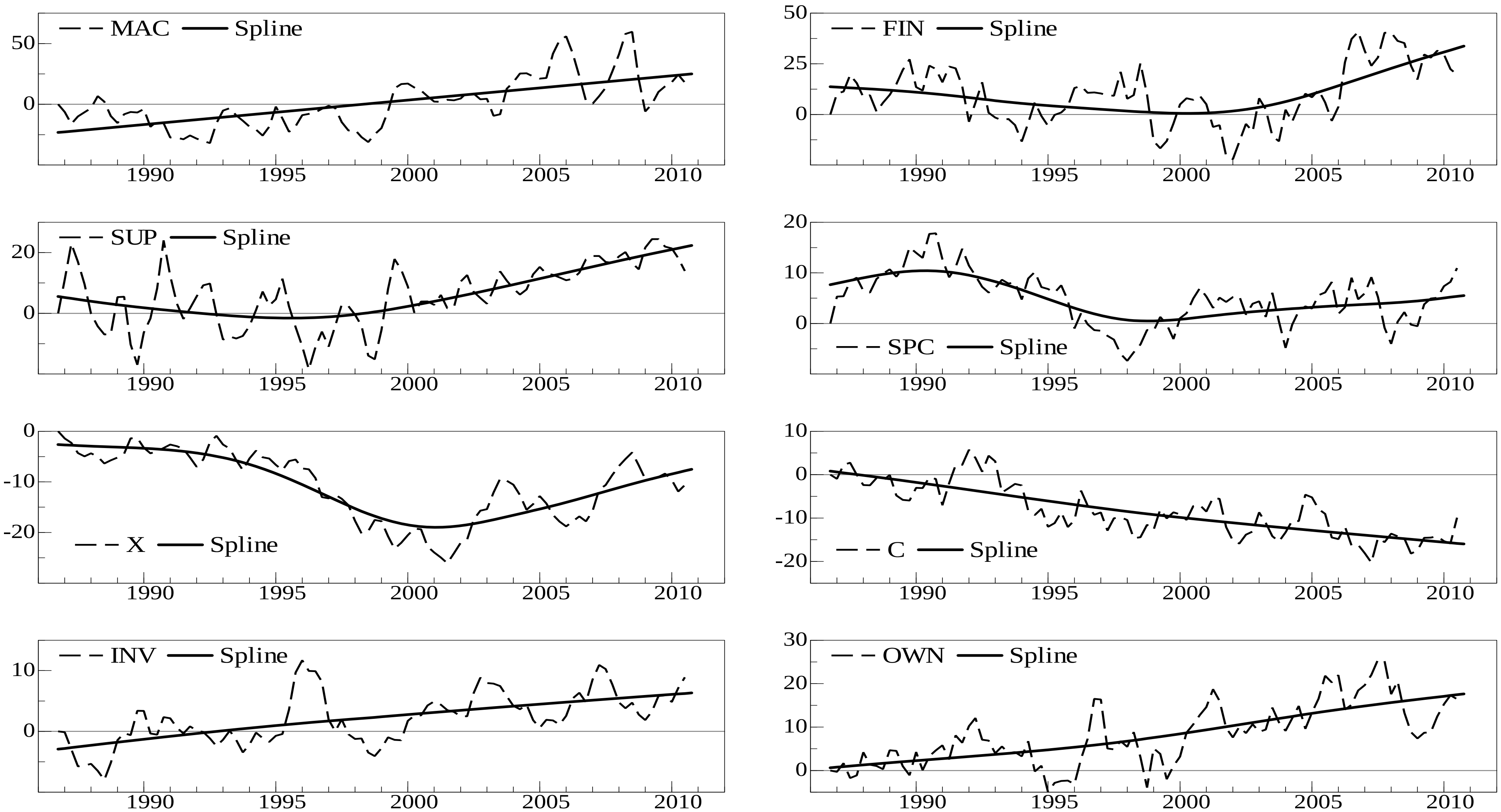

Figure 3: Cumulative contribution of various categories of shocks to the real oil price (dashed line) and spline smoother (solid line); 1986(4)-20010(3); supply side shocks (SUP: reserves, net negative and positive production, refinery margins), oil consumption own shock (C), inventories (I), macroeconomic shocks (MAC: labor supply, labor demand, aggregate demand, fiscal stance, US fiscal deficit, US trade deficit, core inflation, productivity), fundamental financial shocks (FIN: excess liquidity, risk-free rate, term spread, housing prices, risk aversion, size, value, momentum, stocks' liquidity and leverage factors, non-energy commodity prices, stock prices, gold prices, fragility factor) , US$ exchange rate shocks (X), non-fundamental financial shocks (SPC: Working-T index, futures basis), real oil price own shock (OWN).

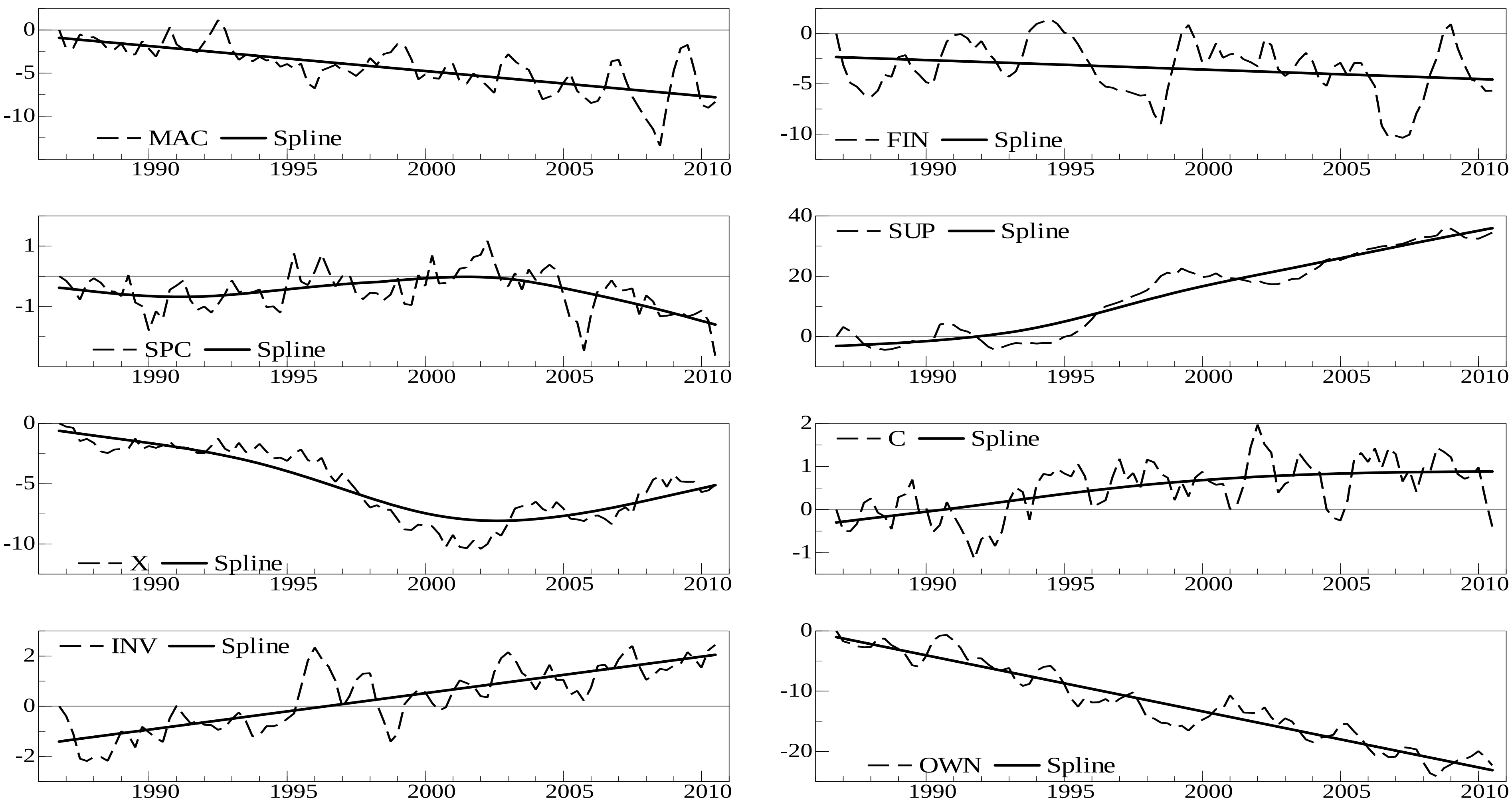

Figure 4: Cumulative contribution of various categories of shocks to the nominal oil price volatility (dashed line) and spline smoother (solid line); 1986(4)-20010(3); supply side shocks (SUP: reserves, net negative and positive production, refinery margins), oil consumption own shock (C), inventories (I), macroeconomic shocks (MAC: labor supply, labor demand, aggregate demand, fiscal stance, US fiscal deficit, US trade deficit, core inflation, productivity), fundamental financial shocks (FIN: excess liquidity, risk-free rate, term spread, housing prices, risk aversion, size, value, momentum, stocks' liquidity and leverage factors, non-energy commodity prices, stock prices, gold prices, fragility factor) , US$ exchange rate shocks (X), non-fundamental financial shocks (SPC: Working-T index, futures basis), nominal oil price volatility own shock (OWN) .

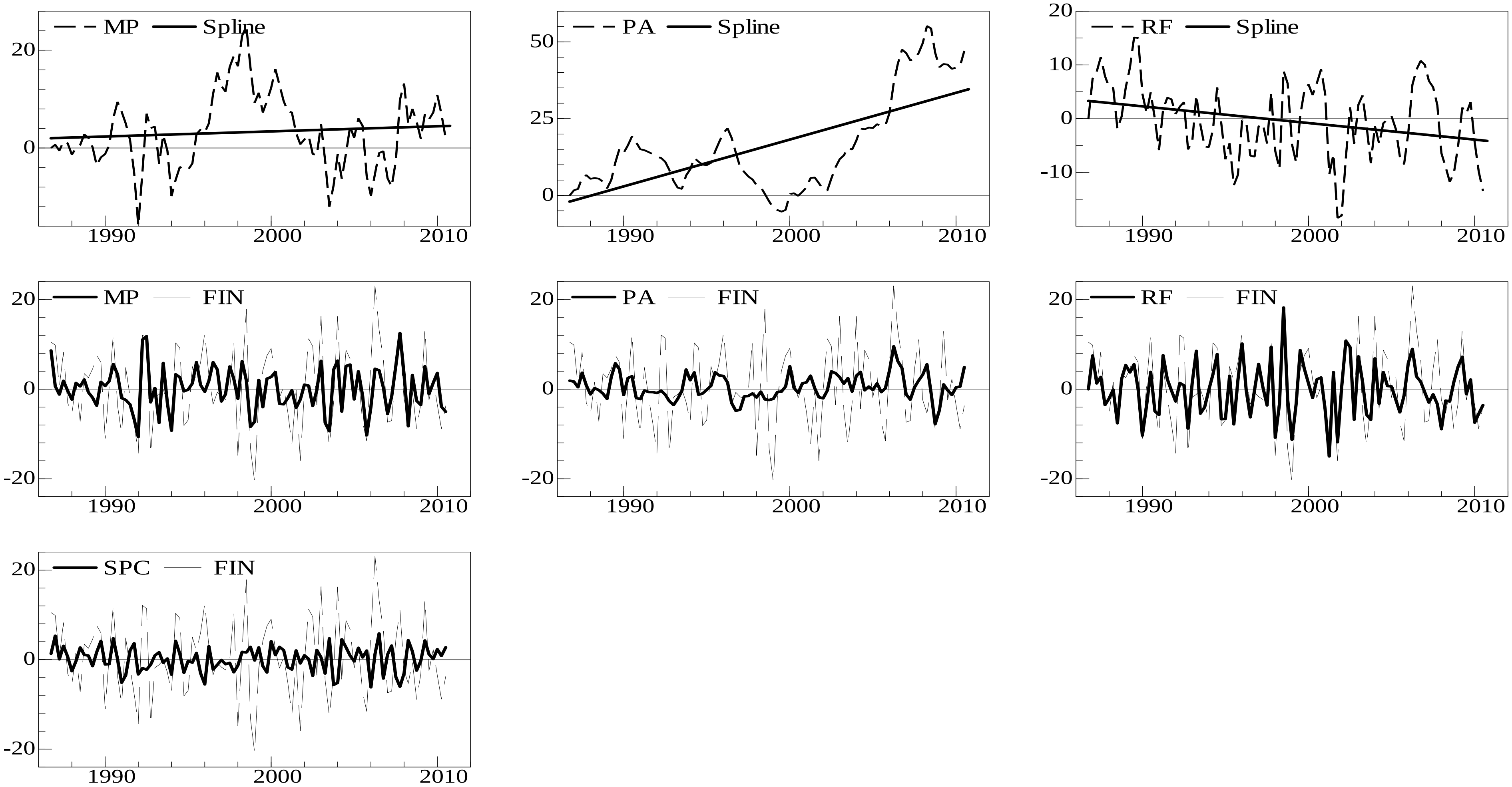

Figure 5: Cumulative contribution of various categories of fundamental financial shocks to the real oil price (dashed line) and spline smoother (solid line) (top plots), contribution of various categories of fundamental financial shocks to the fundamental financial component of real oil price growth (center plots) and relative dimension of non-fundamental and fundamental financial shocks (bottom plot); 1986(4)-20010(3). Contributions from liquidity and interest rate shocks (MP: excess liquidity, risk-free rate, term spread), portfolio allocation shocks (PA: housing prices, non-energy commodity prices, stock prices, gold price) and risk factors shocks (RF: risk aversion, size factor, value factor, momentum factor, stocks' liquidity factor, leverage factor, fragility factor). SPC is the non-fundamental financial component of the real oil price growth rate (SPC: Working-T index + futures basis); FIN is the fundamental financial component of the real oil price growth rate (FIN: MP + PA + RF).

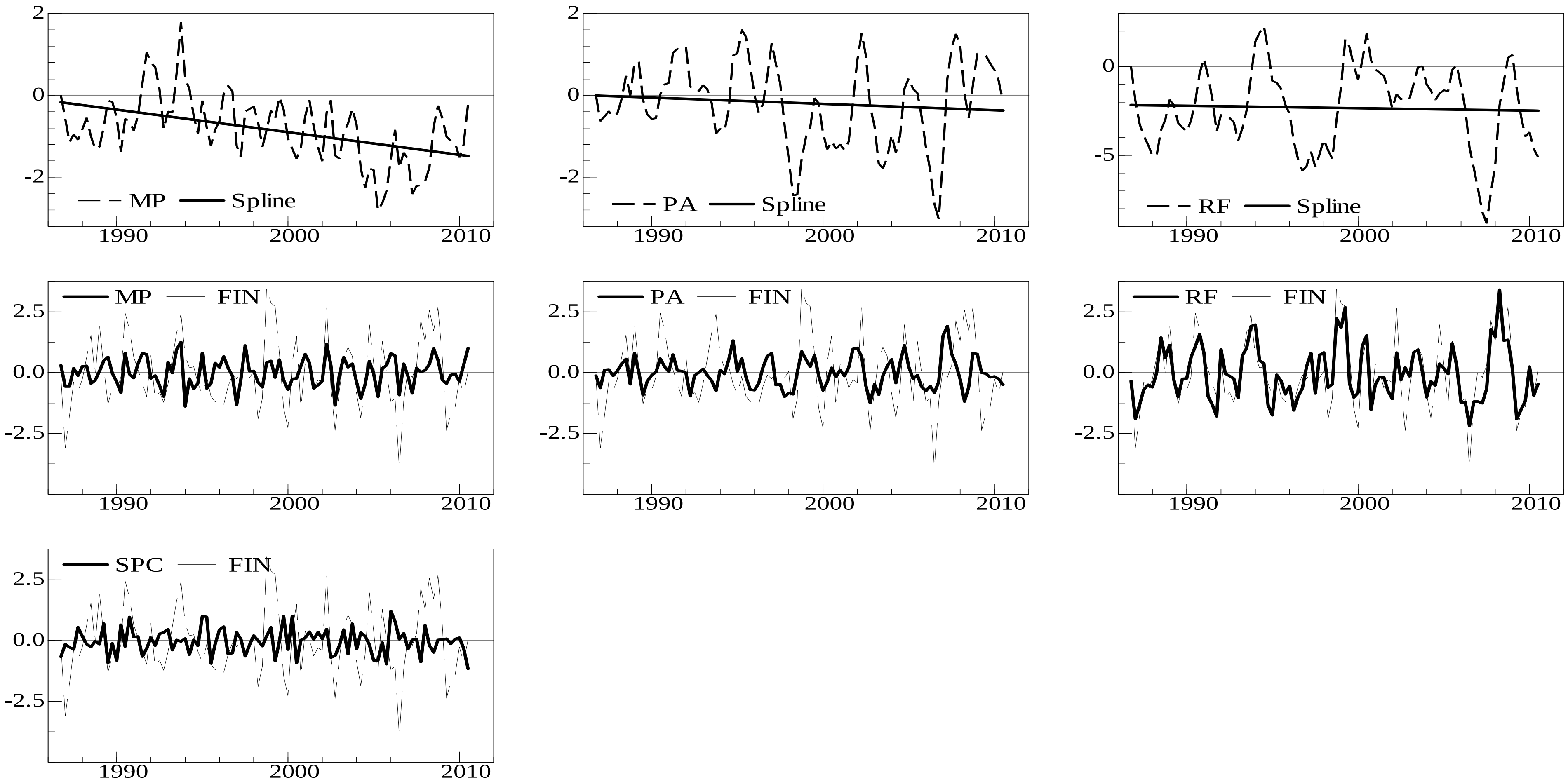

Figure 6: Cumulative contribution of various categories of fundamental financial shocks to nominal oil price volatility (dashed line) and spline smoother (solid line) (top plots), contribution of various categories of fundamental financial shocks to the fundamental financial component of nominal oil price volatility changes (center plots) and relative dimension of non-fundamental and fundamental financial shocks (bottom plot); 1986(4)-20010(3). Contributions from liquidity and interest rate shocks (MP: excess liquidity, risk-free rate, term spread), portfolio allocation shocks (PA: housing prices, non-energy commodity prices, stock prices, gold price) and risk factors shocks (RF: risk aversion, size factor, value factor, momentum factor, stocks' liquidity factor, leverage factor, fragility factor). SPC is the non-fundamental financial component of nominal oil price volatility changes (SPC: Working-T index + futures basis); FIN is the fundamental financial component of nominal oil price volatility (FIN: MP + PA + RF).