On-line Appendix: "Sentiments in SVARs"

(not for publication)

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A Implementation of our Identification Procedure in the VECM

A.1 The Two-Step Procedure

The identification of sentiments shocks is achieved by implementing the following two–step procedure.

A.1.1 Step 1

The first step uses identification I and identification II to uncover the two potential permanent shocks, *i.e.*, the unanticipated and the anticipated technology shocks. This allows us to identify the two first columns of the A_0 matrix. We implement this first step by imposing that the contemporaneous effect of the remaining stationary shock to confidence is set to $\bar{a}_{0,43}$, *i.e.*, an initial value in the procedure that can be either zero or any other. This implies the following organisation of the matrix \tilde{A}_0

$$\tilde{A}_0 = \begin{bmatrix} a_{0,11} & 0 & 0 & 0\\ a_{0,21} & a_{0,22} & a_{0,23} & a_{0,24}\\ a_{0,31} & a_{0,32} & a_{0,33} & a_{0,34}\\ a_{0,41} & a_{0,42} & \bar{a}_{0,43} & a_{0,44} \end{bmatrix}$$

So, conditional on the identification of supply shocks, the matrix \tilde{A}_0 is then just-identified.

Consider now the forecast error of Δy_t function from this identification schema. The k-step ahead forecast error is then given by

$$\Delta y_{t+k} - E_t \Delta y_{t+k} = \sum_{\tau=0}^h C_\tau A_0 \varepsilon_{t+k-\tau} = \sum_{i=0}^h C_\tau \tilde{A}_0 F \varepsilon_{t+k-\tau} \quad ,$$

for all F such that FF' = I and h = k - 1. The matrix F is an orthonormal matrix and $A_0 = \tilde{A}_0 F$. Now consider that F has the following structure

$$F = \left[\begin{array}{cc} I_2 & \mathbf{0_2} \\ \mathbf{0_2} & F_{22} \end{array} \right]$$

,

where I_2 is an identity matrix of dimension 2×2 , $\mathbf{0}_2$ a matrix of dimension 2×2 containing only zero as elements and F_{22} is a 2×2 orthonormal matrix such that $F_{22}F'_{22} = I_2$. Consequently, the first two columns of A_0 and \tilde{A}_0F are the same. These two first columns identify the impact of both supply shocks (unexpected and news shocks on TFP) on the four variables contained in y_t . The first two columns of the matrix A_0 are then identified. Consider the following partition $A_0 = [A_1 A_2]$, where the matrix A_2 is of dimension 4×2 . We identify the last two columns of A_0 by finding a matrix F_{22} with $F_{22}F'_{22} = I$ such that $A_2 = \tilde{A}_2F_{22}$ for all admissible matrices F_{22} and where the matrix \tilde{A}_2 contains the last two columns of \tilde{A}_0 . The resulting moving-average $\operatorname{component}$

$$\sum_{\tau=0}^{h} C_i \tilde{A}_2 F_{22} \varepsilon_{t+h-\tau}^T = \sum_{\tau=0}^{h} C_i A_2 \varepsilon_{t+h-\tau}^T \quad ,$$

gives the forecast error of all variables contained in y_t as function of the transitory shocks only ε_t^T with $\varepsilon_t = \left(\varepsilon_t^{P'}, \varepsilon_t^{T'}\right)'$ and ε_t^P is the vector of the permanent structural shocks. Accordingly, the share of the forecast error of the variable *i* to the transitory shock *j* at horizon *h* is:

$$\Omega_{i,j}(h) = \frac{\sum_{\tau=0}^{h} C_{i,\tau} \tilde{A}_2 F_{22} e_j e'_j F'_{22} \tilde{A}'_2 C'_{i,\tau}}{\sum_{\tau=0}^{h} C_{i,\tau} \Sigma C'_{i,\tau}}$$
$$= \frac{\sum_{\tau=0}^{h} C_{i,\tau} \tilde{A}_2 \gamma \gamma' \tilde{A}'_2 C'_{i,\tau}}{\sum_{\tau=0}^{h} C_{i,\tau} \Sigma C'_{i,\tau}}.$$

where e_j is a selection 2×1 vector with one in the *j*th element and zeros elsewhere and γ is the *j*th column of F_{22} . Given this computed share of forecast error due to transitory shocks, we now turn on the second step that allows to identify the sentiments shock.

A.1.2 Step 2

We choose the impulse vector that maximises the cumulative sum corresponding to the contribution of the sentiments shock to the forecast error variance of confidence up to horizon H given by:¹

$$\gamma^* = \operatorname{argmax}_{\gamma} \sum_{h=0}^{H} \Omega_{4,4}(h) \quad , \tag{A.1}$$

subject to

$$\begin{cases} \tilde{A}_2(1,1) = 0\\ \tilde{A}_2(1,2) = 0\\ \gamma'\gamma = 1. \end{cases}$$

This maximisation problem chooses the sub-matrix A_2 maximizing contributions to $\sum_{h=0}^{H} \Omega_{4,4}(h)$. The constraint $\tilde{A}_2(1,1) = \tilde{A}_2(1,2) = 0$ imposes that the stationary shocks have no contemporaneous impact on TFP. Uhlig (2003) shows that this maximisation problem can be rewritten as a quadratic form in which the non-zero portion of is γ the eigenvector associated with the maximum eigenvalue of a weighted sum of $(C_{4,\tau}\tilde{A}_2)'(C_{4,\tau}\tilde{A}_2)$ over τ (see also Barsky and Sims, 2011). In other words, this procedure essentially identifies sentiments shock as the main driver of the cumulative sum of the confidence variance decomposition (up to the horizon H) conditional on the identification of supply shocks in the the first step (see Identification I and Identification II).

¹Francis, Owyang, Roush and DiCecio (2014) propose to use the forecast error variance for a horizon h given by $\Omega_{i,j}(h)$ instead of its cumulative sum.

A.2 Summing-up

To sum-up, our restrictions imply the followings in the short-run: i) the measure of TFP is unaffected by news and stationary shocks on impact; ii) quantities, inflation and confidence can freely respond to each shock in the short-run and iii) among shocks with non-permanent effects, the sentiments shock is the main driver of confidence in the short-medium-run. According to Identifications I–IV, the matrix of impact responses A_0 is organised as follows:

$$A_{0} = \begin{bmatrix} a_{0,11} & 0 & 0 & 0\\ a_{0,21} & a_{0,22} & a_{0,23} & a_{0,24}\\ a_{0,31} & a_{0,32} & a_{0,33} & a_{0,34}\\ a_{0,41} & a_{0,42} & a_{0,43} & a_{0,44} \end{bmatrix}$$

Three lines are of particular interest for our quantitative analysis: $\{a_{0,2i}, a_{0,3i}, a_{0,4i}\}$ with i = 1, 2, 3, 4 in the A_0 matrix. These lines yield the short-run responses of quantities, prices and confidence to identified shocks. Note that we impose no restriction on these lines except that $a_{0,43}$ is obtained from our identification scheme that the sentiments shock is the main driver of confidence, *i.e.* it is obtained from the maximisation problem (A.1). Most of the restrictions concerns the first line, associated to the response of TFP to the four shocks. So, the measure of TFP is mainly used for identification purpose.

B The Sticky Price Model with Capital Accumulation

The model is borrowed from Ireland (2003) and adapted to the case of permanent technology shocks, that is composed of unexpected (surprise) and expected (news) shocks. In addition, news shocks on TFP can be noisy. Time periods are discrete and indexed by t = 1, 2, ... The economy is composed of a representative households, a representative finished goods-producing firm, a continuum of intermediate goods-producing firms indexed by $i \in [0, 1]$, and a central bank.

B.1 The Representative Household

At the beginning of period t, the representative household holds M_{t-1} units of money, B_{t-1} bonds, and k_t unit of physical capital. She also receives a lump-sum monetary transfer denoted T_t from the monetary authority. The return on bond holding is denoted r_t . The household supplies h_t units of labour at the wage rate w_t and k_t units of physical capital at the rental rates Q_t to each intermediate goods-producing firm $i \in [0, 1]$. The household thus receives the total amount of money $w_t h_t + Q_t k_t$ in period t. In addition, she receives D_t unit of dividend payment from various intermediate goods-producing firms. The household uses these funds to purchase a output at a price P_t from the representative finished good-producing firm. The total purchase is split into consumption c_t and investment i_t . In order to transform investment into new productive capital, she must pay an adjustment cost of the form:

$$\frac{\phi_k}{2} \left(\frac{k_{t+1} - k_t}{k_t}\right)^2 k_t \quad ,$$

where $\phi_k \ge 0$ and the capital is subjected to full depreciation $k_{t+1} = i_t$. The household's budget constraint in period t is given by:

$$\frac{M_{t-1}}{P_t} + \frac{T}{P_t} + \frac{B_{t-1}}{P_t} + \frac{w_t h_t}{P_t} + \frac{D_t}{P_t} + \frac{Q_t k_t}{P_t} \ge c_t + i_t + \frac{\phi_k}{2} \left(\frac{k_{t+1} - k_t}{k_t}\right)^2 k_t + \frac{B_t / r_t}{P_t} + \frac{M_t}{P_t}$$

The expected intertemporal utility function is given by

$$E_t \sum_{i=0}^{\infty} \beta^i \left\{ \log c_{t+i} + \zeta \log \left(\frac{M_{t+i}}{P_{t+i}} \right) - \eta \frac{h_{t+i}^{1+\nu}}{1+\nu} \right\},\,$$

where ζ , $\eta > 0$, $\nu \ge 0$ and E_t is the conditional expectations operator.

B.2 The representative finished good-producing firm

The representative finished good-producing firm uses $y_t(i)$ units of each intermediate good $i \in [0, 1]$ (at a purchased price P_t) to produce y_t units of the finished good according to a constantreturns-to-scale technology

$$\left[\int_{0}^{1} y_t(i)^{\frac{\theta-1}{\theta}} d_i\right]^{\frac{\theta}{\theta-1}} \ge y_t.$$
(B.1)

where $\theta > 1$. The firm seeks to maximise its profit

$$P_t y_t - \int_0^1 P_t(i) y_t(i) di,$$

under the technology constraint (B.1).

B.3 The representative intermediate goods-producing firm

The representative intermediate goods-producing firm uses $h_t(i)$ units of labour and $k_t(i)$ units of physical capital in order to produce $y_t(i)$ units of intermediate good *i* using a constant-returnsto-scale technology

$$k_t(i)^{\alpha} (Z_t h_t(i))^{1-\alpha} \ge y_t(i) \quad ,$$

where $0 < \alpha < 1$ and Z_t denotes an aggregate productivity shock. The log of this shock follows a random walk with a positive drift:

$$\log(Z_t) = \log(Z_{t-1}) + \log(\gamma_z) + \varepsilon_t^z$$

where $\gamma_z > 1$ and the innovation ε_t^z is decomposed into an unexpected TFP shock and an expected TFP shock:

$$\varepsilon_t^z = \varepsilon_t^{\text{unexpected}} + \varepsilon_{t-q}^{\text{news}}$$

for q > 0. We also assume that the firm may receive a noisy signal about expected improvement in technology:

$$s_t = \varepsilon_t^{\text{news}} + \varepsilon_t^{\text{noisy news}}$$

where the noise $\varepsilon_t^{\text{noisy news}}$ has zero mean and variance σ_{ν}^2 .

Since intermediate product are imperfect substitutes in the production of finished goods, the representative intermediate goods-producing firm sells its output in a monopolistically competitive market. She sets the price $P_t(i)$ under the requirement to satisfy the demand of the representative finished goods-producing firm. In addition, she faces an intertemporal adjustment cost on its own price (see Rotemberg, 1982)

$$\frac{\phi_p}{2} \left(\frac{P_t(i)}{\pi P_{t-1}(i)} - 1 \right)^2 y_t \quad ,$$

where $\phi_p \geq 0$ and π is the gross inflation rate at steady-state.

B.4 Monetary authority

The central bank conducts its monetary policy by adjusting short-term nominal interest rate i_t and money growth rate μ_t in response to growth rate of in output and inflation π_t :

$$\omega_r \ln(r_t/i) = \omega_\mu \ln(\mu_t/\mu) + \omega_\pi \ln(\pi_t/\pi) + \omega_y \ln(y_t/y_{t-1}) + \ln(v_t)$$
(B.2)

The shock v_t to the monetary policy follows an autoregressive process of order one

$$\log v_t = \rho_v \log v_{t-1} + \varepsilon_{v,t} \quad ,$$

where $\rho_v \in [0, 1)$. The monetary policy rule (B.2) nests previous representations. For example, when $\omega_r = 1$, $\omega_\mu = 0$, $\omega_\pi > 1$ and $\omega_y > 0$, we retrieve a Taylor type rule. Conversely, $\omega_r = 0$, $\omega_\mu = -1$, $\omega_\pi = 0$ and $\omega_y = 0$, we get a simple exogenous money growth rule.

B.5 Confidence

Following Barsky and Sims (2012), we assume that confidence is possibly related to some fundamental shocks of the economy.

$$Confidence_t = \rho_s Confidence_{t-1} + \mu_1 \underbrace{\left(\varepsilon_t^{\text{news}} + \varepsilon_t^{\text{noisy news}}\right)}_{\text{Noisy signal}} + \mu_2 \varepsilon_t^{\text{monetary}} + \mu_3 \varepsilon_t^{\text{idiosyncratic}}$$

where where $\rho_s \in [0, 1)$. $\varepsilon_t^{\text{monetary}}$ is identical to $\varepsilon_{v,t}$. Depending on the values of μ_i (i=1,2,3) and the standard-errors of the shocks, we can consider various situations: *i*) the case of idiosyncratic shock on confidence ($\mu_1 = \mu_2 = 0$ and $\mu_3 = 1$), *ii*) the case of noisy news ($\mu_1 > 0, \mu_2 = 0$ and $\mu_3 \simeq 0$) *iii*) a situation in which demand shocks explains most of the variance of confidence ($\mu_2 > \mu_3$).

B.6 Calibration

The calibration of the model is reported in Table 1. Parameters describing technology and preferences are fixed to standard values. Notice that we set $\omega_r = 0$, $\omega_{\mu} = -1$, $\omega_{\pi} = 0$ and $\omega_y = 0$ in the monetary policy rule (B.2), so we assume a simple exogenous money growth rule. The two adjustment costs parameters on physical capital ϕ_k and prices ϕ_p are calibrated to obtain persistent responses to shocks. In addition, we play with these two parameters in order to get a positive response (although almost zero on impact) of output to a news shocks (before its materialisation). We report in Figure B.1 the dynamic responses to a news shock, when this shock is known one year in advance. The figure also includes the response to the noise shock. The standard errors of the news and noise shocks are equal.

Subjective Discount Factor	0.99
Capital Share	0.33
Growth Rate of TFP	0.0036
Inverse of the Frish Elasticity of Labour Supply	1
Price Markup	20%
Adjustment Costs on Prices	5
Adjustment Costs on physical capital	60
Persistence of monetary Policy Shock	0.6
S.E. of unexpected TFP Shock	0.005
S.E. of news shock on TFP	0.005
S.E. of noisy news shock on TFP	0 or 0.005
S.E. of monetary policy shock	0.0020
S.E. of idiosyncratic sentiments shock	0 or 0.005
S.E. of measurement error on sentiments	0 or 0.0001

Table 1: Parameter values



B.7 Simulation Results













C Factor Augmented VAR Model

C.1 Impulse Response Functions and Variance Decomposition





C.2 Barsky–Sims Identification and Factor Augmented VAR



Figure C.6: Variance Decomposition (Barsky–Sims and Facror Augmented VAR)

Note: The VAR model includes the adjusted TFP, the real per capita GDP, the rate of inflation (CPI all), the measure E5Y of consumer confidence and one factor. The sample period is 1960:1-2016:4. Three lags are included in the VAR. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to a composite stationary shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.

D Additional Robustness Analysis

D.1 Other conditioning variables

We now investigate the role of conditioning variables. As previously noticed, conclusions about news shock must be more deeply inferred from the short–run responses of other aggregates. In addition, we want to assess if the conditioning variable modifies our main conclusions. We replace the GDP by investment and consumption, successively. We use the same VECM (??) as before and we maintain the same identification scheme. The number of lags is also the same as before. Again, changing the number of lags in the VECM does not modify our results. We just need to adjust for the cointegration relationship between the TFP and the new variable that represents quantities.

Investment

Let us first consider the dynamic responses with the real per capita investment (defined as the sum of private fixed investment and durables) instead of GDP. The dynamic responses of TFP, inflation and consumer confidence after each shock are similar to what we obtained with the GDP in SVAR. The sole difference concerns the size of the response of investment to each shock, reflecting the higher volatility of investment compared to output. In the line with Beaudry and Portier (2006, 2014), we obtain that investment instantaneously increases and very quickly reaches its long-run value after a positive news shock. At the same time, TFP increases gradually. So, our results are supportive of the news-driven business cycle. Again, the consumer confidence highly and persistently reacts to "good" news. The response of inflation to a news shock is persistently negative, as in the benchmark case. The response of investment to a demand shock displays a hump-shape pattern. Inflation still increases, but its effect is not precisely estimated. The demand shock has virtually no effect on consumer confidence. The response of investment to a sentiments shock is hump-shaped and prices increase. However, the dynamic responses are not different from zero. Consumer confidence strongly reacts on impact to a sentiments shock but the response displays less persistence, compared to the benchmark case. Figure D.7 reports the variance decomposition for the four variables. The variance decomposition of TFP is almost same as in the benchmark exercise. Two differences are worth noting. First, the (transitory) demand shock remains the main driver of investment during three years. For more periods after the shock, the news shock becomes the larger contributor. Second, the sentiments shock has a larger but rather limited effect on investment (its larger contribution never exceeds 15%).



Figure D.7: Variance Decomposition (SVECM & Investment)

Note: The VECM includes the growth rate of adjusted TFP, the growth rate of real per capita investment, the rate of inflation (CPI all) and the measure E5Y of consumer confidence. The sample period is 1960:1-2016:4. Three lags are included in the VECM. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to the demand shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.

Consumption

Now, we consider real per capita consumption in our VECM. This variable is defined as the sum of non-durable and services expenditures and then is divided by population 16 and over. Concerning the dynamic responses, the picture is almost the same as we obtained with GDP.² The sentiments shock has limited effects on consumption and inflation, not precisely estimated. Sentiments shock only affects consumer confidence, without any apparent propagation effect on main aggregates. Figure D.8 reports the variance decomposition for TFP, consumption, inflation and consumer confidence, respectively. The variance decomposition of TFP is almost identical to the benchmark case: the unexpected TFP shock explains almost totally the variance of TFP in the short–run and the share of news shock on TFP increases with the horizon. Concerning real per capita consumption, the news shock is the main driver (60% on impact and more than 95% after ten years). The sentiments shock contributes in the short–run (around 20%), but its effects quickly decreases. Concerning inflation, the main difference is that demand shock explains the larger share of its variance (more than 70%) and the contribution of the news shocks is reduced compared to the benchmark case. As in the previous cases, news and sentiments shocks account for most of the volatility of consumer confidence.

 $^{^{2}}$ As for investment, inflation decreases after a news shocks, making the negative response a robust fact (see Barsky, Basu and Lee, 2014).



Figure D.8: Variance Decomposition (SVECM & Consumption)

Note: The VECM includes the growth rate of adjusted TFP, the growth rate of real per capita consumption, the rate of inflation (CPI all) and the measure E5Y of consumer confidence. The sample period is 1960:1-2016:4. Three lags are included in the VECM. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to the demand shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.

D.2 Relaxing the Zero Short–Run Restriction

We have also relaxed the assumption that demand shocks cannot have an effect (on impact) on TFP. As emphasised in Ben Zeev and Pappa (2015), this restriction has strong implications for the quantitative assessment of the shortûrun propagation of unexpected fiscal shocks that are a part of our identified demand shock. Rather than imposing a zero restriction, we set a non zero value for the (1×3) entry in the initial matrix \tilde{A}_o of our approach. In practise, we select an initial positive value, such that the short–run response of output is similar to what obtained in Ben Zeev and Pappa (2015) when the TFP is allowed to respond to government spending shock. The demand shock has now an immediate effect on TFP but none of our previous results are affected. The news shock remains the main driver of GDP and inflation, and the sentiments shock explains a tiny share of their variance.



Figure D.9: Non zero Restriction on Demand Shock – Variance decomposition

Note: The VECM includes the growth rate of adjusted TFP, the growth rate of real per capita GDP, the rate of inflation (CPI all) and the measure E5Y of consumer confidence. The sample period is 1960:1-2016:4. Three lags are included in the VECM. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to the demand shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.

D.3 Data Measurement on Inflation

We replace the Consumer Price Index all commodities by the Consumer Price Index less food and energy. The role of energy prices appears to be of first importance, because its cyclical pattern has changed quite a lot. During the seventies and the early eighties, energy prices were countercyclical consecutive to the successive oil shocks. Conversely, these prices became procyclical afterwards as the world economic growth (notably emerging economies) has led to an upward pressure. Energy prices can thus potentially contaminate our identification of supply and demand shocks. This is not the case. As shown in Figure D.11, the results are the same. The sole difference is that demand shock contributes more to the variance of inflation.



Figure D.10: CPI Less Food and Energy – Variance decomposition

Note: The VECM includes the growth rate of adjusted TFP, the growth rate of real per capita GDP, the rate of inflation (CPI less food and energy) and the measure E5Y of consumer confidence. The sample period is 1960:1-2016:4. Three lags are included in the VECM. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to the demand shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.

D.4 Shorter Sample (1960-2006)

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Figure D.11: Shorter Sample (1960:1-2006:7) – Variance decomposition

Note: The VECM includes the growth rate of adjusted TFP, the growth rate of real per capita GDP, the rate of inflation (CPI all) and the measure E5Y of consumer confidence. The sample period is 1960:1-2006:4. Three lags are included in the VECM. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to the demand shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.

D.5 Sensitivity to the Maximisation Horizon



Figure D.12: Sensitivity to the Maximisation Horizon (1 year) – Variance decomposition

Note: The VECM includes the growth rate of adjusted TFP, the growth rate of real per capita GDP, the rate of inflation (CPI all) and the measure E5Y of consumer confidence. The sample period is 1960:1-2016:4. Three lags are included in the VECM. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to the demand shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.



Figure D.13: Sensitivity to the Maximisation Horizon (5 years) – Variance decomposition

Note: The VECM includes the growth rate of adjusted TFP, the growth rate of real per capita GDP, the rate of inflation (CPI all) and the measure E5Y of consumer confidence. The sample period is 1960:1-2016:4. Three lags are included in the VECM. The selected horizon for IRFs is 40. The white area corresponds to the share of variance explained by the sentiments shock, the light grey area to the demand shock, the dark grey area to the news shock on TFP and the dark area to the surprise shock on TFP.

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