Appendix (Not for Publication) for:

Oil Price Shocks, Inventories and Macroeconomic Dynamics

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Abstract

This paper investigates the time delay in the transmission of oil price shocks using disaggregated manufacturing data on inventories and sales. VAR estimates indicate that industry-level inventories and sales respond faster to an oil price shock than aggregate GDP, especially industries that are energy intensive. In response to an unexpected oil price increase, sales drop and inventories are accumulated. This leads to future reductions in production. We estimate a modified linear-quadratic inventory model to inquire whether the patterns observed in the VAR impulse responses are consistent with rational behavior by the firms. Estimation results suggest that three mechanisms play a role in the industry-level dynamics. First, oil prices act as a negative demand shock. Second, the shock catches manufacturers by surprise resulting in higher than anticipated inventories. Third, because of their desire to smooth production, manufacturers deviate from the target level of inventories and spread the decline in production over various quarters, hence the delay in the response of aggregate output.

Keywords: oil shocks, macroeconomic fluctuations, inventories.
JEL Classification: E22, E32,Q43.

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1 The Optimization Problem in Matrix Form

Note that, with constants set to zero, the cost function in (4) can be written as:

$$C_t = (1/2)\mathbf{g}_t^{'}\mathbf{G}_0\mathbf{g}_t$$

where $\mathbf{g}_t = \begin{bmatrix} Q_t - Q_{t-1} \\ Q_t - U_{c,t} \\ H_{t-1} - a_3 S_t \end{bmatrix} = \mathbf{\Lambda}' \begin{bmatrix} u_t \\ \mathbf{x}_t \end{bmatrix}$.

Let $\mathbf{\Lambda}' = \begin{bmatrix} 1 & -2 & 1 & 0 & 0 & 0 & 1 & \mathbf{0}_5 \\ 1 & -1 & 0 & 0 & -1 & 0 & 0 & \mathbf{0}_5 \\ 0 & 1 & 0 & -a_3 & 0 & 0 & -a_3 & \mathbf{0}_5 \end{bmatrix}$,

$\mathbf{G}_0 = \begin{bmatrix} a_0 & 0 & 0 \\ 0 & a_1 & 0 \\ 0 & 0 & a_2 \end{bmatrix}$,

and $\mathbf{x}_t = (H_{t-1}, H_{t-2}, S_{t-1}, v_{c,t}, v_{c,t-1}, v_{s,t}, v_{s,t-1}, o_t, o_{t-1}, o_{t-2}, o_{t-3})'$ denote the state vector that summarizes information relevant for the firm's decision, $u_t = H_t$ denote the control variable, and $\mathbf{0}_5$ denote a (1×5) vector of zeros.

Notice further that if we collect equations inventory identity(**??**), the equation of motion for $\mathbf{x}_t$ (**??**) can be written as

$$\mathbf{x}_{t+1} = \mathbf{A}\mathbf{x}_t + \mathbf{B}u_t + \mathbf{C}\mathbf{w}_{t+1}. \tag{1}$$

$$
\text{where } \mathbf{A} = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \theta_{c1} & \theta_{c2} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & \lambda_{s1} & \lambda_{s2} & \lambda_{o1} & \lambda_{o2} & \lambda_{o3} & \lambda_{o4} \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \omega_{o1} & \omega_{o2} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0
\end{bmatrix};
$$

$\mathbf{B} = \begin{bmatrix} 1 \\ \mathbf{0}_{10} \end{bmatrix}$, $\mathbf{0}_{10}$ denotes a (1×10) vector of zeros;

$$
\mathbf{C} = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & \lambda_{o0} & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}, \quad \mathbf{w}_t = \begin{bmatrix}
0 \\ 0 \\ 0 \\ \varepsilon_{c,t} \\ 0 \\ \varepsilon_{s,t} \\ 0 \\ \varepsilon_{o,t} \\ 0 \\ 0 \\ 0
\end{bmatrix}
$$

and all elements of $E(\mathbf{w}_t\mathbf{w}_t')$ are zero except the (4,4), (6,6), and (8,8), and elements, which are

σ_{cc}, σ_{ss}, and σ_{oo}, respectively.

Then the firm's optimization problem can then be rewritten as in equations (**??**) and (**??**):

$$\min_{\{u_t\}_{t=0}^{\infty}} E\left\{\sum_{t=0}^{\infty}\beta^t \begin{bmatrix} u_t & \mathbf{x}_t' \end{bmatrix} \mathbf{G} \begin{bmatrix} u_t \\ \mathbf{x}_t \end{bmatrix} \mid \mathcal{F}_0 \right\}$$

subject to

$$\mathbf{x}_{t+1} = \mathbf{A}\mathbf{x}_t + \mathbf{B}u_t + \mathbf{C}\mathbf{w}_{t+1}$$

where $\mathcal{F}_0$ denotes the information set at $t = 0$.

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Table A.1. Time Series Properties of Manufacturing Inventories and Sales

Sector	Unit root tests: Inventories ADF	Unit root tests: Inventories DF-GLS	Unit root tests: Sales ADF	Unit root tests: Sales DF-GLS	Cointegration tests Inventories - Sales: Engle-Granger	Cointegration tests Inventories - Sales: Perron-Rodriguez
Industries						
Food	-1.614	1.147	-0.940	2.270	-3.165 *	-2.781 **
Tobacco	-3.609 ***	-2.861 ***	-2.148 **	-2.024 **	-4.181 ***	-2.866 **
Textiles	-2.050	1.249	-1.599	0.616	-3.181 *	-2.449
Apparel	-2.407	0.874	-2.028	0.505	-6.782 ***	-6.063 ***
Paper	-2.151	2.517	-2.259 *	1.810	-3.809 **	-3.771 ***
Printing and publishing	-2.788 *	2.025	-2.055	1.397	-2.977	-2.971 **
Petroleum products	-1.866	2.382	-1.823	1.347	-4.349 ***	-4.353 ***
Chemical	-2.809 *	-0.478	-1.779	0.805	-4.305 ***	-3.427 ***
Rubber and plastics	-1.188	2.073	-1.016	1.626	-3.722 **	-3.427 ***
Leather	-2.851 *	-1.228	-0.220	0.714	-2.903	-1.472
Lumber	-3.611 ***	-0.156	-1.435	0.485	-5.041 ***	-2.914 **
Furniture and fixtures	-1.673	2.275	-0.558	1.470	-2.927	-2.021
Stone, clay and glass products	-1.962	1.738	-0.962	0.443	-2.014	-1.831
Primary metals products	-2.464 *	-0.145	-2.355	-0.471	-3.188 *	-3.468 ***
Fabricated metals products	-1.356	2.480	-1.409	1.093	-3.040	-2.997 **
Industrial machinery	-0.955	2.650	1.279	3.565	-1.510	-0.943
Electrical machinery	-1.969	2.217	0.589	3.217	-2.612	-1.014
Transportation equipment						
Motor vehicles	-0.859	1.131	-1.616	0.431	-5.143 ***	-5.260 ***
Other transportation equipment	-1.844	0.482	-1.708	-0.239	-3.874 **	-3.475 ***
Instruments	0.595	3.471	-1.827	2.653	-1.097	-0.396
Other durables	-2.496	0.810	-0.789	1.567	-2.436	-1.972
Aggregates						
Manufacturing	-2.297	2.492	-0.476	2.132	-4.868 ***	-2.989 **
Nondurables	-2.358	2.141	-1.688	1.912	-4.370 ***	-3.883 ***
Durables	-1.092	3.282	-0.120	2.099	-2.581	-2.212

Note: DF-GLS is the value for Elliott, Rothenberg and Stock (1996) unit root test; ADF is the value of the Augmented Dickey-Fuller test; Engle-Granger is the value of the Engle-Granger (1987) residual based cointegration test; Perron-Rodriguez is the value for Perron and Rodriguez (2001) residual based cointegration test. The number of lags for all tests was selected using the BIC. **, and * denote significance at the 1%, 5%, and 10% level, respectively.

Table A. 2. Cost of Energy Input per Dollar of Output

	Cost of oil and natural gas for each dollar of sale
Food	0.027
Tobacco	0.009
Textiles	0.040
Apparel	0.030
Paper	0.035
Printing and publishing	0.012
Petroleum products	0.803
Chemicals	0.150
Rubber and plastics	0.036
Leather	0.031
Lumber	0.020
Furniture and fixtures	0.018
Stone, clay, and glass products	0.038
Primary metals products	0.044
Fabricated metals products	0.018
Industrial machinery	0.013
Electrical machinery	0.020
Motor vehicles	0.020
Other transportation equipment	0.012
Instruments	0.015

Note: computations based on the 1977 Input-Output tables published by the Bureau of Economic Analysis. This cost represents the total direct and indirect energy requirements per dollar of output sold by the particular industry.

Table A.3. Manufacturing Industries for which Motor vehicles Represent a Good Demand-shift Instrument

SIC	Industry	Instrument	DDS	UDS	DCS	UCS
Three-digit SIC industries						
239	Miscellaneous apparel	Transportation equipment (SIC 37)	30.6	18.5	2.3	--
		Motor vehicles (SIC 371)	29.2	17.2	3.2	1.6
253	Public building furniture	Transportation equipment (SIC 37)	25.4	17.2	--	--
		Motor vehicles (SIC 371)	23.2	14.9	--	--
301	Tires	Transportation equipment (SIC 37)	19.1	13.0	4.3	2.1
304	Rubber and plastic hose and belting	Transportation equipment (SIC 37)				
		Motor vehicles (SIC 371)	19.4	14.5	6.0	2.8
321, 3229	Glass products, except containers	Transportation equipment (SIC 37)	23.7	17.9	1.3	1.3
		Motor vehicles (SIC 371)	21.5	15.2	1.7	1.5

Source: Shea (1993).

Notes:

DDS: direct demand share of industry *I* for industry *J* is the share of domestically originating demand for *J*'s output directly attributable to capital or intermediate purchases by industry *I*.

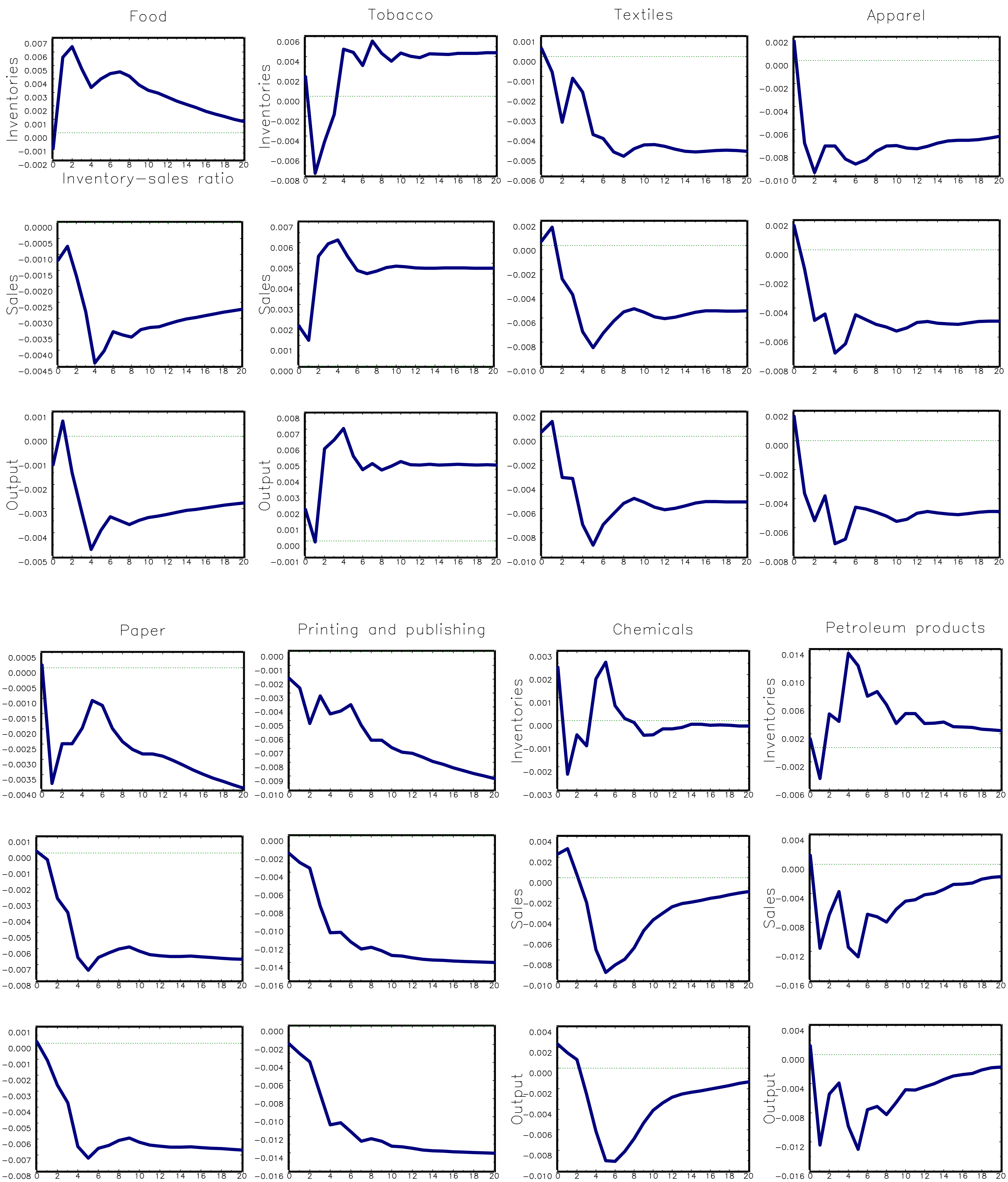
UDS: ultimate demand share of industry *I* for industry *J* is the share of J's output ultimately embodied in final demand for *I* incorporating both direct and indirect links.

DCS: direct cost share of industry *Y* for industry *Z* is the value of Y directly required as an intermediate or capital input per dollar of *Z*'s output.

UCS: ultimate cost share of industry *Y* for industry *Z* is the labor cost ultimately originating in *Y* per dollar of *Z*'s output.

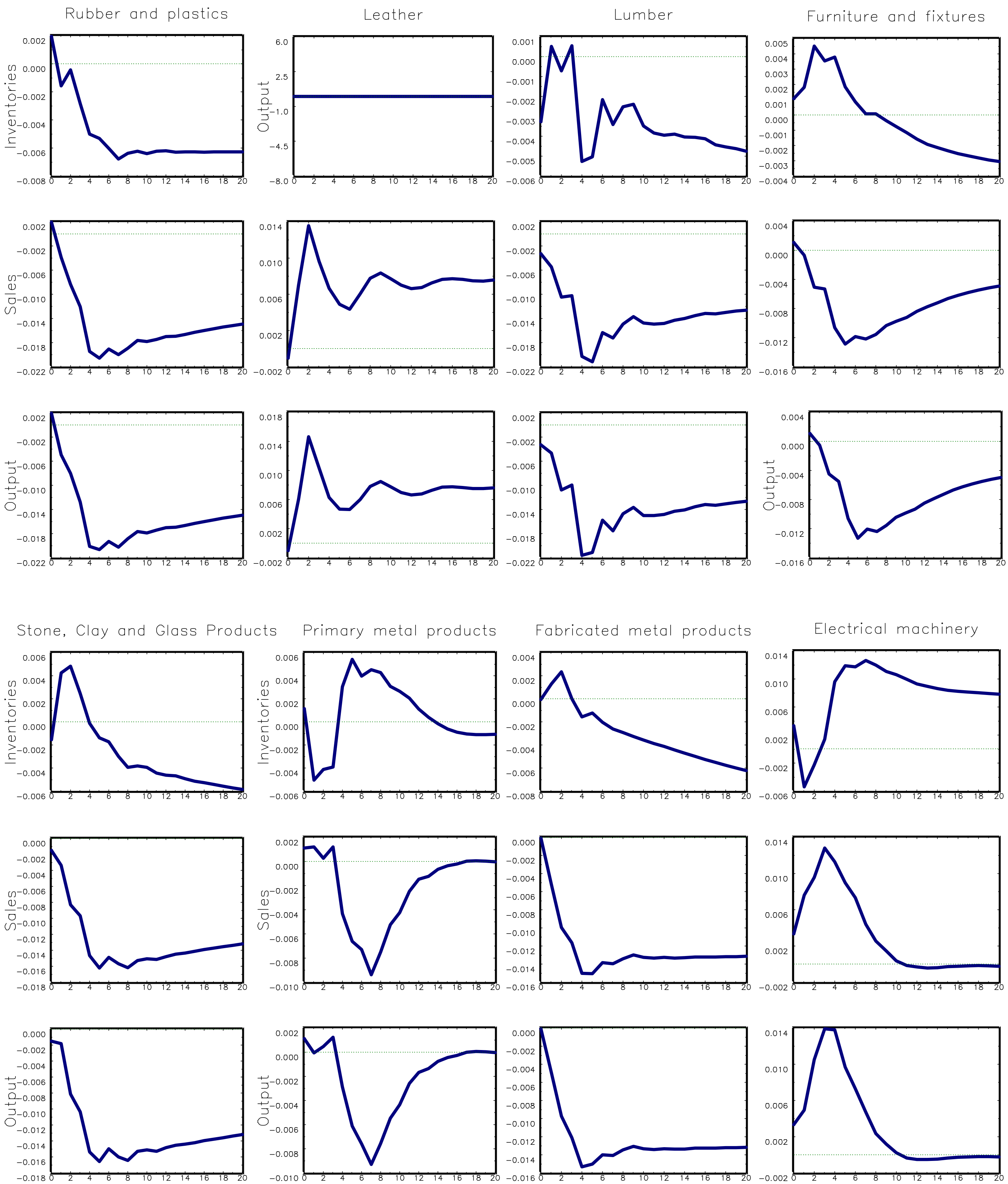
-- indicates unknown, less than 2%.

Figure A.1a: Cumulative Response to a 10% Increase in the Real Oil Price



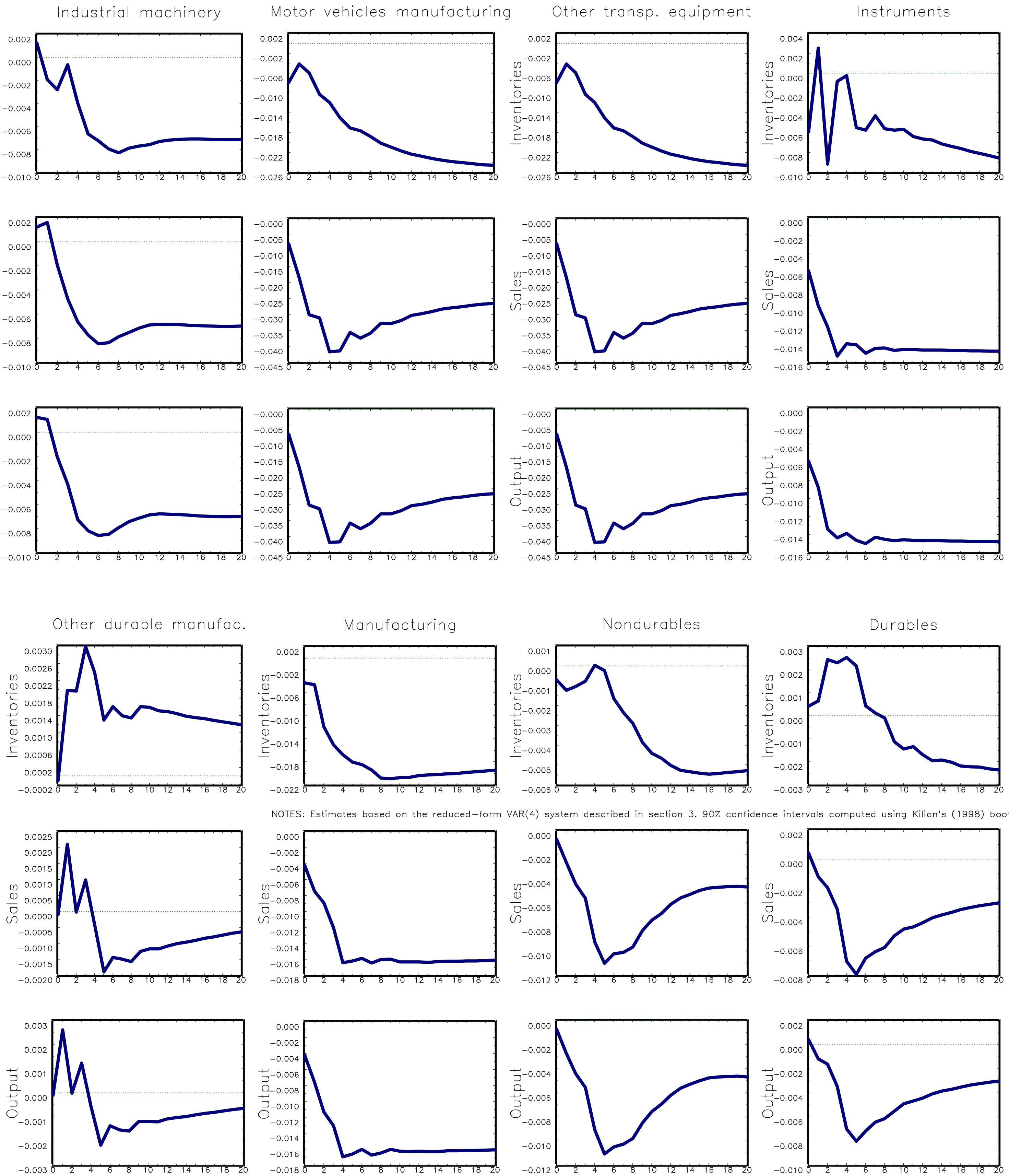
NOTES: Estimates based on the reduced−form VAR(4) system described in section 3. 90% confidence intervals computed using Kilian's (1998) bootstrap−after bootstrap method.

Figure A.1b: Cumulative Response to a 10% Increase in the Real Oil Price



NOTES: Estimates based on the reduced-form VAR(4) system described in section 3. 90% confidence intervals computed using Kilian's (1998) bootstrap-after bootstrap method.

Figure A.1c: Cumulative Response to a 10% Increase in the Real Oil Price



NOTES: Estimates based on the reduced−form VAR(4) system described in section 3. 90% confidence intervals computed using Kilian's (1998) bootstrap−after bootstrap method.