3. Data

- **Observations**: Monthly series from January 1986 to June 2020.

- **Data Source**:

a) Oil Price: the spot price of West Texas Intermediate (WTI) crude oil, from the *U.S. Energy Information*

b) Policy Uncertainty: Canadian economic policy uncertainty index, from the *Economic Policy Uncertainty* website

c) Real Economic Activity: production indices of Canadian industrial, manufacturing, and construction activities, from the *OECD Main Economic Indicators*

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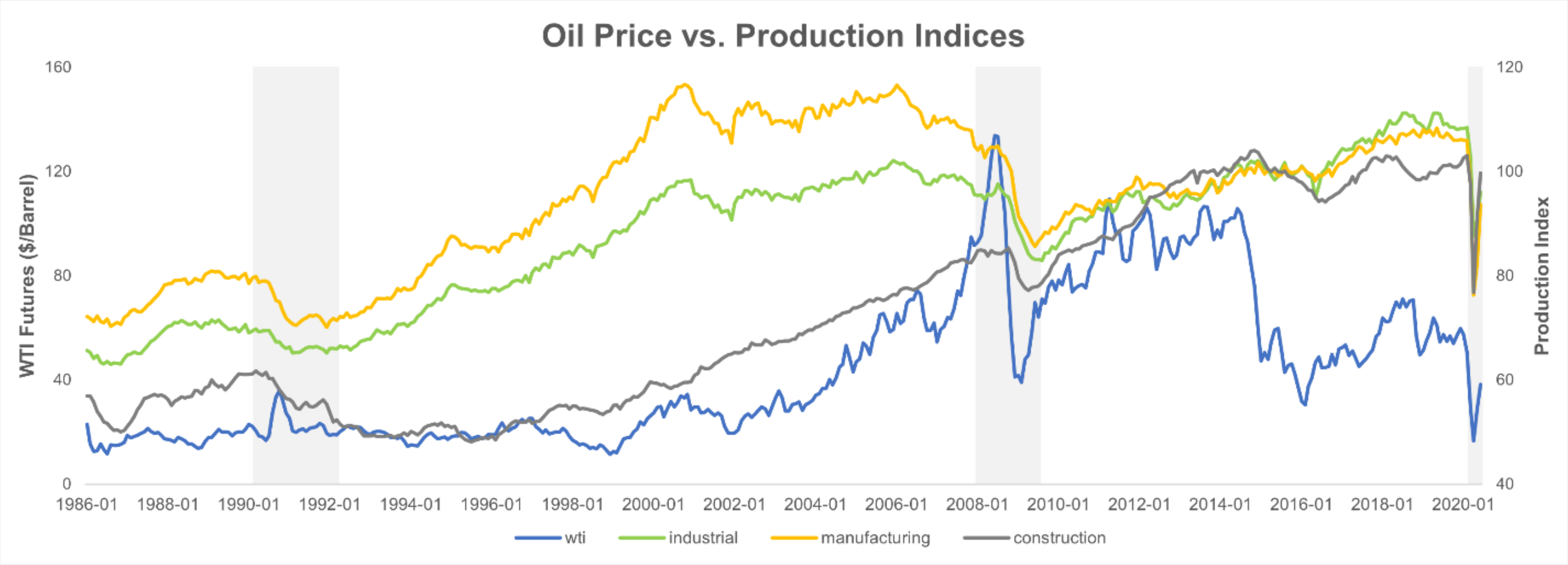
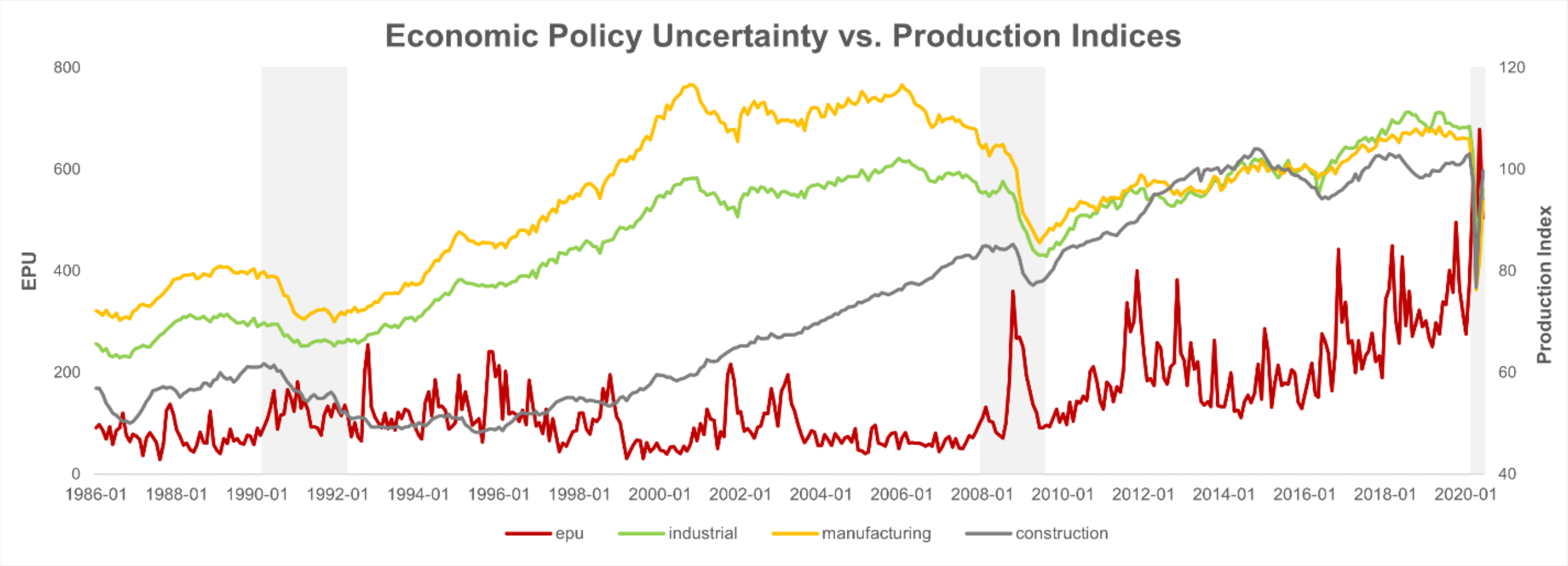
3.1 Time Series Plot





- **Trend**: each series has an overall upward trend except the oil price series.

- **Correlations**: economic policy uncertainty series seems to move in an opposite direction to other variables.

- **Cycles**: apparent cyclical patterns seems evident for each series.

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3.2 Covariance Stationarity

- Augmented Dickey Fuller (ADF), Dickey Fuller GLS (DFGLS), KPSS tests
- **Null Hypotheses (H_0)**:

a) ADF & DFGLS: the series has a unit root

b) KPSS: the series is covariance stationary

- I include 11 deterministic seasonal dummy variables and a linear trend in the testing equations as control variables
- I select 11 augmentation terms to ensure the validity of the tests while using monthly data.
- The critical value is based on α = 10% due to the low power of the tests.

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3.2 Covariance Stationarity

Series	ADF		DF-GLS		KPSS	
	Test Statistic	Crit. Val ($\alpha = 10\%$)	Test Statistic	Crit. Val ($\alpha = 10\%$)	Test Statistic	Crit. Val ($\alpha = 10\%$)
WTI	-2.096		-2.100		0.233	
EPU	-1.232		-1.352		0.429	
Industrial	-1.707	-3.130	-1.805	-2.560	0.327	0.119
Manufacturing	-1.186		-0.963		0.436	
Construction	-1.389		-1.252		0.402	

Note: The number of augmentation lags for both the ADF and the DF-GLS tests is set at 11 for each auxiliary regression. For the KPSS test, the #bandwidth is selected through using the Bartlett kernel, and is equal to 15 for EPU and 16 for the other series.

- Each of the series is **covariance non-stationary** with at least one unit root.

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3.3 Seasonal Unit Roots

Frequency	WTI	EPU	Industrial	Manufacturing	Construction
0 & 2π	-1.720	-0.137	-1.665	-1.872	-0.782
2π/12 & 22π/12	22.721***	25.918***	41.635***	22.168***	29.180***
4π/12 & 20π/12	30.366***	39.893***	24.255***	9.192***	5.872***
6π/12 & 18π/12	30.175***	55.041***	16.541***	11.692***	1.679**
8π/12 & 16π/12	43.438***	27.200***	19.990***	14.291***	4.022***
10π/12 & 14π/12	33.384***	22.870***	42.522***	35.132***	13.503***
π	-6.013***	-6.072***	-5.895***	-5.736***	-3.014**
All seasonal frequencies	606.388***	74.796***	30.020***	373.439***	215.603***
All frequencies	557.472***	71.682***	28.313***	348.928***	198.284***

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

- I undertake HEGY test to detect the presence of seasonal unit roots
- **Null Hypotheses (H_0)**: the series has a unit root at the specified frequency (or degree).
- If a series has a unit root at the frequencies other than 0, we may say that the series exhibits a seasonal unit root.
- The test results indicate that all series have a **non-seasonal** unit root but no seasonal unit roots.

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3.4 Cointegration Test

- I perform Johansen's (1988, 1991) maximum-eigenvalue and trace tests to explore for possible cointegrating (long-term) relationships among the series in the same system.

- Each system contain three series: the oil price, economic policy uncertainty, each production type. Therefore, I undertake the test for each considered production variable.

3.4 Cointegration Test

- **Maximum-eigenvalue Test**:

$H_0^1: r = 0$ vs. $H_a^1: r = 1$

$H_0^2: r = 1$ vs. $H_a^2: r = 2$

$H_0^3: r = 2$ vs. $H_a^3: r = 3$

- **Trace Test**:

$H_0^1: r = 0$ vs. $H_a^1: r = 3$

$H_0^2: r = 1$ vs. $H_a^2: r = 3$

$H_0^3: r = 2$ vs. $H_a^3: r = 3$

- r denotes the number of cointegrating vectors in the system.

- If we fail to reject H_0^1, we stop testing, concluding no cointegrating relationships.

3.4 Cointegration Test

Production Series	Maximum-Eigenvalue Test (H_0: r = 0 vs. H_a: r = 1)		Trace Test (H_0: r = 0 vs. H_a: r = 3)	
	Statistic	Crit. Val (α = 5%)	Statistic	Crit. Val (α = 5%)
Industrial	4.662	21.132	8.361	29.797
Manufacturing	5.277		9.519	
Construction	11.232		17.629	

- There are **no** cointegrating relationships in each system, and using the first difference of each series in the VAR estimation seems reasonable.

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3.5 VAR Diagnostics

$$Y_t = \alpha + \sum_{i=1}^{p} \phi_i Y_{t-i} + \sum_{j=1}^{11} \psi_j D_{t,j} + \varepsilon_t$$

- Y_t = [Δwti_t, Δepu_t, $\Delta production_t^k$]'; k = industrial, manufacturing, or construction
- Y_{t-i}: lagged values at order i
- Φ_i: the (3 $\times$ 3) matrix of reduced-form autoregressive parameters
- $D_{t,j}$: binary variable for the j^{th} month
- ε_t: the (3 $\times$ 1) vector of reduced-form error terms

- Based on the Akaike's (1974) Info Criterion, choose p = 4 for the models consisting of industrial and manufacturing productions and p = 6 for construction production.

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3.5 VAR Diagnostics

Dependent Variable	Independent Variables	χ^2	p-value
Δind	Δwti	26.842	0.0000
	Δepu	4.927	0.2948
	All	39.374	0.0000
Δman	Δwti	19.604	0.0006
	Δepu	7.946	0.0936
	All	35.290	0.0002
Δcon	Δwti	17.976	0.0063
	Δepu	23.319	0.0007
	All	52.491	0.0001

- **Granger's (1969) non-causality test**: tests for one-period ahead predictability.
- **Null Hypothesis (H_0)**: the lagged independent variable does not help explain or Granger cause the current value of the dependent variable.
- The price of crude oil Granger causes all production types, while policy uncertainty only help explain construction production.

4. Methodology

- Functional form
- Identifying restrictions

4.1 Functional Form

$$A_0 Y_t = \alpha + \sum_{i=1}^{p} A_i Y_{t-i} + \sum_{j=1}^{11} \gamma_j D_{t,j} + u_t$$

- A_0: the (3 $\times$ 3) contemporaneous coefficient matrix between the endogenous variables
- A_i: the (3 $\times$ 3) matrix comprising the structural autoregressive parameters at order i
- u_t: the (3 $\times$ 1) vector of structural error terms

- I impose **short-run** restrictions via the error terms, as there are likely no cointegrating relationships amongst the oil price, policy uncertainty, and each real production.

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4.2 Identifying Restrictions – Expressions

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

$$\begin{bmatrix} \varepsilon_t^{\Delta wti} \\ \varepsilon_t^{\Delta epu} \\ \varepsilon_t^{\Delta production} \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} u_t^{\Delta wti} \\ u_t^{\Delta epu} \\ u_t^{\Delta production} \end{bmatrix}$$

$$\begin{bmatrix} \varepsilon_t^{\Delta wti} \\ \varepsilon_t^{\Delta epu} \\ \varepsilon_t^{\Delta production} \end{bmatrix} = \begin{bmatrix} a_{11} u_t^{\Delta wti} \\ a_{21} u_t^{\Delta wti} + a_{22} u_t^{\Delta epu} \\ a_{31} u_t^{\Delta wti} + a_{32} u_t^{\Delta epu} + a_{33} u_t^{\Delta production} \end{bmatrix}$$

- $u_t^{\Delta wti}$: Oil price shock
- $u_t^{\Delta epu}$: Policy uncertainty shock
- $u_t^{\Delta production}$: Shock in real activity

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4.2 Identifying Restrictions – Economic Reasonings

$$\begin{bmatrix} \varepsilon_t^{\Delta wti} \\ \varepsilon_t^{\Delta epu} \\ \varepsilon_t^{\Delta production} \end{bmatrix} = \begin{bmatrix} a_{11} u_t^{\Delta wti} \\ a_{21} u_t^{\Delta wti} + a_{22} u_t^{\Delta epu} \\ a_{31} u_t^{\Delta wti} + a_{32} u_t^{\Delta epu} + a_{33} u_t^{\Delta production} \end{bmatrix}$$

a. The oil price does not respond to shocks in Canadian economic policy uncertainty and real activity because it captures the oil market price of the entire world.

b. A change in the oil price can affect Canadian policy uncertainty, as we cannot anticipate the direction of that change.

c. Both the world oil price and economic policy uncertainty are necessary determinants of domestic real economic activities.

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5. Results

- I interpret and discuss my empirical findings based on:

a) Impulse response functions (IRFs)

b) Forecast error variance decompositions (FEVDs)

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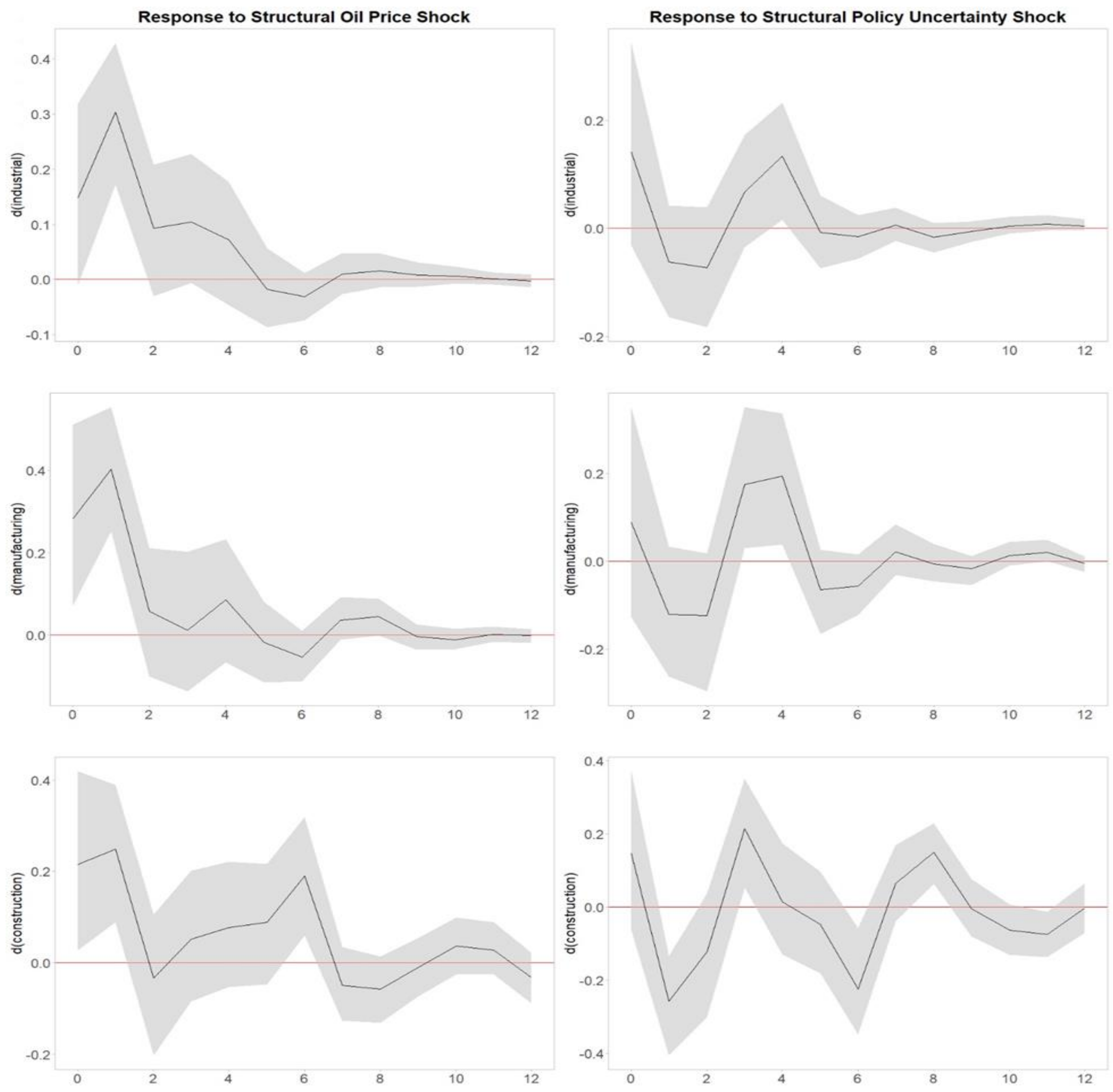
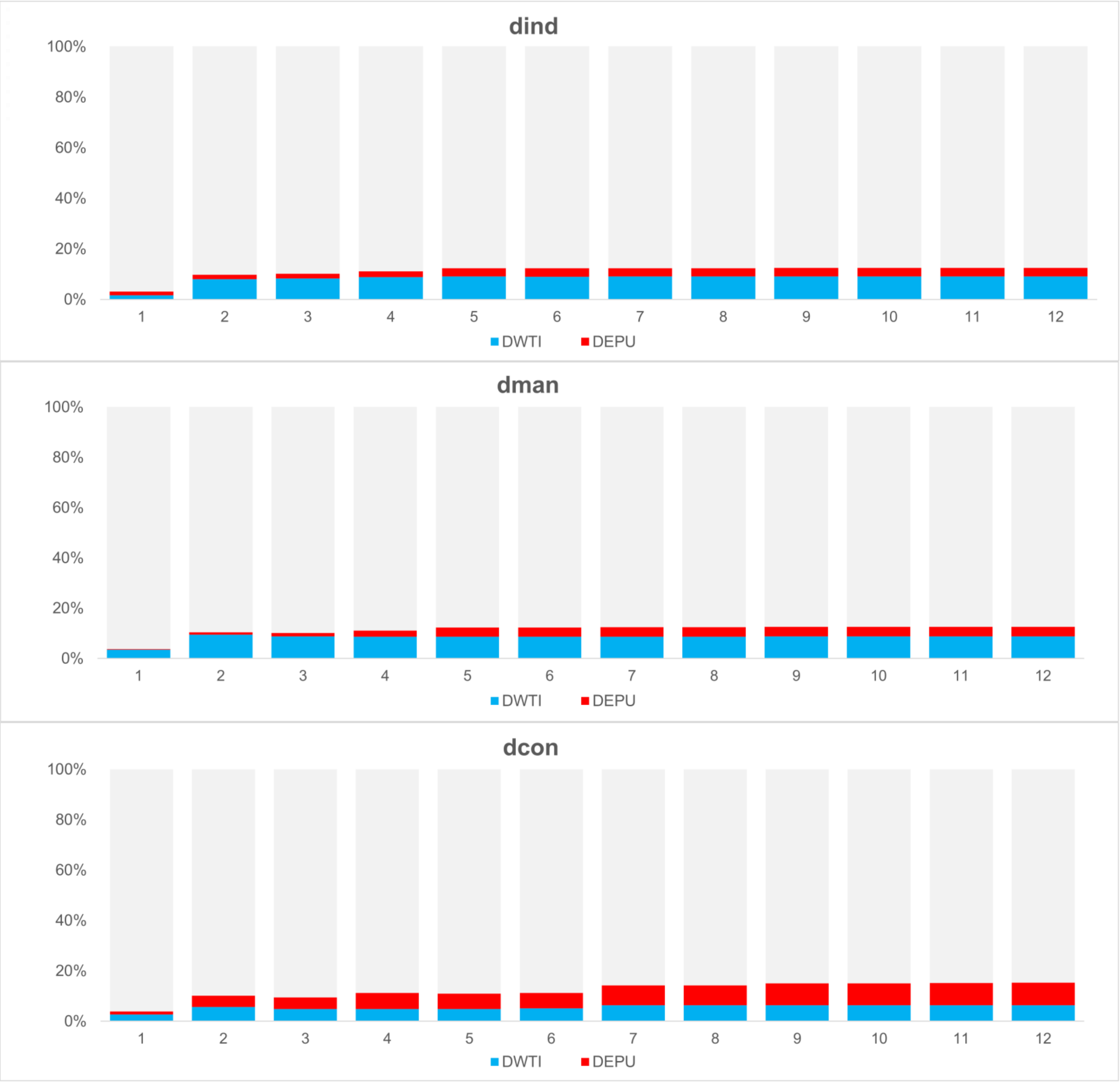
5.1 Impulse Response Analysis



- The oil price shock leads to an instantaneous **positive** response for all types of real productions, but this effect dissipates quickly.

- The policy uncertainty shock has a statistically significant impact on construction production, being negative instantaneously but becoming positive shortly thereafter.

5.2 Forecast Error Variance Decomposition



- The structural shocks to the oil price and to policy uncertainty jointly explain **15-20%** of the forecast error variance in productions.

- The oil price shock contributes a higher proportion of the variability in industrial and manufacturing productions than policy uncertainty shock; This is the inverse *w.r.t.* construction production