Asymmetries in the oil price-industrial production relationship? Evidence from 18 OECD countries

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Motivation

- Is the relationship between economic activity and oil prices linear? → *Do oil price increases lead to recessions but decreases do not result in booms?*

- A large volume of literature argues the relationship is asymmetric:
  - Mork (1989): oil price increases lead to recession while oil price decreases don't lead to expansions.
  - Hamilton (1996, 2003) and Li, Ni and Ratti (1995): other nonlinear transformations of oil prices do a better job at capturing the nonlinearity of the relation:

- Why is this asymmetry important?
  - Amplification of oil price shocks

Motivation

- The importance of accounting for asymmetries in the relationship between changes in energy price and macroeconomic aggregates seemed to be widely agreed on by the early 2000s.

- It has been common in the literature to estimate VAR models of the form

$$x_t^{\#} = A_{11}(L)x_{t-1}^{\#} + A_{12}(L)y_{t-1} + \varepsilon_{1,t}$$

$$y_t = A_{21}(L)x_{t-1}^{\#} + A_{22}(L)y_{t-1} + \varepsilon_{2,t}$$

- Censored variables have been commonly used in the literature to study the effect of oil price shocks.

Data Censoring – Oil Prices

- Let o_t be the Refiners' Acquisition Cost measured in the local currency

1. Mork's (1989) oil price increase

$$x_t^1 = \max\{0, \ln(o_t) - \ln(o_{t-1})\}$$

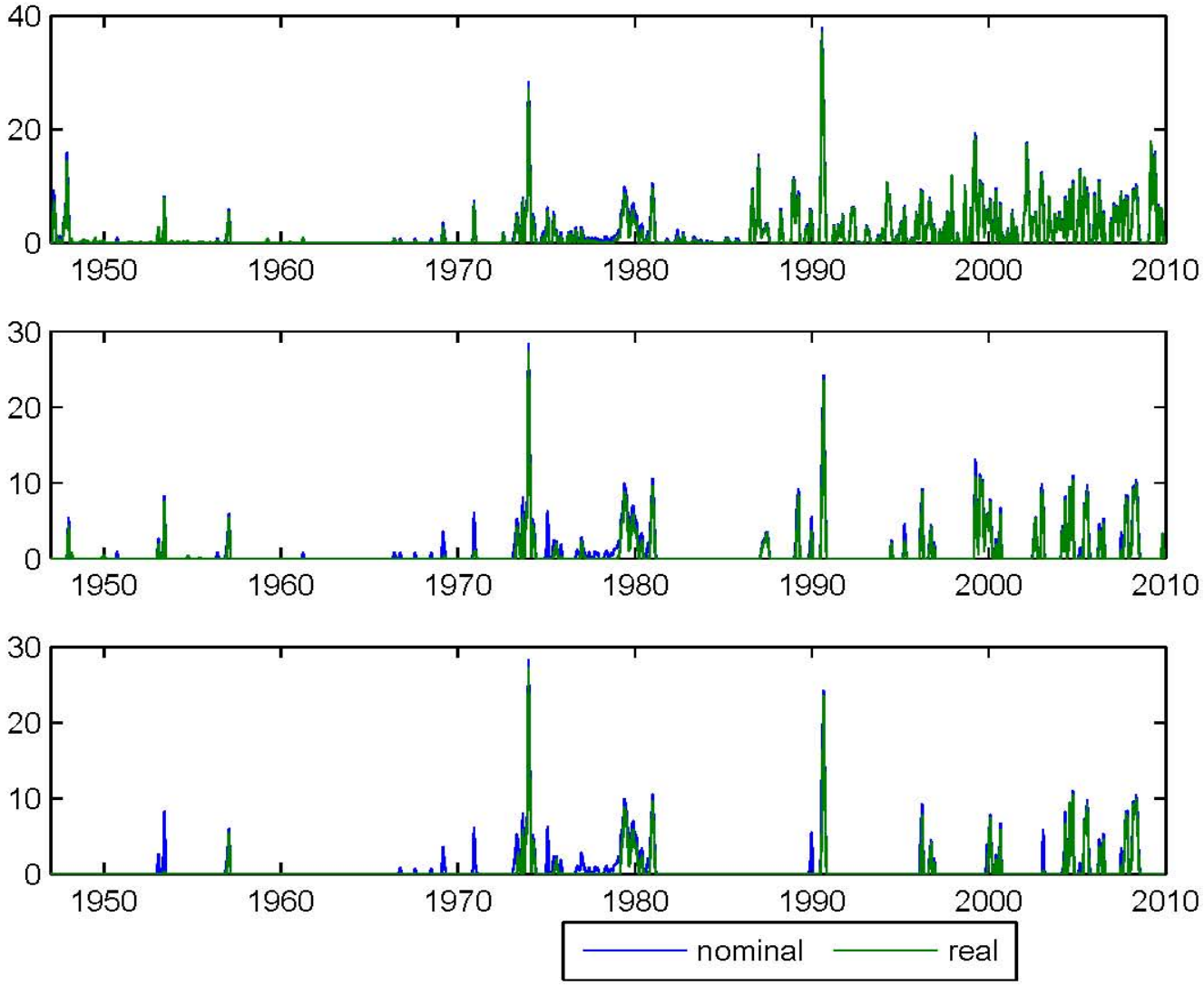
2. Hamilton (1996) net oil price increase over the previous 12-month maximum

$$x_t^{12} = \max\{0, \ln(o_t) - \max(\ln(o_{t-1}), \ldots, \ln(o_{t-12}))\}$$

3. Hamilton (2003) net oil price increase over the previous 36-month maximum

$$x_t^{36} = \max\{0, \ln(o_t) - \max(\ln(o_{t-1}), \ldots, \ln(o_{t-36}))\}$$

Censored Oil Prices



Motivation

- Killian and Vigfusson (QE, 2011) show that:
  - Using a censored variable biases the estimates $\Rightarrow$ IRF estimates exaggerate the macroeconomic responses to oil price shocks.
  - If a true linear model is mistakenly estimated as a non-linear model $\Rightarrow$ asymmetry in responses of macroeconomic aggregates is artificially created.
  - If the true relationship is non-linear, but one estimates a linear specification, then the estimated parameters are asymptotically biased.

Motivation

- Yet:
  - Evidence of asymmetry is dependent on:
    - Oil measure (Hamilton 2011)
    - Sample period (Kilian and Vigfusson 2011, Herrera, Lagalo and Wada 2011)
  - It is important to consider ‘large’ shocks
  - Moreover…

Contribution

- The discussion regarding nonlinearities has focused on US data.
  - GDP growth (Kilian and Vigfusson 2010, Hamilton 2010)
  - Growth of the IP index (Herrera, Lagalo and Wada, 2011)

- **No work** has been done addressing the question of asymmetry in the IRF **using international data**.

Contribution II

- Propose a measure of asymmetry → **mean squared distance**

- We compute **data mining robust critical values**

- Our methodology can be **applied to a variety of cases.**

Data: IP indices for OECD

- Samples for some countries start in the 1960s.

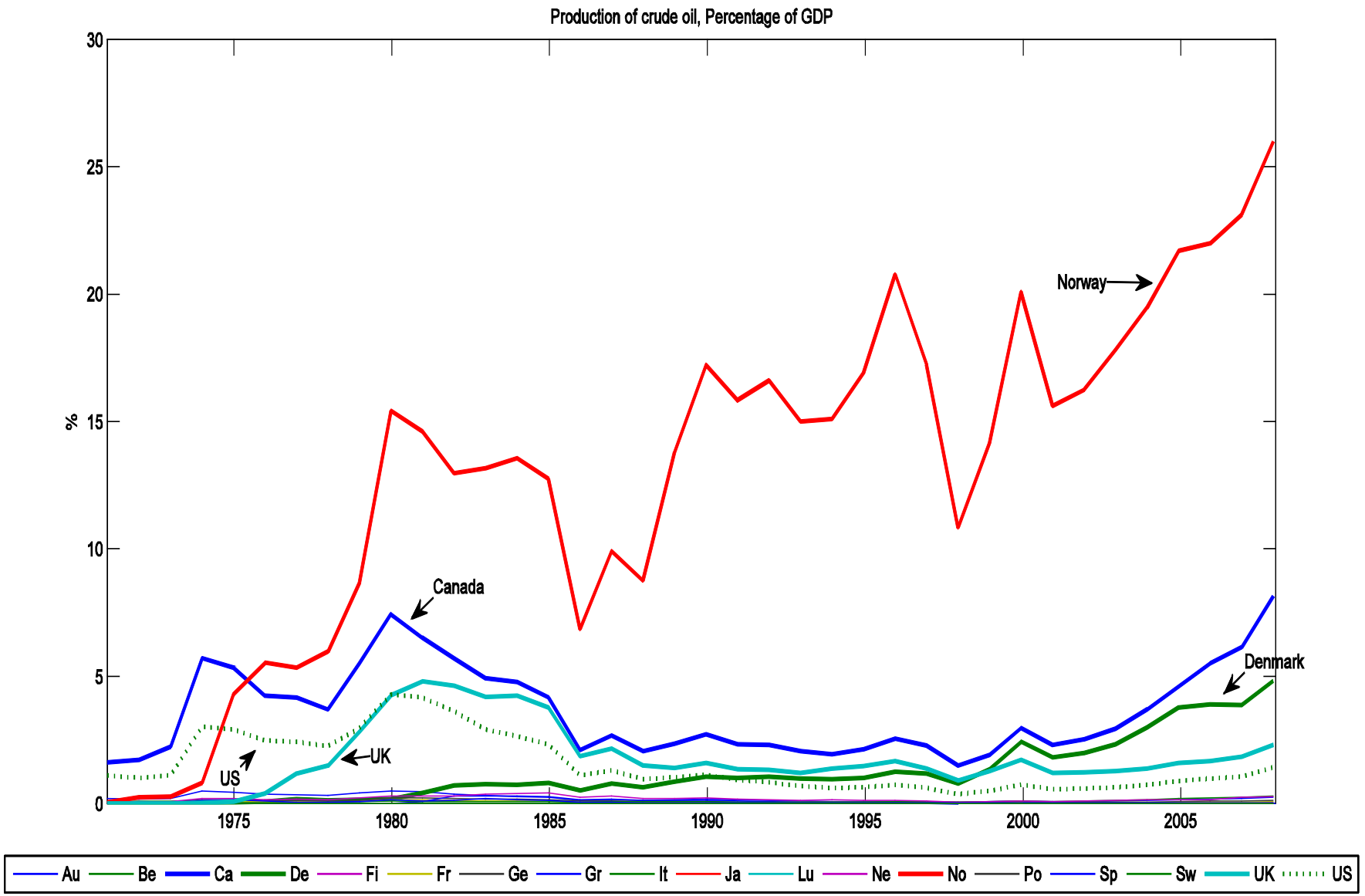
- Yet, **we use post-1973**

Country	Sample period
Austria	1961:1-2010:7
Belgium	1961:1-2010:7
Canada	1961:1-2010:7
Finland	1961:1-2010:7
France	1961:1-2010:7
Germany	1961:1-2010:7
Italy	1961:1-2010:7
Japan	1961:1-2010:7
Luxemburg	1961:1-2010:7
Netherlands	1961:1-2010:7
Norway	1961:1-2010:7
Portugal	1961:1-2010:7
Sweden	1961:1-2010:7
UK	1961:1-2010:7
US	1961:1-2010:7
G7	1961:1-2010:7
OECD-Europe	1961:1-2010:7
Greece	1962:1-2010:7
Spain	1965:1-2010:7
Denmark	1974:1-2010:7
OECD-Total	1975:1-2010:7

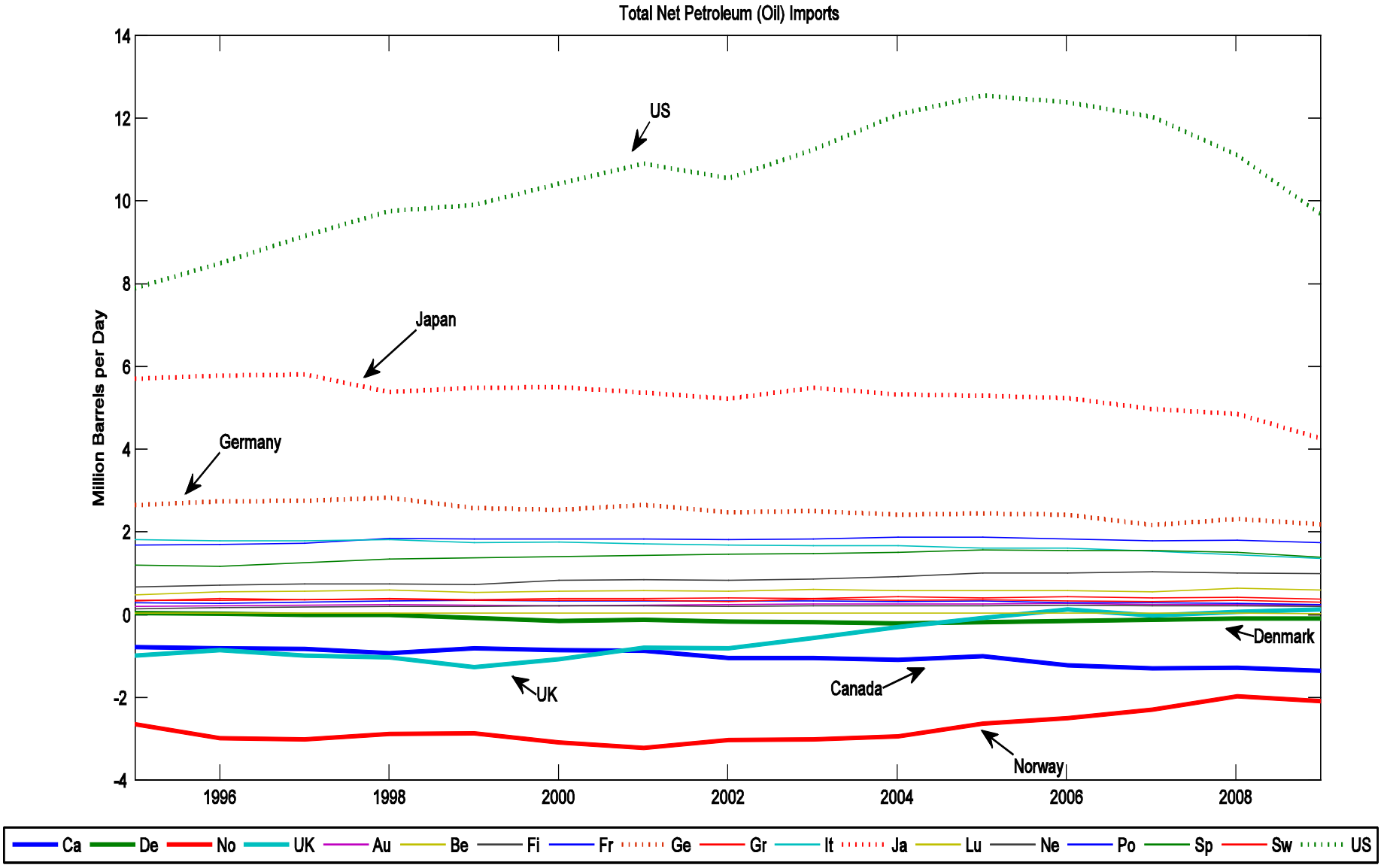
Why the shift towards international data?

- Three reasons why this data set is a good testing ground for the issue of symmetry.

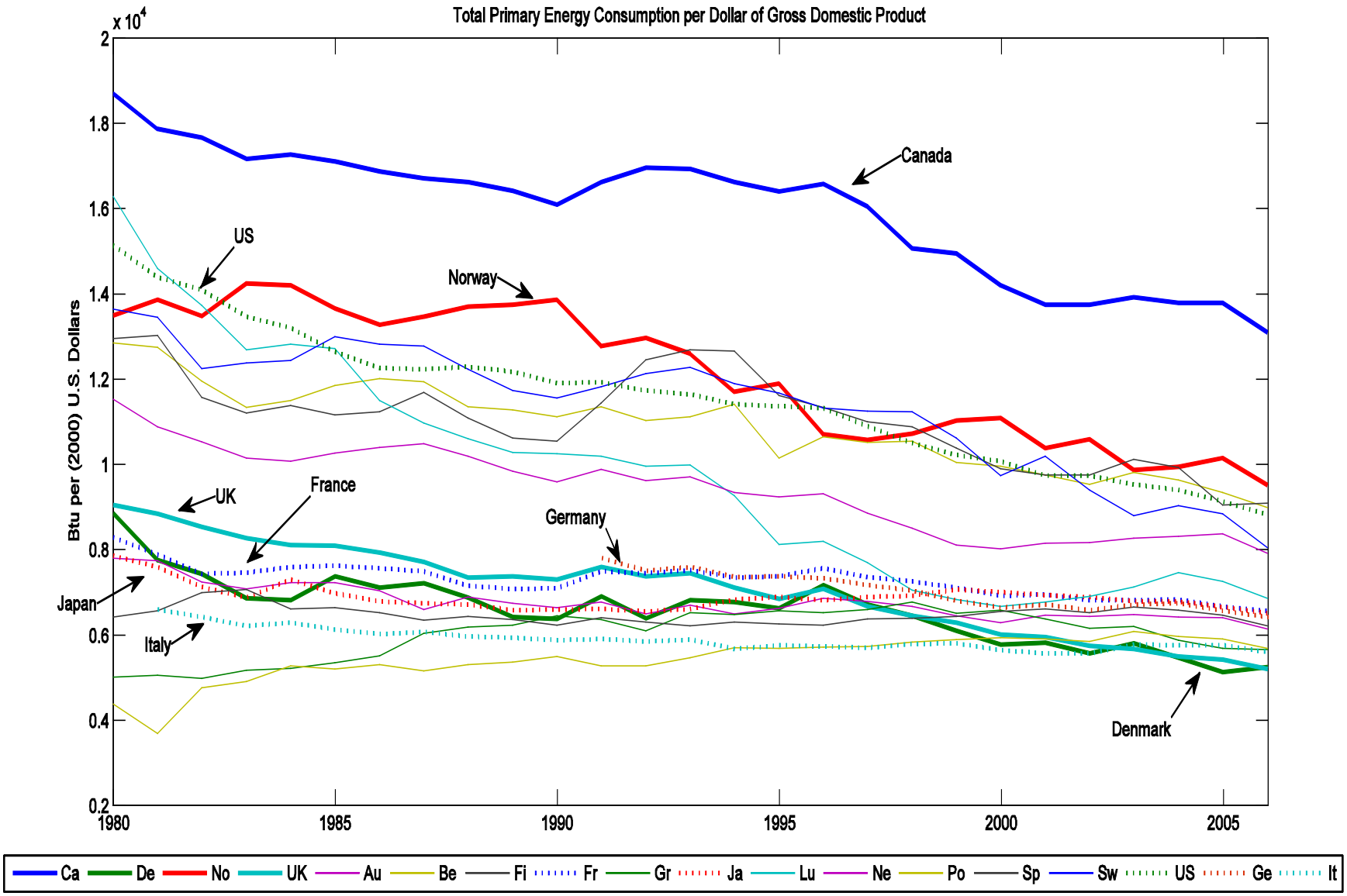
1. Importance of oil production in GDP



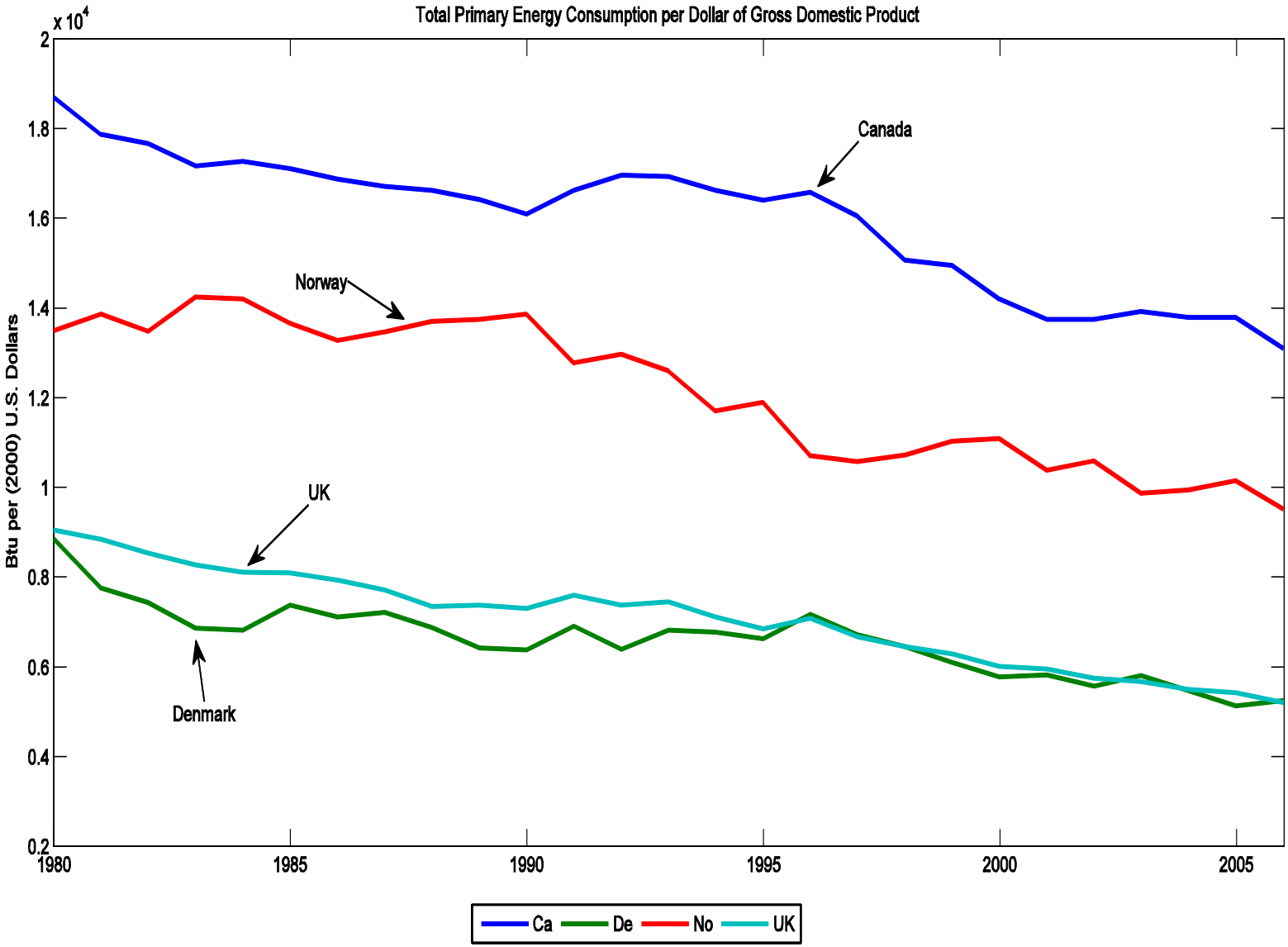
2. Oil Importers vs. Oil Exporters



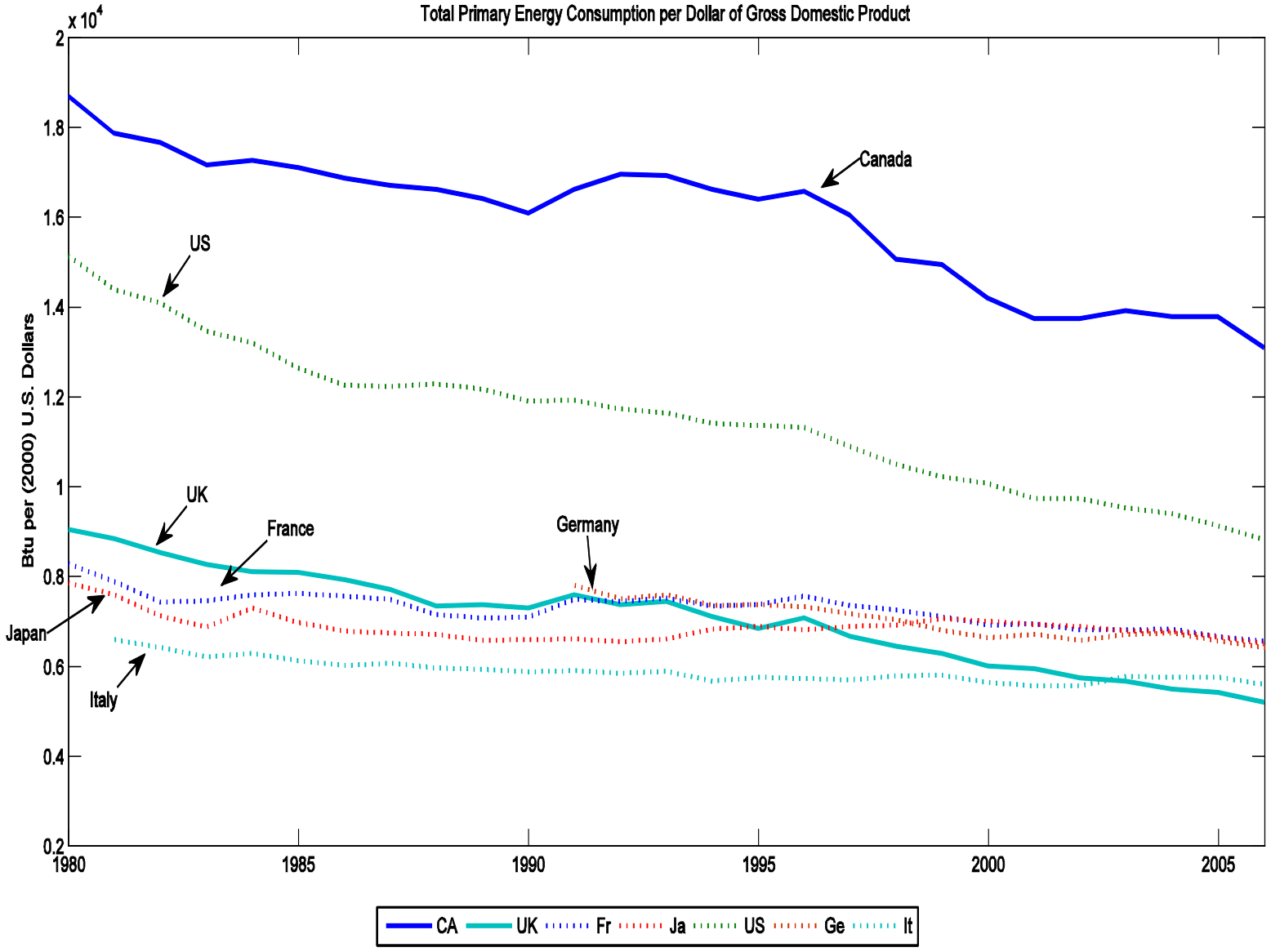
3. Energy intensity in consumption



3. Energy intensity – Oil exporters



3. Energy intensity – G7



Outline of this talk

- Motivation
- Related Literature
- Theoretical Background
- Tests of Asymmetry or Nonlinearity
  - Slope based tests of non linearity
  - Impulse-response function based test
- The Magnitude of the Asymmetry
- The Effect of Data Mining
- Conclusions

Related Literature

- Oil importer/exporter: In a sample of 7 OECD countries, all but Norway show negative correlations between oil prices and the macro aggregate (Mork, Olsen and Mysen 1994).

- Manufacturing output responds to oil price shocks differently across countries in France, Italy, Spain and Germany but similarly in the U.K. and the U.S. (Jiménez-Rodríguez, 2009).

Theoretical Background

- The transmission of oil price shocks:
  1. Supply-side effects
     - Direct effect of an increase in oil prices on energy use and output
     - Indirect effect of capital and labor reallocation
  2. Demand-side effects
     - Direct effect of income transfer and consequent effect on purchasing power
     - Indirect effect of heightened uncertainty

1. Supply-side effects

- The Direct Effect

Consider a representative firm that uses capital, labor and energy in production

$$F(K, L, E)$$

then, it can be shown that

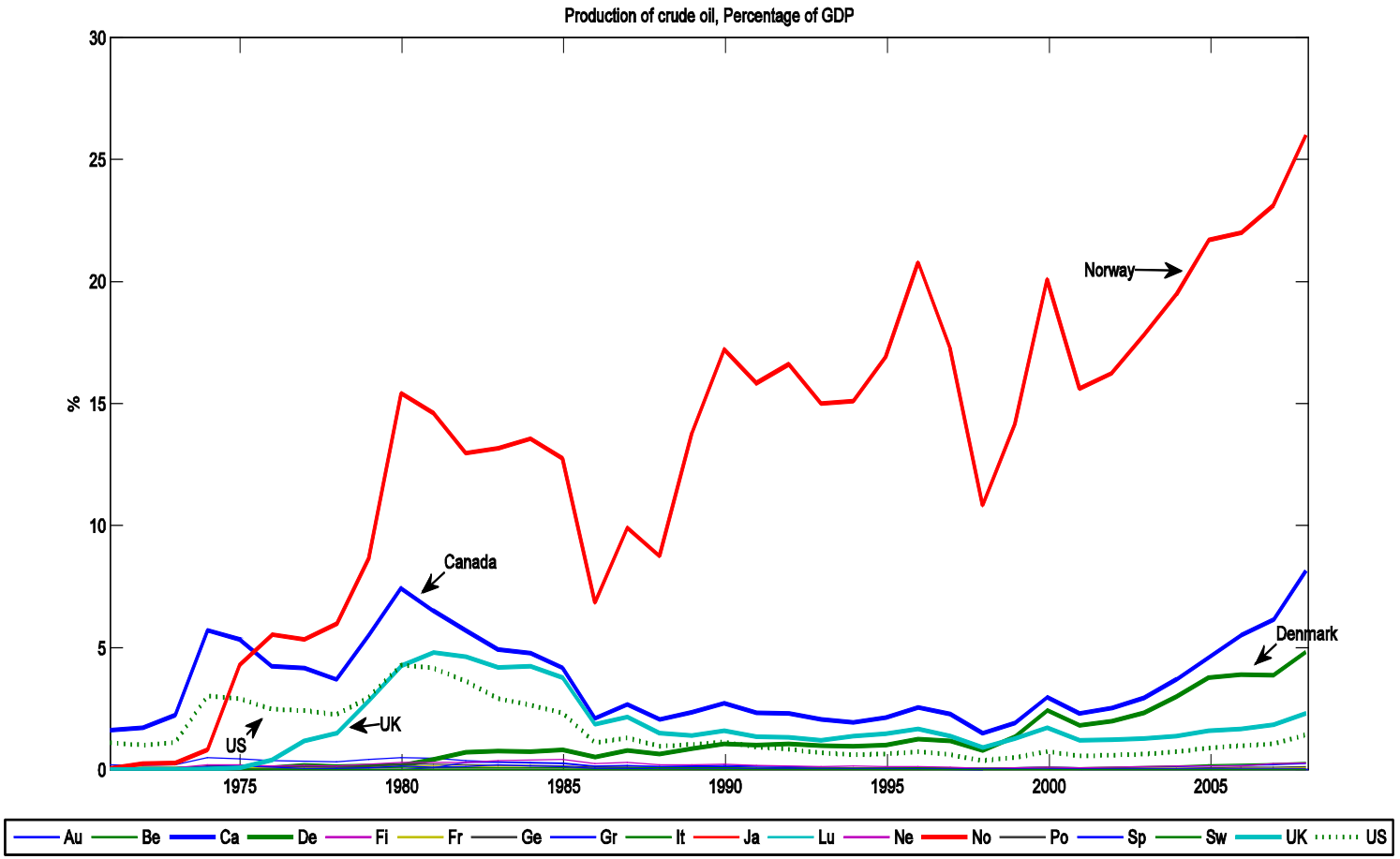
$$\frac{p_E E}{Y} = \frac{\partial Y}{\partial E}\frac{E}{Y} = \varepsilon_{Y,E} \quad \text{where} \quad p_E = \frac{P_E}{P}$$

Moreover, if *K* and *L* are fixed then

$$\frac{\partial Y}{\partial p_E}\frac{p_E}{Y} = \varepsilon_{Y,E}\frac{\partial E}{\partial p_E}\frac{p_E}{E}$$

1. Supply-side effects

- The Direct Effect
  - Effect is symmetric and bounded by the share of energy in output



1. Supply-side effects

- Indirect Effects: reallocation of capital and labor
- Atkeson and Kehoe (1999)P: putty-clay capital
- Finn (2000): capital utilization that changes with energy
- Leduc and Sill (2004): adding wage rigidities

- These models generate amplification but NO asymmetry.

1. Supply-side effects

- Indirect Effects: reallocation disturbances

- Sectoral Reallocation (Davis 1987a, Davis 1987b, Bresnahan and Ramey 1993, and Davis and Haltiwanger, 2001)

- Slow relocation of workers (Hamilton 1988)

- These models generate amplification AND asymmetry.

2. Demand-side effects

- The Direct Effect: income transfer from oil importing to oil exporting countries

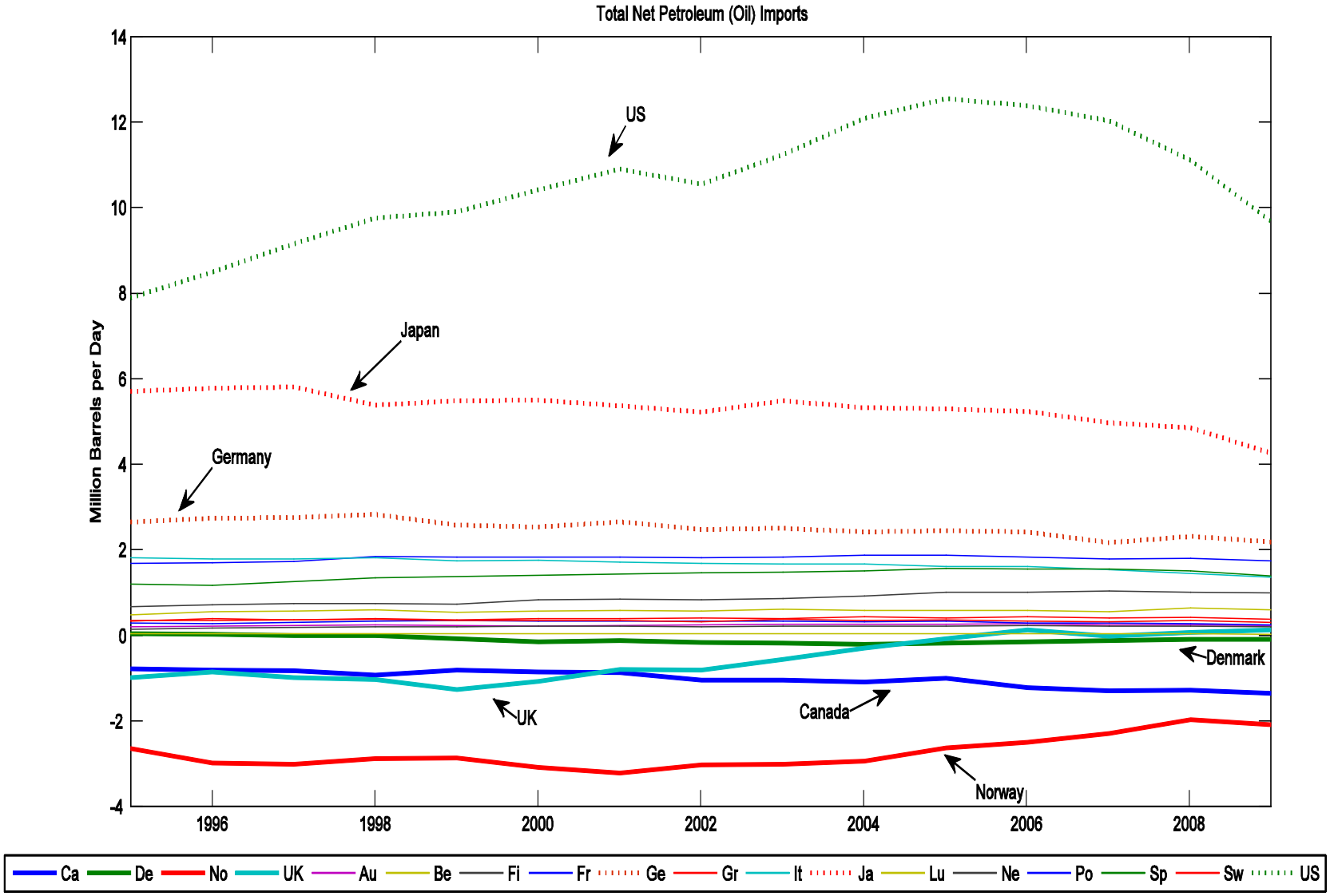
  This effect is symmetric and bounded.

- Indirect effects:
  - Heightened uncertainty (Bernanke 1983, Pindyck 1991)
  - Change in the composition of demand (Ramey and Vine 2010)
  - Change in purchasing power and precautionary saving (Edelstein and Kilian, 2009)

  These effects generate amplification AND asymmetry.

2. Oil Importers vs. Oil Exporters

- Direction and magnitude of the asymmetry?



Sources of asymmetries and their effect on output growth

	Oil Importers		Oil Exporters	
Sign of oil price shock	+δ	-δ	+δ	-δ
1. Supply-side effects				
Direct effect	-	+	?	?
Indirect effects				
Reallocation of *K* and *L*	-	-	-	-
Reallocation disturbances	-	-	-	-
2. Demand-side effects				
Direct effect	-	+	+	-
Indirect effects				
Heightened uncertainty	-	-	-	-
Changes in the composition of demand	-	-	-	-
Precautionary demand	-	-	-	-

VAR Model

- Kilian and Vigfusson's (2010) structural VAR (nesting linear and non-linear models):

$$x_t = a_{10} + \sum_{j=1}^{12} a_{11,j} x_{t-j} + \sum_{j=1}^{12} a_{12,j} y_{i,t-j} + \varepsilon_{1,t}$$

$$y_{i,t} = a_{20} + \sum_{j=0}^{12} a_{21,j} x_{t-j} + \sum_{j=1}^{12} a_{22,j} y_{i,t-j} + \sum_{j=0}^{12} g_{21,j} x_{t-j}^{\#} + \varepsilon_{2,t}$$

where

$y_{i,t}$: is the log growth in the IP index rfor country i

x_t : is the log growth in the real oil price

$x_t^{\#}$: is one of the non - linear measures of oil price change

$\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ are orthogonal

- Oil price shocks have contemporaneous effect on IP
- Oil prices are assumed to be predetermined.

1. Slope based test

- Problem: We don't know the link between a rejection of H_0 and the degree of asymmetry in the response to a shock.

- Therefore, we do not use the slope test to evaluate asymmetry in the response.

2. KV Impulse-response-based test

- Do impulse-responses exhibit asymmetry?

- Due to the censored variables, impulse responses depend on:
  - The magnitude of the shock
  - The history of the observations

  $\Rightarrow$ computing impulse responses requires Monte Carlo integration (Koop et al 1996).

2. KV Impulse-response-based test

$$x_t = a_{10} + \sum_{j=1}^{12} a_{11,j} x_{t-j} + \sum_{j=1}^{12} a_{12,j} y_{i,t-j} + \varepsilon_{1,t}$$

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2. KV Impulse-response-based test

Steps:

(i) For a given horizon, h , conditional on the history Ω^t, and the size of the shock δ, the conditional IRFs, $I_y(h,\delta,\Omega^t)$ can be computed:

a) $y_{t,r}^1$ is the path of y_t after the shock δ

$y_{t,r}^2$ is the path of y_t after ε_{1t}

b) After R replications,

$$I_y\left(h,\delta,\Omega^t\right)=\frac{1}{R}\sum_{r=1}^{R}y_{t,r}^1-\frac{1}{R}\sum_{r=1}^{R}y_{t,r}^2 \quad for \quad h=0,1,\ldots,H.$$

$$where \quad I_y\left(h,\delta,\Omega^t\right)\xrightarrow{p}E\left[y_{t+h}\middle|\delta,\Omega^t\right]-E\left[y_{t+h}\middle|\Omega^t\right] as\ R\to\infty$$

2. KV Impulse-response-based test

(ii) The unconditional IRF is generated by repeating (1) for all possible Ω^t, t=1,…,T and then taking the mean over all the histories:

$$I_y(h,\delta)=\frac{1}{T}\sum_{t=1}^{T} I_y\left(h,\delta,\Omega^t\right)$$

(iii) The test of symmetry is

$$H_0 : I_y(h,\delta)=-I_y(h,-\delta) \quad for \quad h=0,1,2,\ldots,H.$$

2. KV Impulse-response-based test

The test statistic is given by

$$W = (R\hat{\beta})'(R\hat{\Xi}R')^{-1}(R\hat{\beta}) \sim \chi^2_{H+1}$$

where

$$\underset{2(H+1)\times 1}{\hat{\beta}} = \begin{bmatrix} I_y(0,\delta) \\ \vdots \\ I_y(H,\delta) \\ I_y(0,-\delta) \\ \vdots \\ I_y(H,-\delta) \end{bmatrix}; \quad \underset{(H+1)\times 2\times (H+1)}{R} = \begin{bmatrix} I_{H+1} & I_{H+1} \end{bmatrix}$$

$$\underset{2(H+1)\times 2(H+1)}{\Xi} = E\left[\left(\hat{\beta}-\beta\right)\left(\hat{\beta}-\beta\right)'\right]$$

2. KV Impulse-response-based test

2. Impulse-response-based test

- Small shocks:
  - Results for x_t^1 *and* x_t^{12} suggest asymmetries mainly for:
    - Large oil exporting: Canada and Norway
    - Large oil importing: US and Japan

- Large shocks:
  - Results for x_t^1 (more grounded on theory than on behavioral model) suggest asymmetries for
    - Large oil exporting: Canada and Norway
    - Large oil importing: US and Japan
    - Plus some other countries (Finland, Germany, and Greece)

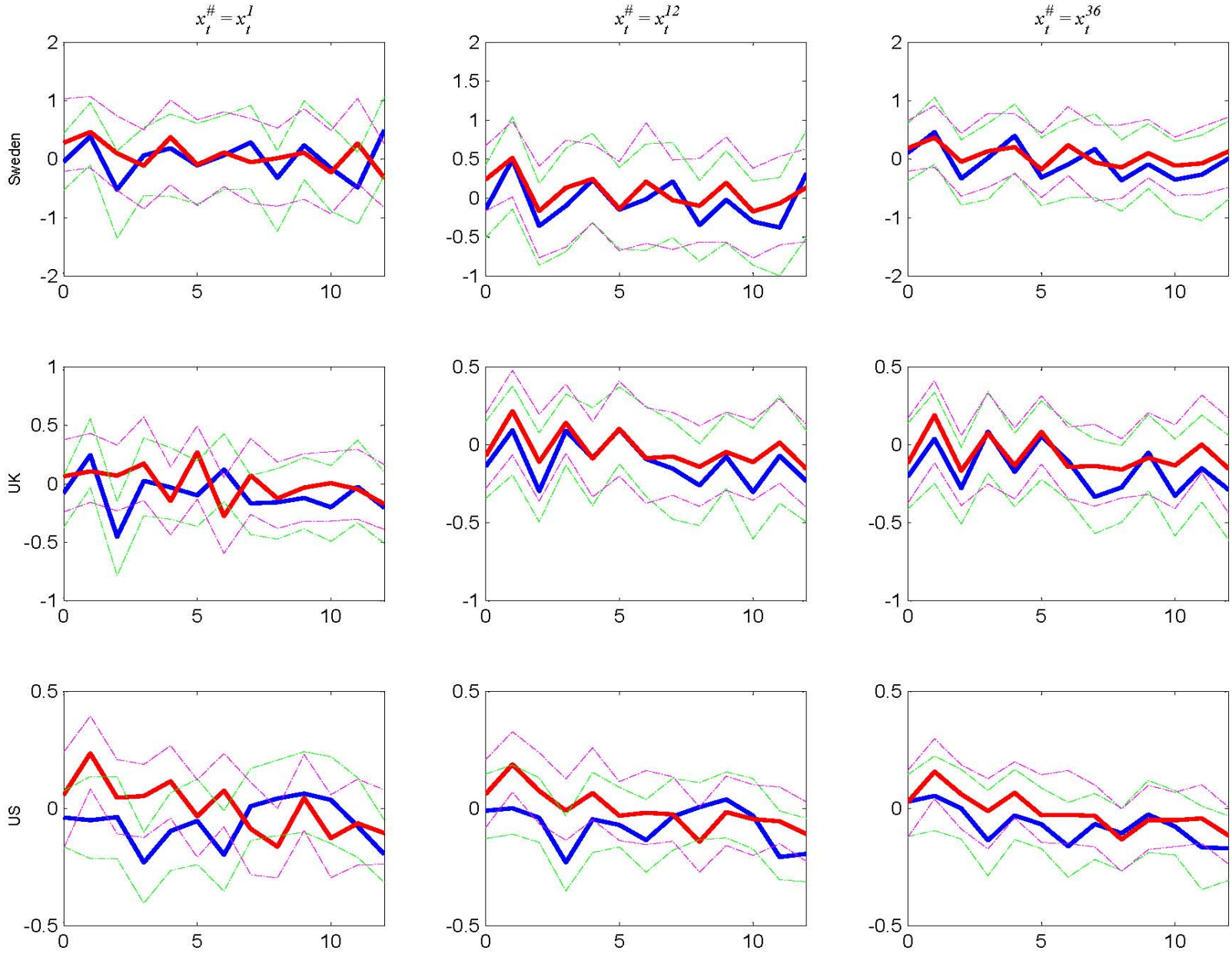
The Magnitude of the Asymmetry

- How big is the difference between the response of industrial production to positive and negative shocks?

  - 2 Exporters: After a year, a positive shock of 1 s.d. leads to a contraction of industrial production of 0.6% in Canada and 1.3% in Norway. A negative shock of the same magnitude would result in a 0.7% contraction in Canada, but no change in Norway.

  - For the largest oil importer: …

Figure 2e: Impulse response to two standard deviation positive and negative shocks to the real oil price (percentage): Sub sample



Estimates are based on the VAR in (5) where the number of replications to obtain the IRFs equal 1000

The Magnitude of the Asymmetry

- We define the ***mean squared distance*** between the response to a positive shock and that of a negative shock as

$$d = \frac{1}{H}\sum_{h=0}^{H}\left[I_y(h,\delta) - \left(-I_y(h,-\delta)\right)\right]^2$$

The Magnitude of the Asymmetry

	Small Shock			Large Shock		
	1-month	12-month	36-month	1-month	12-month	36-month
Net Exporters						
Canada	0.03	0.01	0.01	0.20	0.12	0.08
Denmark	0.09	0.03	0.02	0.50	0.22	0.18
Norway	0.17	0.03	0.03	0.92	0.22	0.23
UK	0.03	0.01	0.01	0.19	0.08	0.10
Net Importers						
Austria	0.07	0.02	0.01	0.36	0.19	0.11
Belgium	0.06	0.03	0.02	0.32	0.23	0.17
Finland	0.07	0.03	0.02	0.42	0.27	0.19
France	0.04	0.02	0.01	0.21	0.13	0.09
Germany	0.05	0.01	0.01	0.25	0.11	0.09
Greece	0.11	0.04	0.03	0.60	0.28	0.24
Italy	0.05	0.01	0.01	0.29	0.12	0.11
Japan	0.04	0.01	0.01	0.28	0.12	0.12
Luxembourg	0.06	0.03	0.03	0.37	0.25	0.26
Netherlands	0.10	0.02	0.02	0.51	0.17	0.18
Portugal	0.06	0.01	0.02	0.32	0.12	0.17
Spain	0.06	0.02	0.02	0.30	0.12	0.14
Sweden	0.05	0.01	0.02	0.30	0.18	0.19
US	0.02	0.01	0.00	0.14	0.10	0.07
Aggregates						
G7	0.02	0.01	0.00	0.14	0.09	0.06
OECD-Europe	0.02	0.01	0.00	0.11	0.07	0.06
OECD-Total	0.02	0.01	0.00	0.12	0.07	0.06

The Effect of Data Mining

- Our purpose: to test for symmetry in a country-by-country basis

- We use 21 Wald tests for each *h* and each oil price measure, thus the results are subject to data mining

The Effect of Data Mining

- Data Mining: Instead of rolling the forecast, we add countries

The Effect of Data Mining

- Using the OLS residuals ε_{1t} and ε_{2t}, together with the estimated parameters, we generate 100 sets of pseudo-data: $\{(x_{it},y_{it})\}_{i=1:21}$

- For each data set $\{(x_{it},y_{it})\}_{i=1:21}$ we conduct the IRF based-test and take the supremum of the Wald statistic across all countries.

- Compute the distribution of Sup-Wald and the 5% critical values.

The Effect of Data Mining

- We see very few rejections.

- Not clear whether this result is due to:
  - True effect of data mining
  - Low power of the test (small sample)
  - Small number of replications

Conclusions

- We find ***some*** evidence of asymmetry for about half of the countries

- In general, the linear model is suitable for gauging the impact of small oil price shocks.

- Care must be taken when considering large oil price shocks.

- Especially for countries:
  - Oil exporters where oil represents a large percentage of GDP
  - Large oil importers

Conclusions

- The fact that evidence of asymmetry is more prevalent for the oil price increase than the net increase suggest transmission mechanisms at play are:
  - Reallocation disturbances
  - Heightened uncertainty
  - Changes in the composition of demand

- Yet…

Conclusions

- After using the data mining robust critical values, however, almost no rejections are found.

- Question still to be answered:
  - Power of the test