Economic Risks of Oil Supply Disruptions

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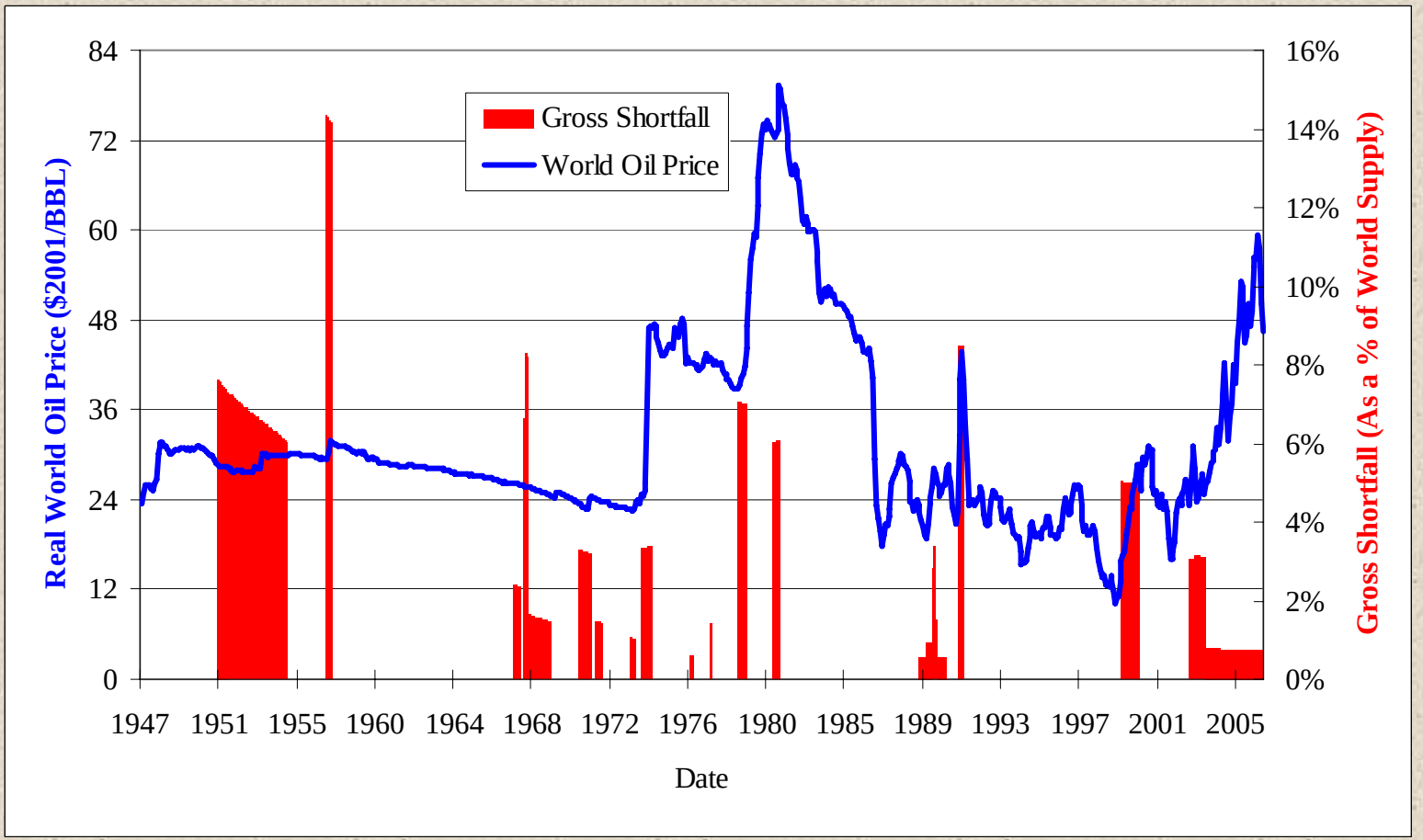
Overview

- Risk depends on (likelihood of supply loss) x (price effect) x (economic consequences of disruption)

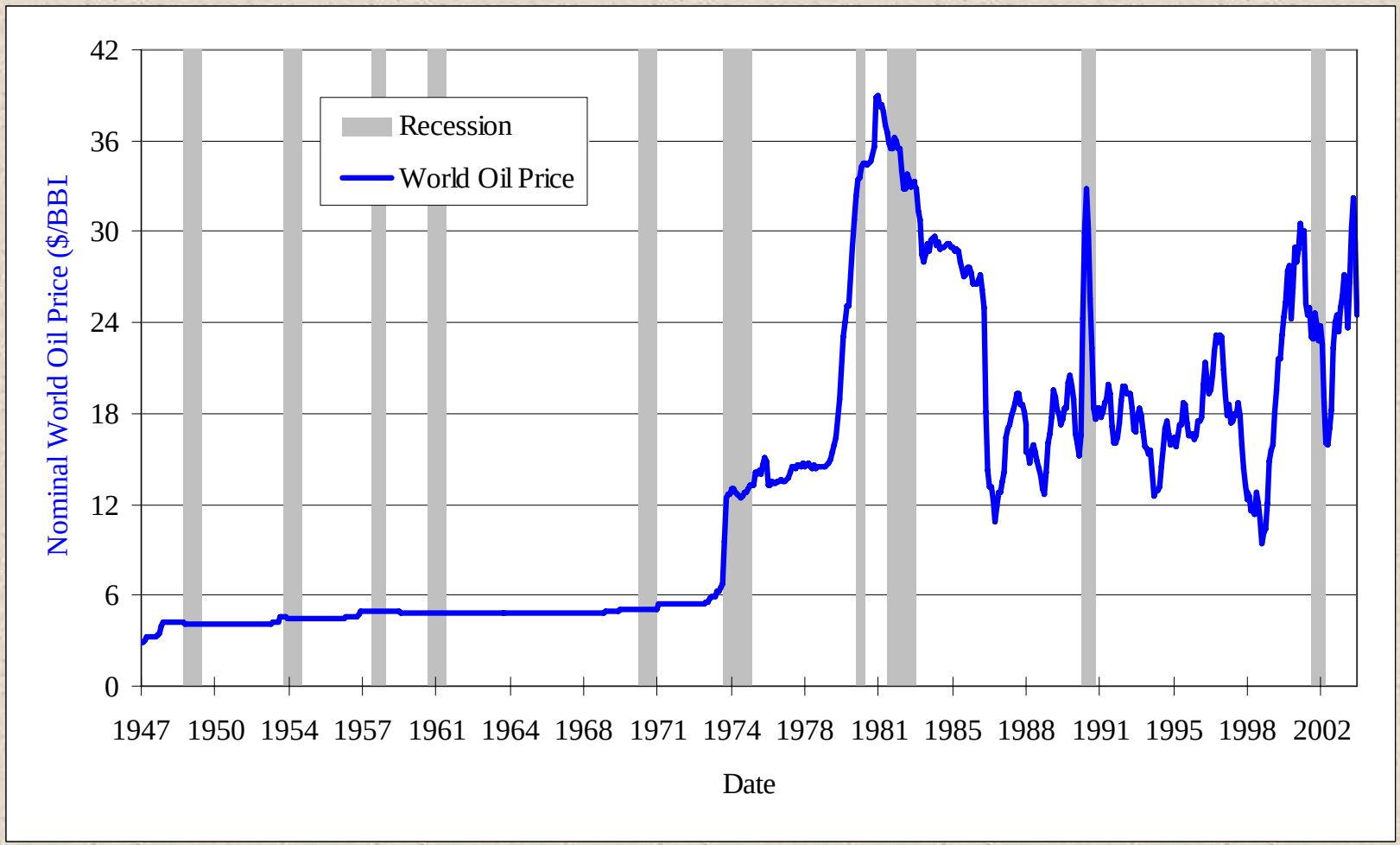
$$Risk = \Pr ob[\Delta Q] \cdot \Delta Q \cdot \frac{\Delta P}{\Delta Q} \cdot \frac{\Delta Cost}{\Delta P}$$

- Consider historical frequency of disruptions
- Review what is known about macroeconomic consequences of shocks
- Some Implications for Stockpiling

History of ~27 Disruptions Since 1950, With Diverse Effects on Price



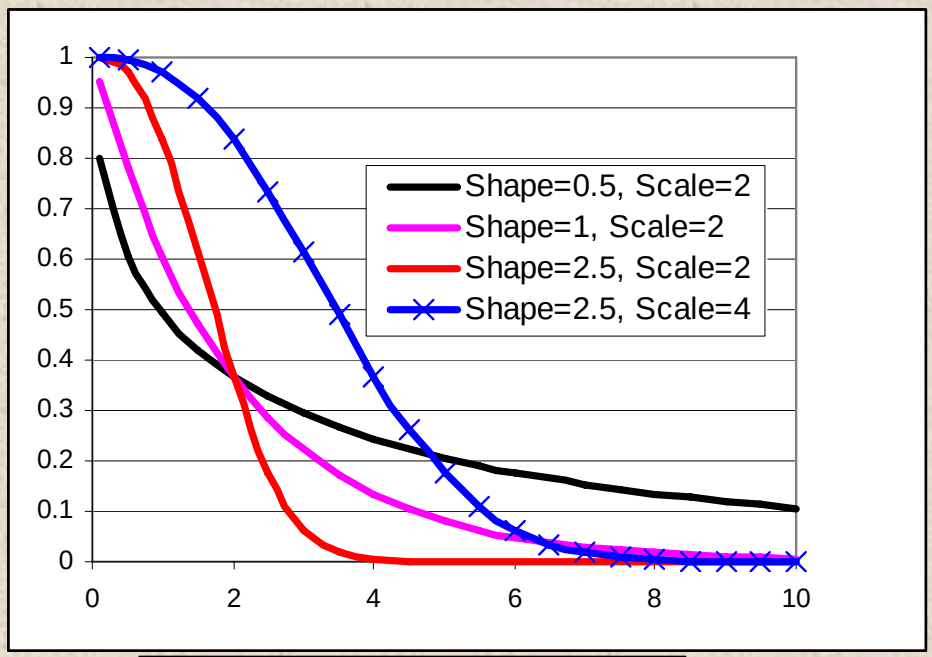
Not all price shocks cause recessions, but 9 of 10 Post-war recessions were preceded by an Oil Shock (Hamilton 1983, 2005)



I. Disruption Risk ΔQ: Seek to Fit Historical Data to Probability Distribution (Weibull Allows Wide Range of Shapes)

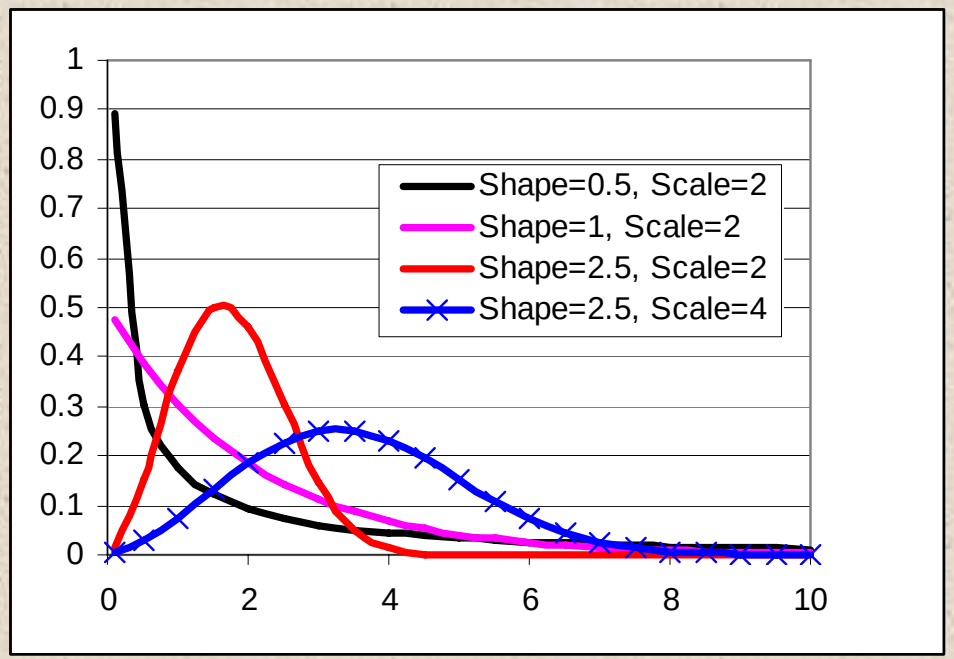
Survival (Excess Prob) Function

(1-F(x) = Prob X ≥ x)



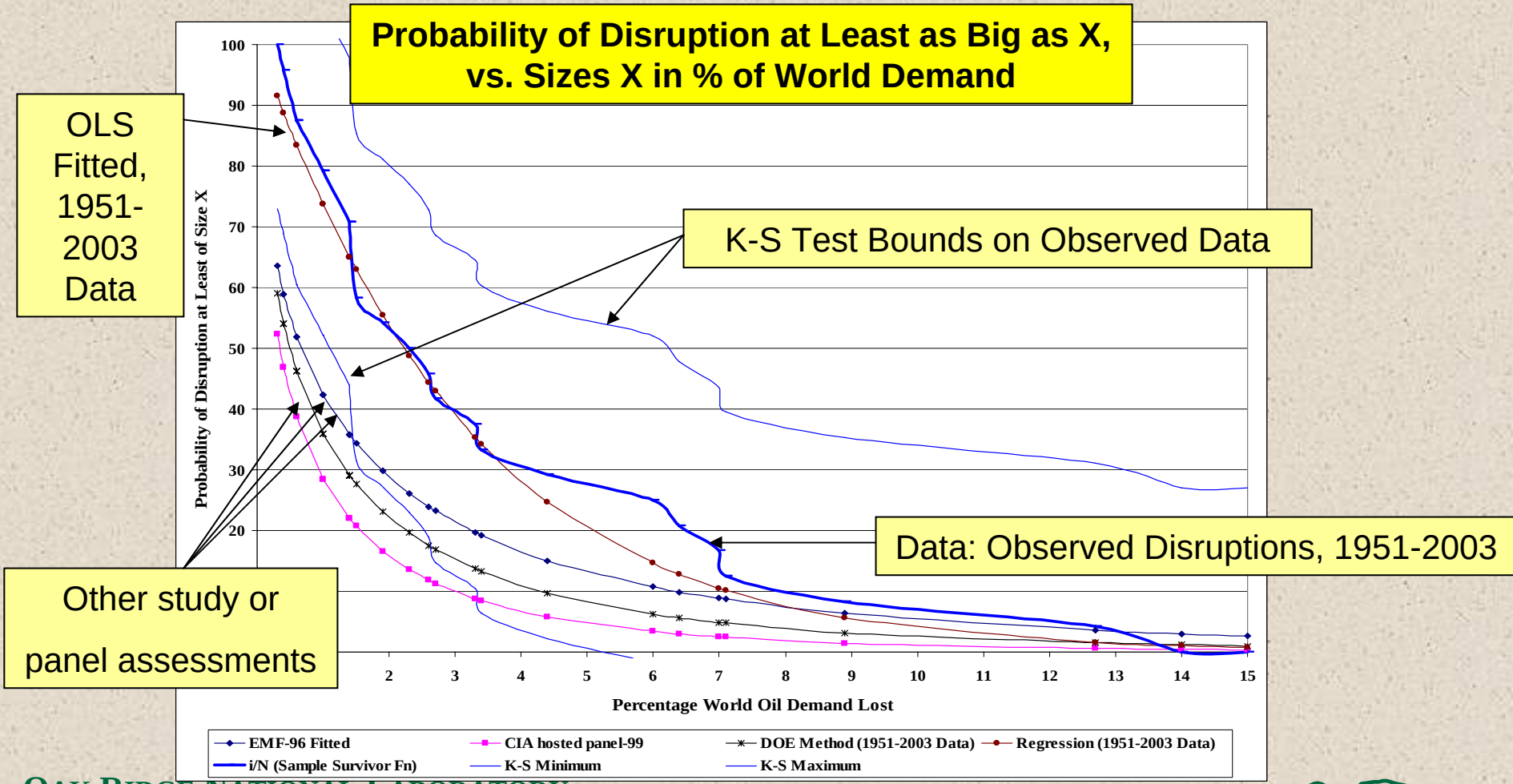
Probability Density Function

(f(x) = dF(x)/dx)



$$1 - F(x) = e^{-\left(\frac{x}{a}\right)^{b}}$$

Regression Estimates Fit Data Better: K-S statistic rejects non-OLS Weibulls



Source: Oladosu, Leiby and Bowman, 2005 (Draft)

Results of Regression Estimates of 2-Parameter Weibull (OLS of log-log form)

Based on 1951-1989 Data			
R-Square	0.884		
Adjusted R-Square	0.877		
Parameter	**Coefficient**	**Std Error**	**t-Stat**
Intercept	-2.057	0.128	-16.04
ln(x)	1.100	0.103	10.71
Shape Parameter	1.100	0.103	10.71
Scale Parameter	6.488	0.859	7.56

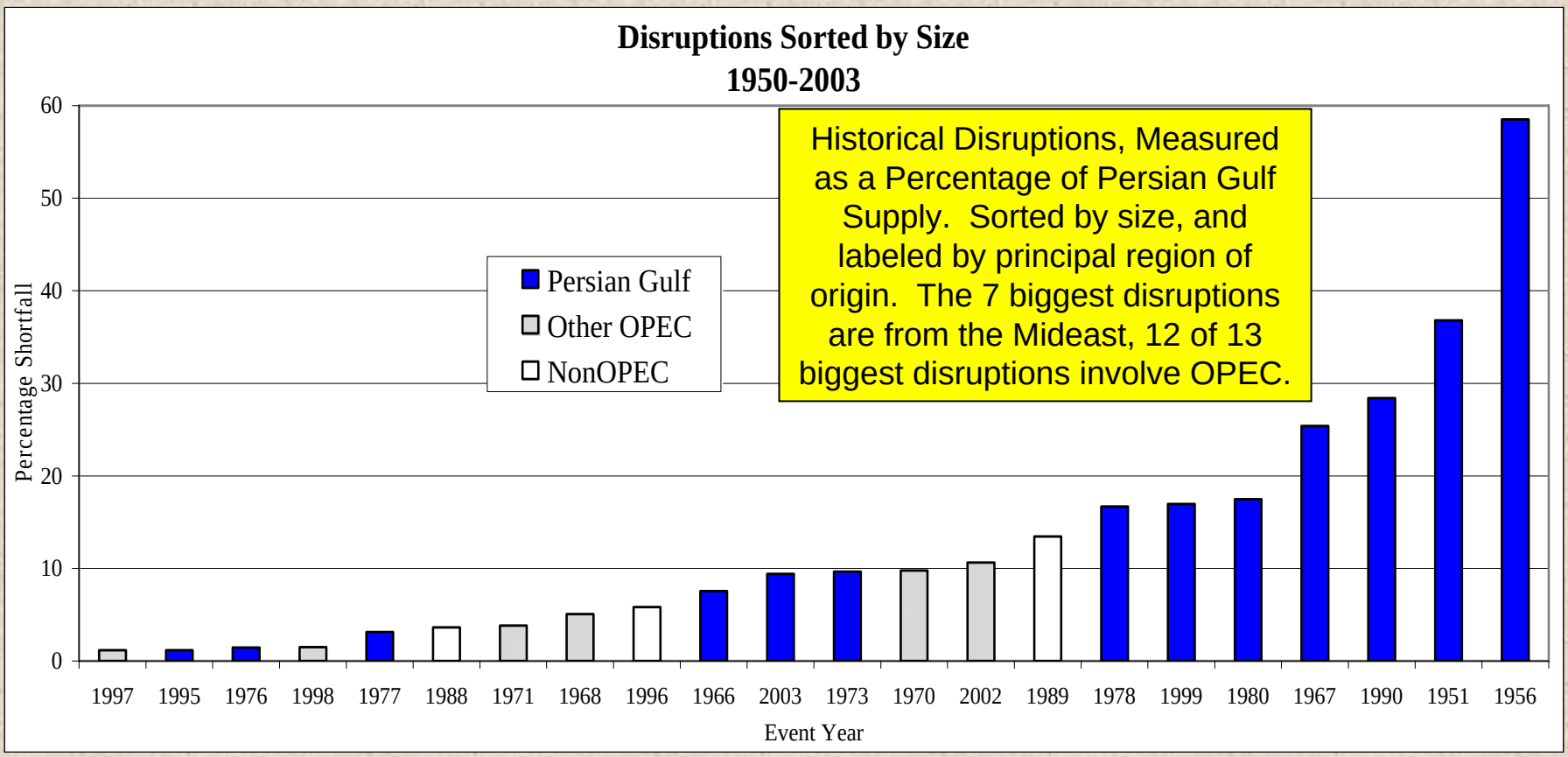
Based on 1951-2003 Data			
R-Square	0.957		
Adjusted R-Square	0.955		
Parameter	**Coefficient**	**Std Error**	**t-Stat**
Intercept	-1.187	0.053	-22.21
ln(x)	1.027	0.043	24.07
Shape Parameter	1.027	0.043	24.07
Scale Parameter	3.177	0.188	16.91

Concern: Instability of parameter estimates *may* reflect unsuitability of applying OLS to linearized Weibull.

Two Strategies for Advancing the Analysis

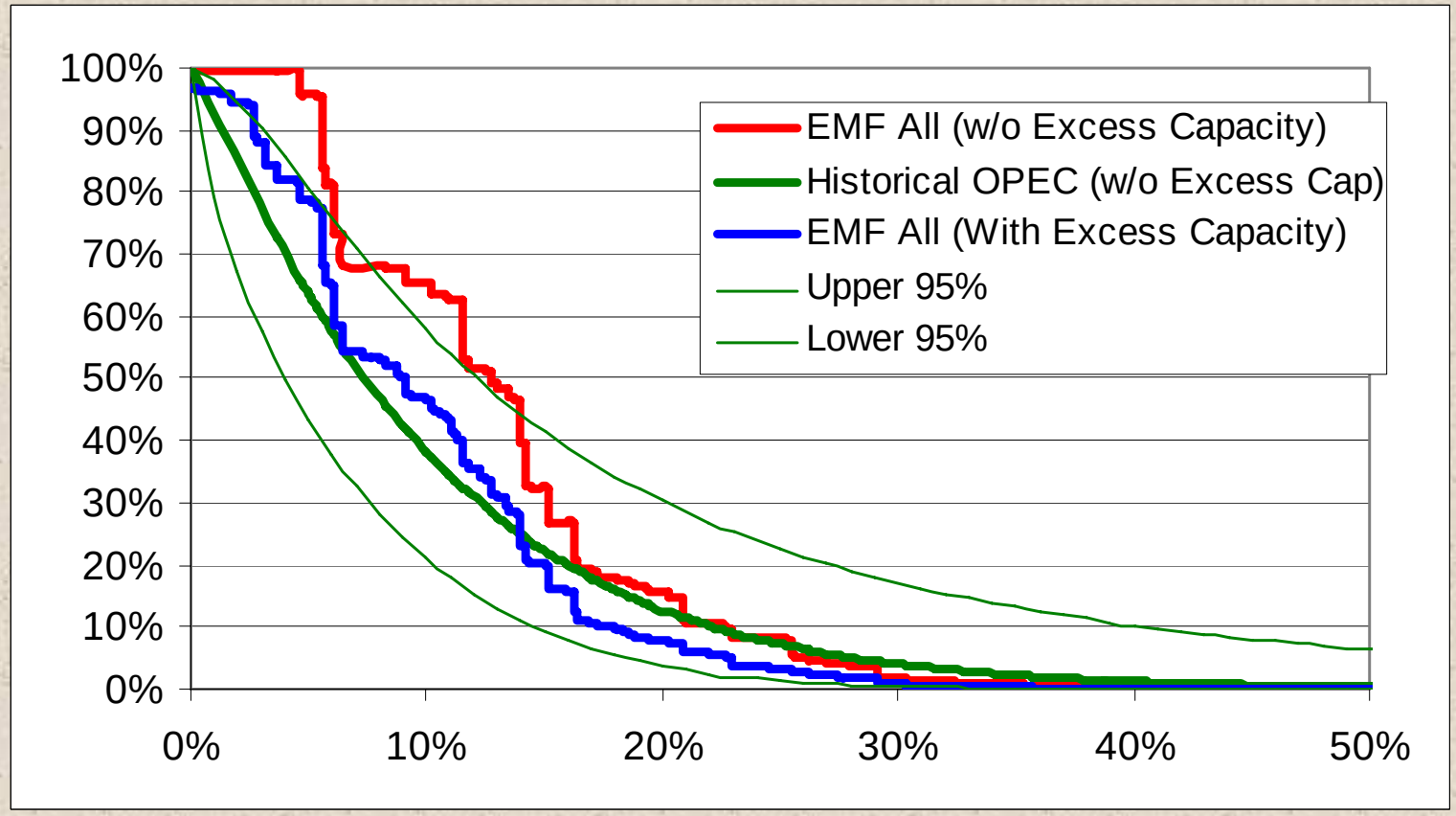
- Consider focusing on disruptions from particular regions. Different specifications of independent variable
  - Disruptions at % of World supply
  - Disruptions as % of OPEC supply
  - Disruptions as % of Persian Gulf supply
- Apply Maximum-likelihood estimation with advanced (non-linear) generation of statistics and tests

Historically, Disruption Risk Centered in OPEC Region: should Probability-focus be here?

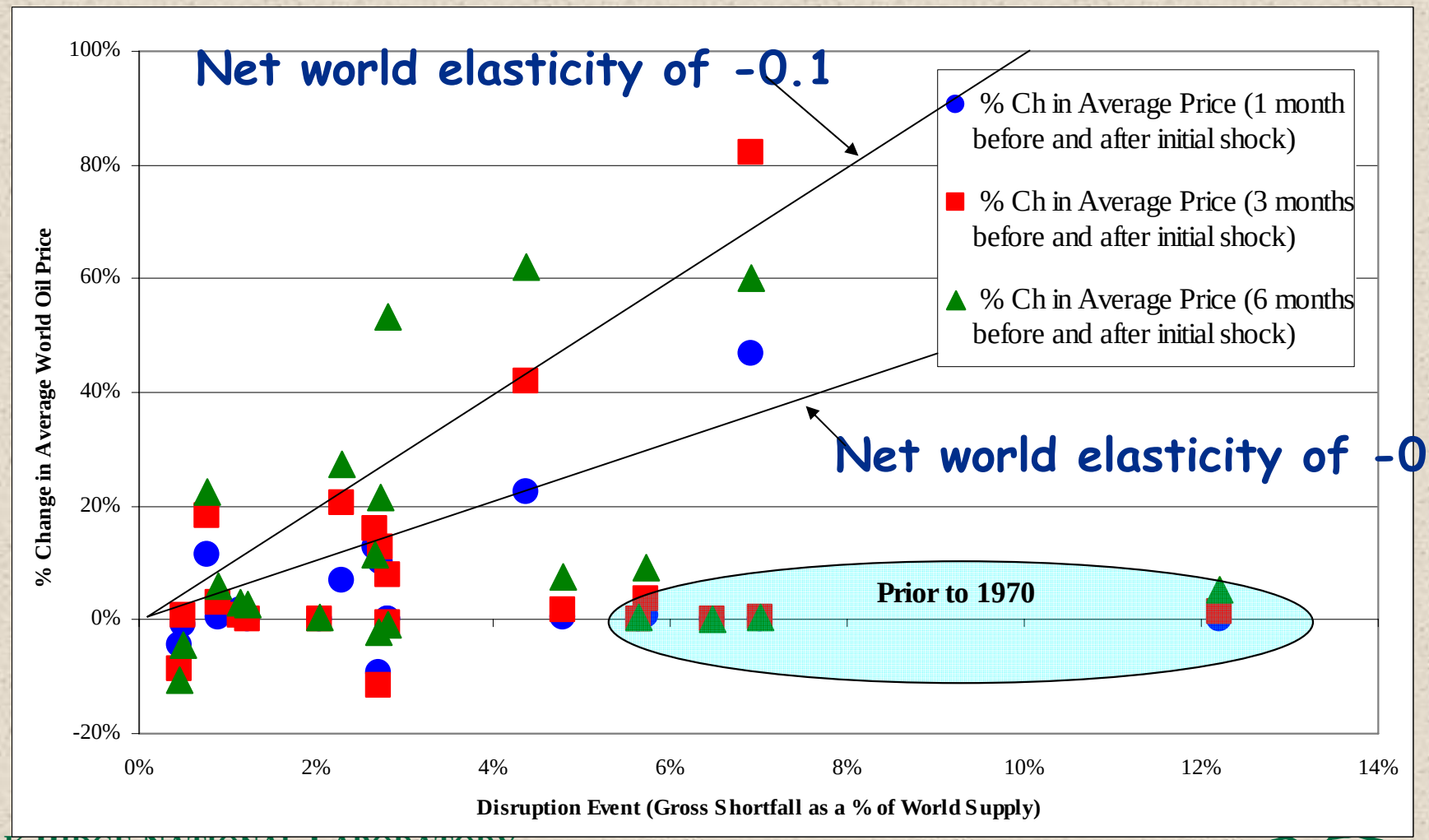


Note: 1989 Event is overlapping events of UK Piper Alpha platform explosion, UK Fulmer floating storage accident, Exxon Valdez spill, and UK Cormorant Platform

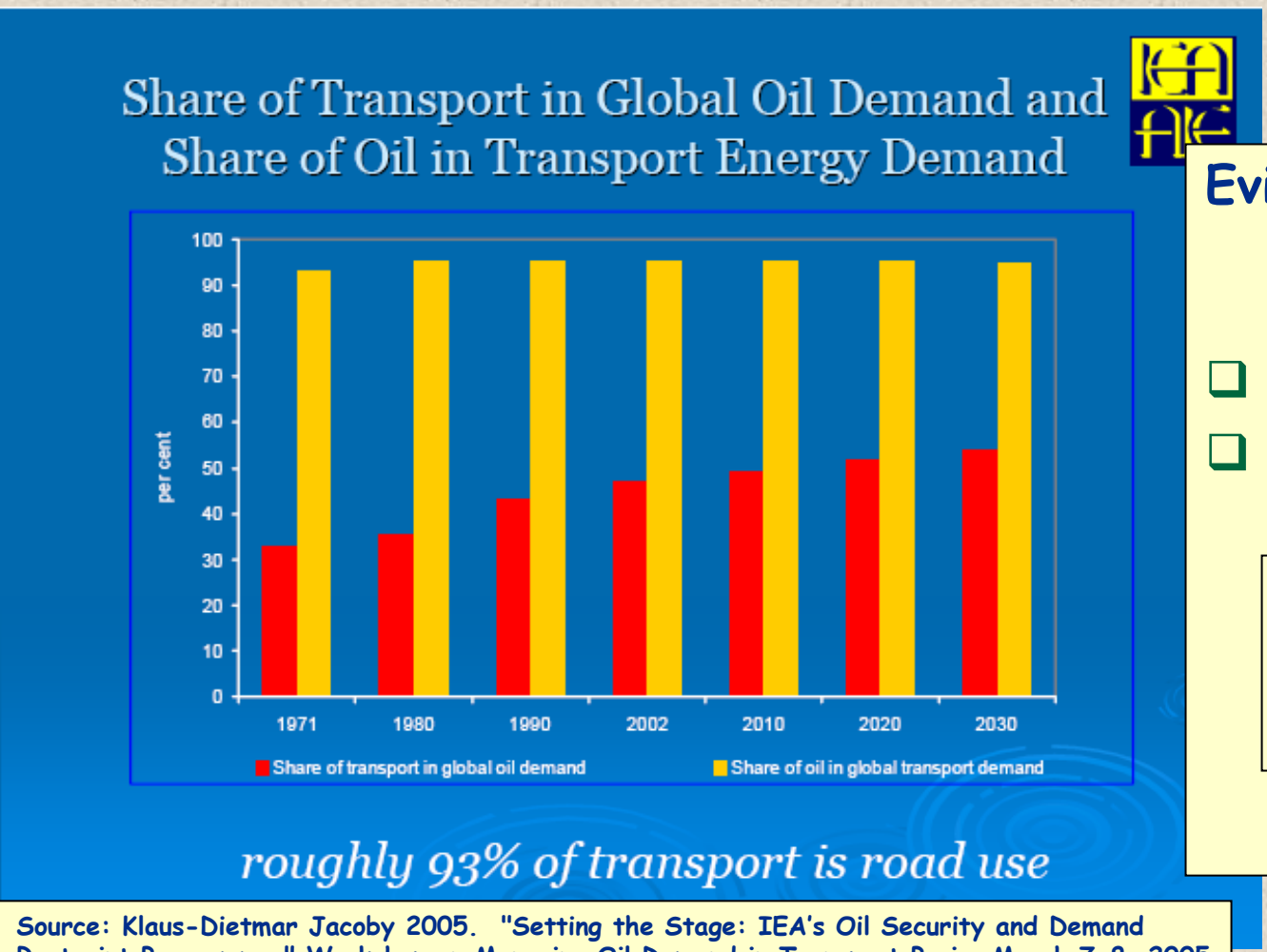
Remarkable Degree of Consistency: Historical Estimates for OPEC Disruptions Match Prospective Risk Based on Expert Judgment of EMF Panel



II. Price Effects ΔP: Despite Diverse Historical Effects, Severe Events Entailed Much Steeper Price Increase Than Often Modeled



Troubling Combination:
Growing share of oil used in transport, (which is inelastic in general)
+ Declining flexibility of motor-fuel demand



Source: Klaus-Dietmar Jacoby 2005. "Setting the Stage: IEA's Oil Security and Demand Restraint Programme," Workshop on Managing Oil Demand in Transport Paris, March 7-8, 2005

Evidence of declining short-run elasticity of gasoline demand

- 1975-80 est: -0.30
- 2001-06 est: -0.04

Source: Hughes, Knittel and Sperling 2007. "Short-Run Gasoline Demand Elasticity: Evidence of Structural Change in the U.S. Market for Gasoline," Presented at TRB Annual Meeting.

III: Economic Cost of Price Shocks, ΔCost: Growing Understanding of Mechanisms and Nature of Shock Effects

- **Shocks cause *Aggregate & Allocative Effects***
  - ***Aggregate Channels*: potential output, income transfer, sticky wage effects)**
  - ***Allocative Channels*: both oil price increases & decreases cause factor reallocations & losses (**Davis & Haltiwanger (1996 & 2001), Keane & Prasad (1996)
- ***Widespread intersectoral reallocations*** of resources
  - **Plant-level research shows oil price shocks cause more job destruction than creation**
  - **Particularly in industries creating durable, energy-using goods**
- ***Surprise matters***, implying shock threshold effects:
  - **"Investment Pause" mechanism given uncertainty**

Summary of Oil-Macro Conclusions from advanced studies, 1994-2005

- ***Asymmetric oil price-GDP response explainable:*** *Not* an artifact of monetary policy or spurious relationship
- Ability to use ***monetary policy*** to avoid impacts is ***limited***
  - (Hamilton and Herrera 2001, Leduc and Sill 2004, Finn 2002)
- ***Stable oil price-GDP relationship identified*** over the entire period 1947:2-1999:4. (Jimenez-Rodrigues & Sanchez 1972-2001:4)
  - ***Relationship is nonlinear***.
  - Obtained using transformed price series (either Lee-Ni-Ratti or Hamilton 3-year "NOPI" oil price specification)
    - Increases more important than decreases
    - Increases that correct recent decreases have little effect
  - NOPI shocks significant with > 99% confidence thru 2004
    - **(Hamilton (2005), Brown Fu and Yucel (2005))**

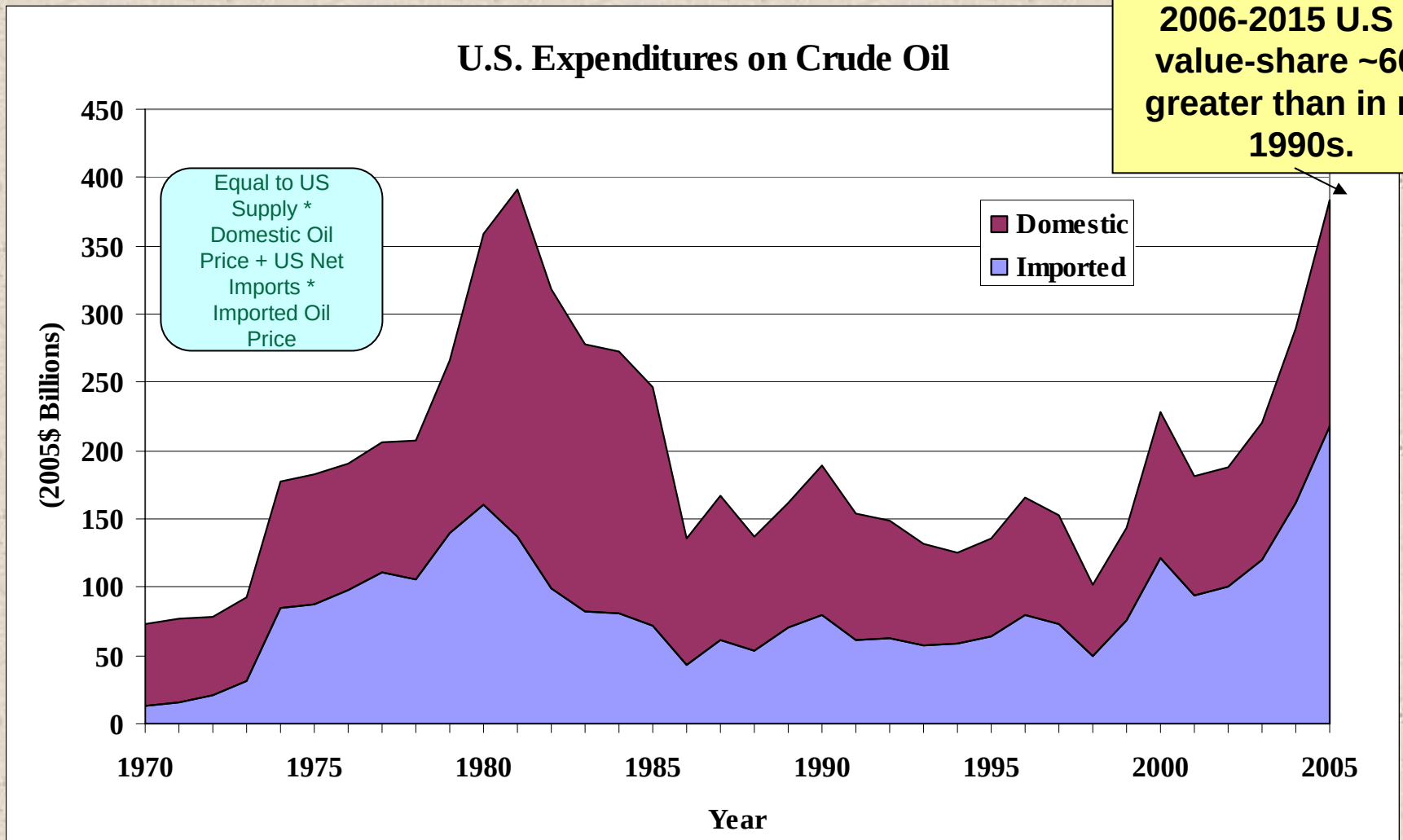
Is Price-shock effect declining, e.g. with oil/GDP share?

- **Expect yes, but Uncertain.**
  - Simple aggregation production function model implies loss bounded by value-share of oil in economy
- **Large macro-Models say yes by construction**
  - Guerrieri/FRB: "oil price/GDP multiplier is basically a linear function of oil share"
- **However no evidence of oil-share effect yet**
  - Huntington (2005) find influence of oil share ambiguous
  - Brown et al (2005): influence of energy/GDP share lost given 3-yr NOPI
- **Furthermore**
  - Value-share of oil in GDP rising in recent years

Real US Expenditures on Crude Oil Returning to Historical Highs

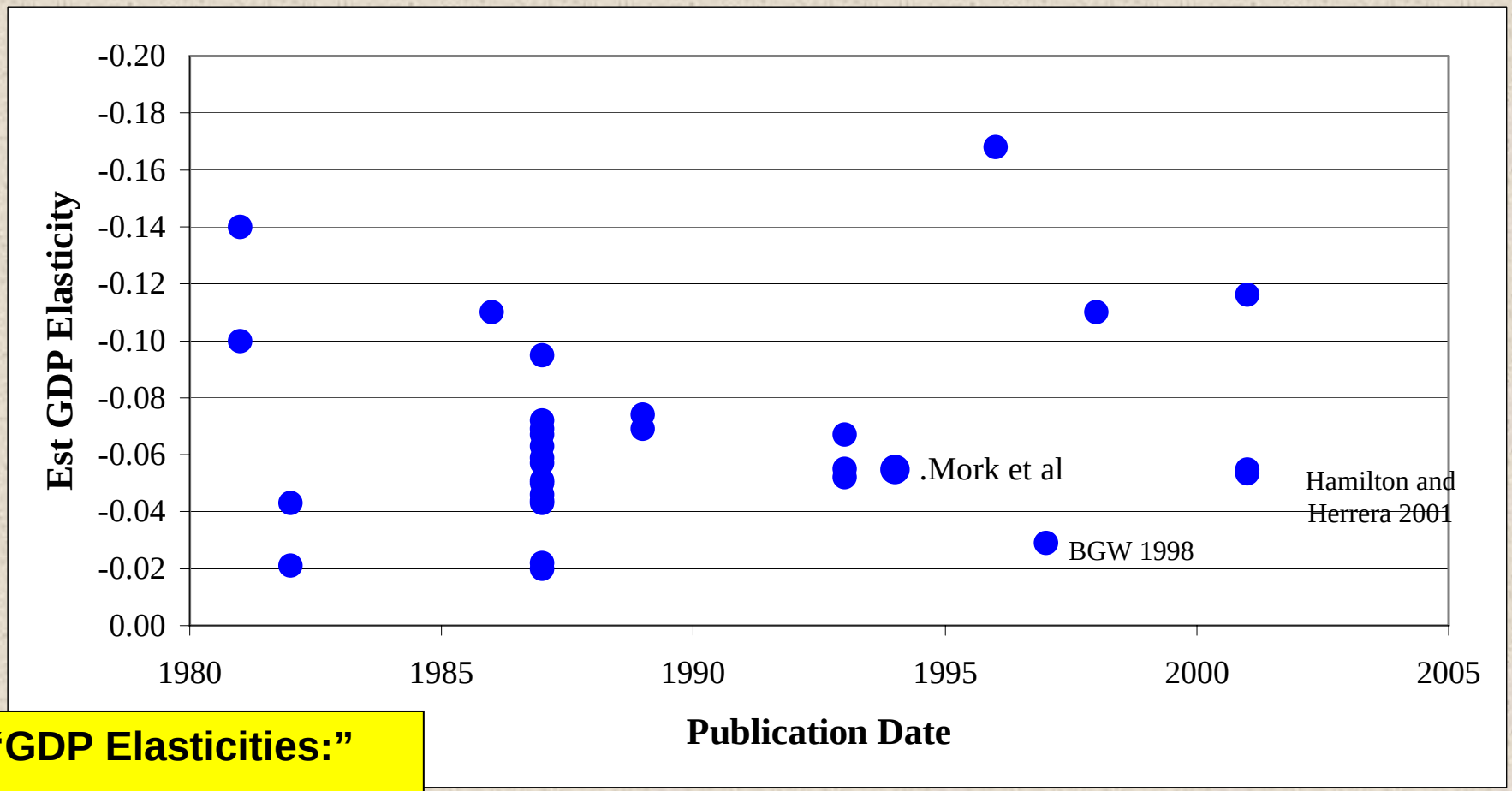
(constant 2005$)

AEO2006 projects 2006-2015 U.S oil value-share ~60% greater than in mid 1990s.



Source: Annual Energy Review 2006 and International Energy Review 2004. Year 2005 values preliminary.

Observation 1: Published Estimates of U.S. GDP Loss from Oil Price Changes Range Widely

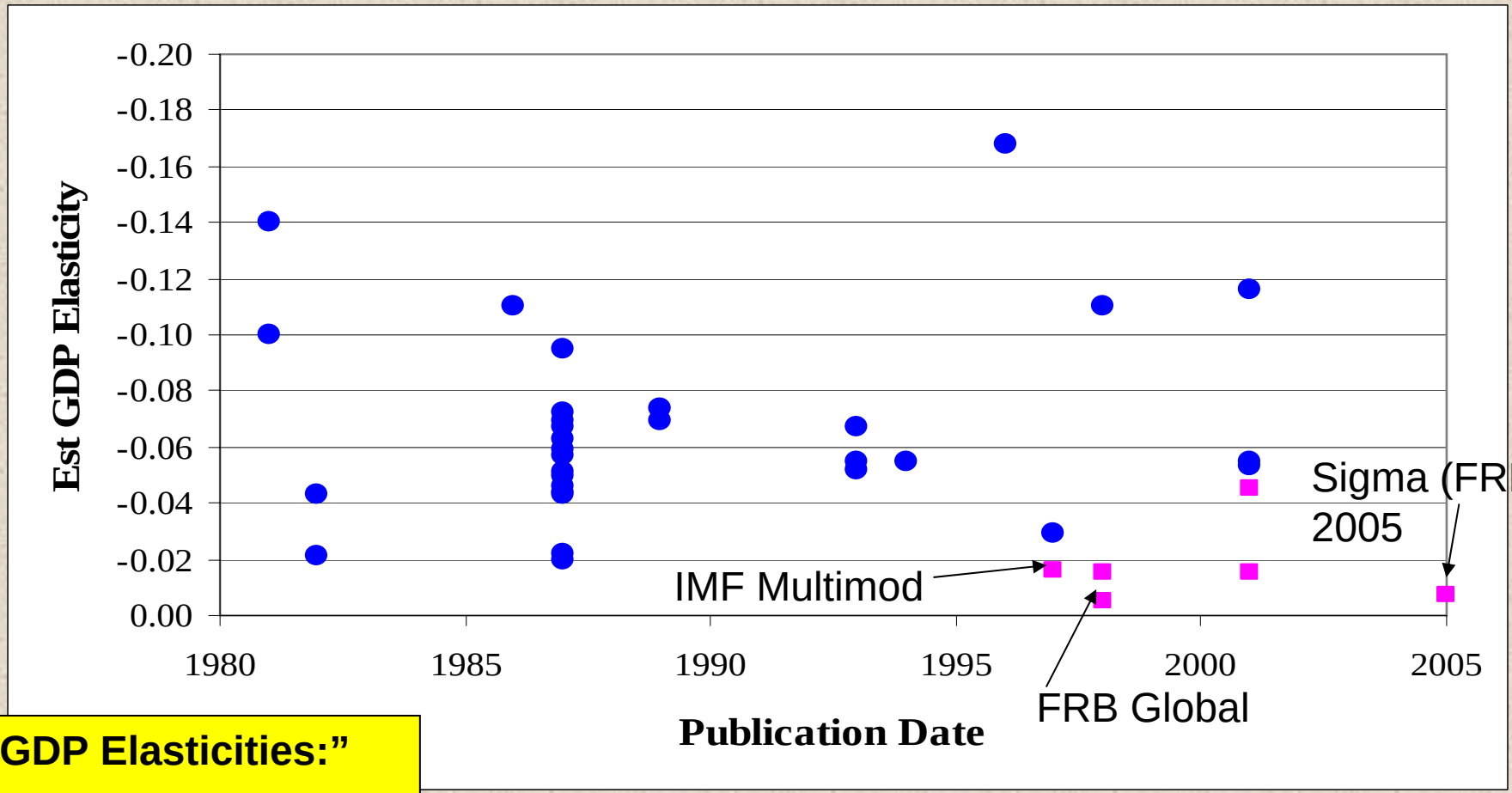


"GDP Elasticities:"

(GDP change for a price doubling, cumulative over ~2 yrs)

Source: ORNL worksheet (ElasTable4_GDPElasticities.xls), updated Nov. 2002

Observation 2: Published Ests of U.S. GDP Loss from Large Macro Models Generally Below Non-Structural Econometric Estimates



"GDP Elasticities:"

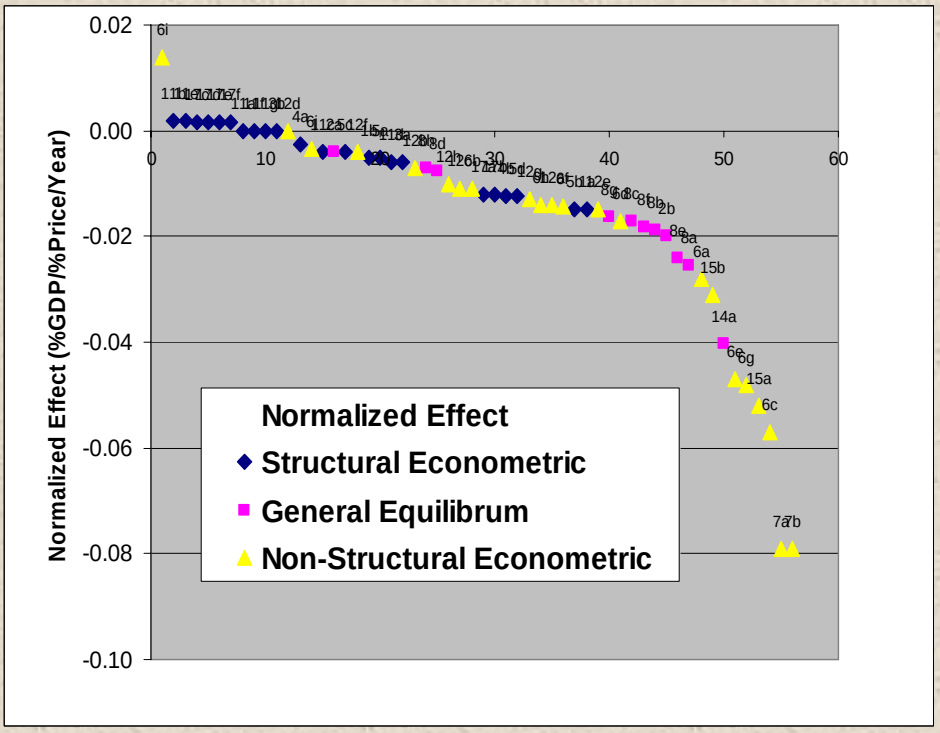
(GDP change for a price doubling, cumulative over ~2 yrs)

Models of the Oil-Macroeconomy Relationship Differ in Key Ways

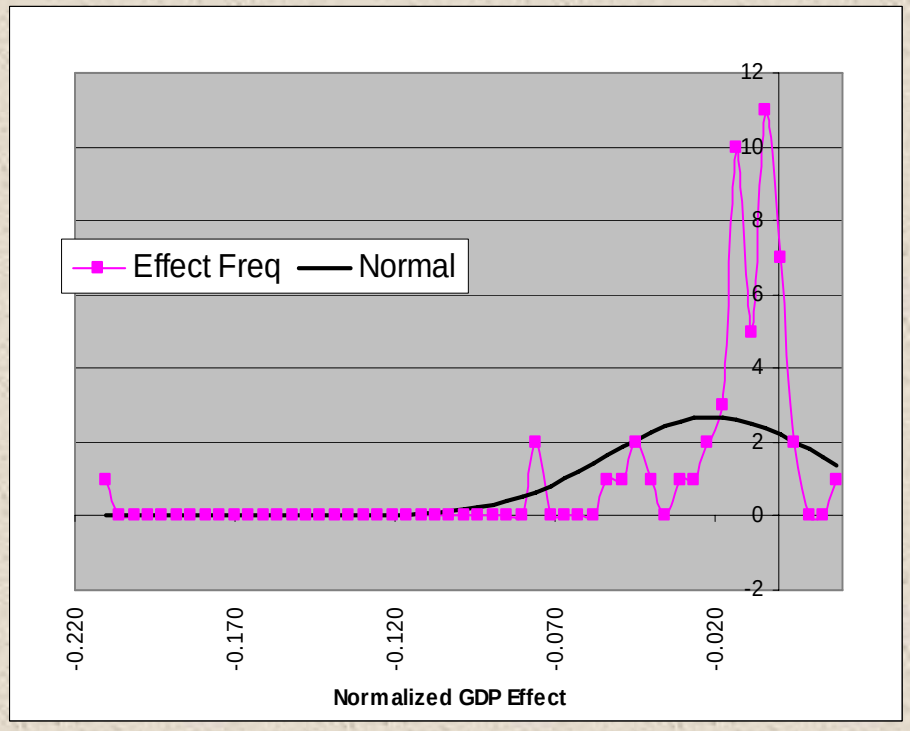
- **Modeling Approaches with Fundamental Differences. Three categories**
  - Structured Macro-econometric (SE),
  - General Equilibrium (GE) and
  - Non-Structural Econometric (NSE) (e.g. VAR) models
- **Observed Data represent Different Economic, Policy and Political Conditions and Mechanisms**
  - Estimates would be affected by
    - Which factors are operational in underlying data and
    - Whether or not they are captured in the analysis.
- **Studies Differ Greatly**
  - Methodological Approach, cases considered
  - If Structured: Selection of Mechanisms Represented
  - Underlying Data

Meta-Analysis Data: Range and Distribution of Normalized Estimates from Studies

Chart of Sorted Estimates (and indicating Type of Model)



Distribution of Estimates (and Normal dist w/ same mean/var)



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Initial Sample: 57 estimates from 13 studies

UT-BATTELLE

Starting From Oil-GDP Mechanisms Posited in Literature, Relevant Model Attributes Identified and Gathered

Mapping of Posited Mechanisms to Model/Study Attributes of Interest	
Mechanisms	**Attribute/Variable Category**
Supply-Side Effects	Production Function Specification Focus of Analysis (aggreg and/or channels) Oil supply specification
Demand Side Effects	Sector Detail Geographical Scope Oil demand specification
Real Balance Effects	Inflation rate specification
Policy Response Effects	Monetary Policy Specification Fiscal policy specification
Trade Balance/Terms of Trade Effects	Income Transfer: Constraints on Absorption Trade specification Exchange rate mechanism
Dynamics (forward/backward looking)	Dynamics: Forward-Looking Intertemporal Adjustment Capital/Investment Specification Lag Length in VAR Model (Years)
Nature of the Price Shock	Type of Shock (Oil Price var Linear, Net price, Surprise, Asym.) Size of Shock (% price change) Length of Shock (Permanent, Temp, Persistent)
Wage/Price Adjustment & Household/Producer Adj Costs	Inflation Specification: Philip's Curve Unemployment specification Sectoral Scope Price formation spec (compet.vs mkt power) Household Consumption Specification Household Detail
Study Methodology Controls	Percentage Change in Price Variable Years after Change in Price Variable Cumulative Effects Reported? (Y/N) Type of Model (SE/GE/NSE) Simulation period (Yr/Qtr/Mo) Data/Model parameters (est or calib)

Initial Results From Simple Specification of Meta-Analysis Model, Focusing on "Model Type" Regressing Normalized GDP Effect on Shock Size, Length and Model-Type

(More negative means greater loss)

	Estimates Applying White's Heteroscedastic Consistent Covariance					
Variable	VarName	Estimates	Std.Errors	T-ratios	P-values	Signif?
Shock Size: Percentage Change in Price	Size	-0.00088	0.00017	5.08	0.0%	**
Years after Change in Price Variable	Years	0.00282	0.00100	2.83	0.7%	**
Cumulative	Cum1	0.01825	0.00811	2.25	2.9%	*
Length of the Shock: Temporary	Lngth1	0.02682	0.00651	4.12	0.0%	**
Length of the Shock: Persistent	Lngth2	0.03285	0.00732	4.49	0.0%	**
Type of Model: General Equilibrium	TypM1	-0.01452	0.00517	2.81	0.7%	**
Type of Model: Non-Structural Econometri	TypM2	-0.06319	0.01109	5.70	0.0%	**
Simulation Period: Quarter	SimP1	0.01767	0.00423	4.18	0.0%	**
Simulation Period: Month	SimP2	-0.06218	0.03737	1.66	10.3%	

*Signif @95%;
**Signif @ 99%

Base Case If All Dummies=0:
Cumulative Effect=No;
Length of Shock=Permanent;
Type of Model=Structure Econometric,
Simulation Period=Year

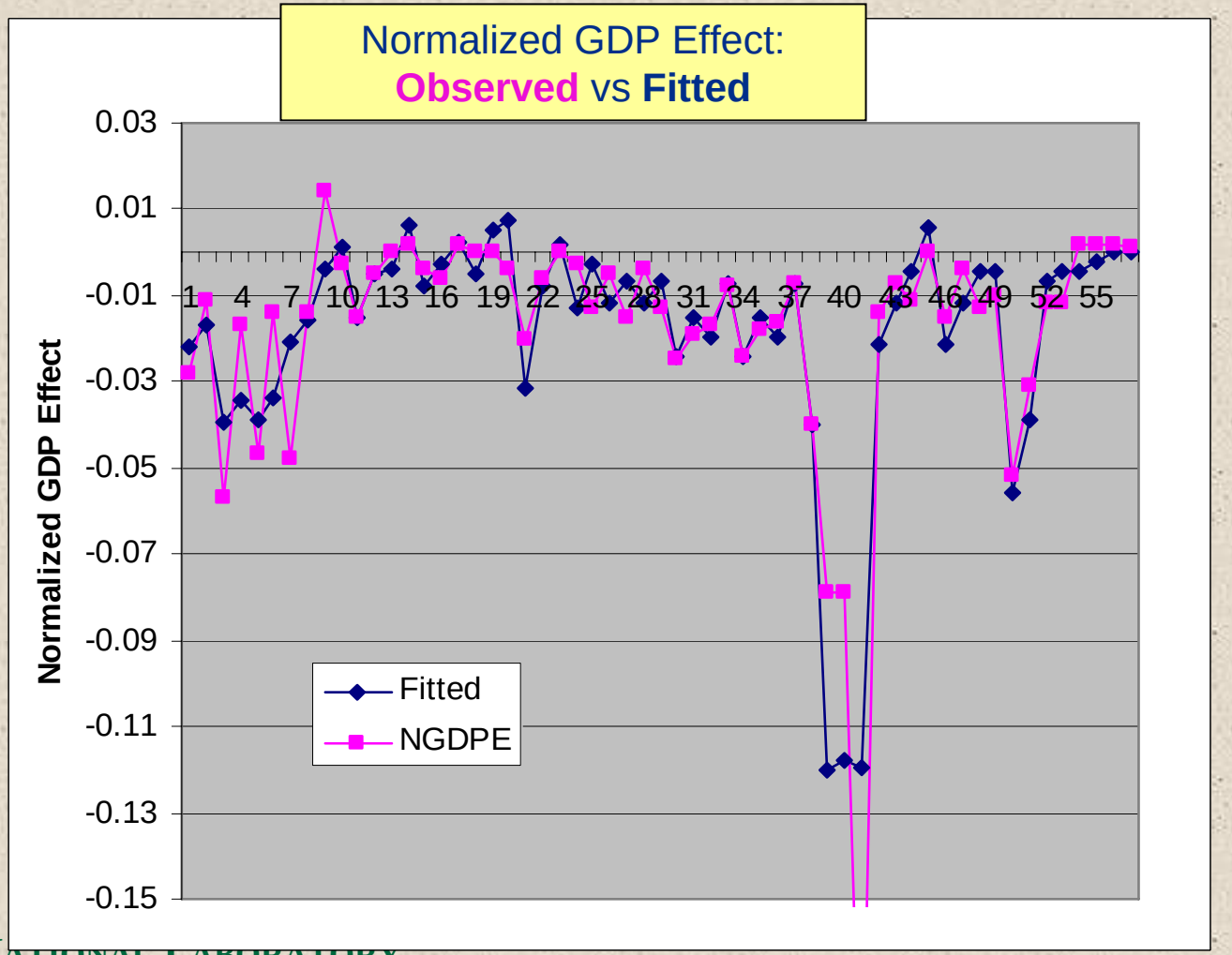
R2 = 0.690387
R2-adjusted = 0.638785
Akaike Information = -6.464161
Bayesian Information = -7.260567

Estimation sample = 57
Number of parameters = 9

Interpretation of Basic Results in Last Slide

- A good fraction of variation in estimates of Normalized GDP Effect from a price shock can be explained by
  - Model Type (SE, GE, or NSE),
  - Size of Shock,
  - Length of Shock, and
  - Years since shock began
- These are highly significant variables, with coefficients of expected sign.
  - Mean Normalized Effect (slightly) more negative with Size
  - Negative Effect diminishes toward zero with time after shocks
  - Effect from a GE model is about -0.0145 more negative than SE
  - Est Effect from a NSE model is about -0.063 more negative
  - Analysis with shorter (quarterly) simulation period show less negative effect.

Simple Meta-Models Explain about 60% of Model Variation



Source: "mdata with fitted Values Rev2006Jun27.xls"

Conclusions:

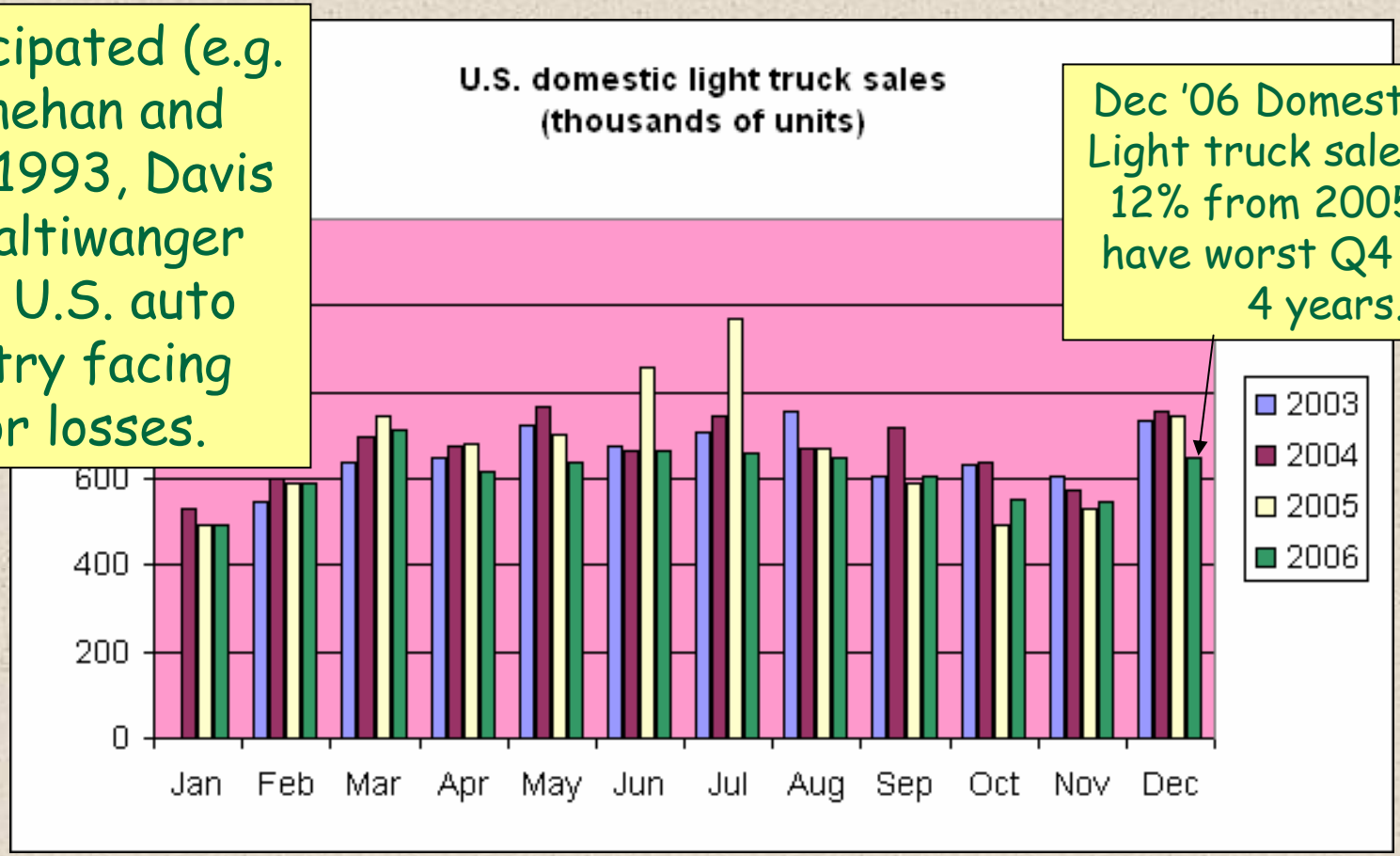
- Disruption likelihood can be assessed by expert and historical pattern
  - Stories surprisingly similar (on *percent* loss basis)
  - Wide range encompasses chance of extreme disruptions
- Reasons to remain vigilant regarding possible future supply shocks
  - Not all trends positive
  - Growing influence of OPEC suppliers, NOCs
  - Decreasing flexibility (elasticity) of demand
  - Larger oil value share in economy
- Price effect of supply shortfalls has been steeper than commonly assumed in models or scenarios

Implications for the Value of Stockpiling, and for Stockpile Use Policy

- **Method for estimating GDP impact of oil price changes must be chosen carefully, to suit purpose**
  - Structured Macro-Simulation so far do not adequately capture shock events
- **Structural behavior specification in macro-simulations are well-suited to gradual, long-lasting price changes**
  - "Factor share" argument applies absent dislocation and disruption in consumer/firm spending
- **SPR utilization:**
  - Evidence for asymmetric and threshold price effects suggests particular concern for sudden, unusual ΔPrice
  - Disruptive events with disturbing news are more critical for macro costs

Current price effects: "there is not simply a mechanical relation, even a nonlinear one, between prices and output."

As anticipated (e.g. Bresnehan and Ramey 1993, Davis and Haltiwanger 2001) U.S. auto industry facing major losses.



Dec '06 Domestic-made Light truck sales down -12% from 2005. Cars have worst Q4 sales in 4 years.

Source: Wards Auto, Econobrowser.com

"Net Oil Price Increase" Filters Out Less Significant Price Changes

$$\Delta P_t \geq n\sigma(P) \quad or \quad P_t \geq \max_{L=1\ldots12}(P_{t-L})$$