An Empirical Approximation of the Effects of Trade Sanctions with an Application to Russia

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> *We have to get rid of our dependency on Russian fossil fuels all over Europe. Last year, Russian gas accounted for 40% of our gas imports. Today it's down to 9% pipeline gas.*
> *— Ursula Von Der Leyen, State of the Union 2022*

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Compare results implied by approximation vs. exact responses in model

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- Russia affected much more than EU by either embargo;
  Russia much more affected by ban on its exports to EU than by ban on its imports from EU.

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- Russia affected much more than EU by either embargo;
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- Within EU, small ex-Soviet Union "satellite" countries much, much more affected by either embargo than large West European countries.

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- We show this happens because East European countries supply chains intimately interlinked with Russian economy. In particular pipelines are an important driving force.

Plan

Model

Production:

$$Y_i^r = Z_i^r \left[(H_i^r)^{\alpha^r} (K_i^r)^{1-\alpha^r} \right]^{\eta^r} (M_i^r)^{1-\eta^r}, \text{ where } M_i^r = \left(\sum_j \sum_s (\mu_{ji}^{sr})^{\frac{1}{\epsilon}} (M_{ji}^{sr})^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}$$

Households choose consumption to maximize:

$$U\left(C_i - \sum_r (H_i^r)^{1+\frac{1}{\psi}} \right) \text{ s.t. } P_i^c C_i = \sum_r W_i^r H_i^r + \sum_r R_i^r K_i^r,$$

where

$$C_i = \left[\sum_j \sum_s (\nu_{ji}^s)^{\frac{1}{\rho}} (C_{ji}^s)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}.$$

Model (continued)

Market Clearing:

$$P_i^r Y_i^r = \sum_j P_j^c C_j \, \pi_{ij}^r + \sum_j \sum_s (1 - \eta^s) \, P_j^s Y_j^s \, \xi_{ij}^{rs},$$

with expenditure shares

$$\xi_{ij}^{rs} = \frac{\mu_{ij}^{rs}(\tau_{ij}^r P_i^r)^{1-\epsilon}}{\sum_{k,l} \mu_{kj}^{ls}(\tau_{kj}^l P_k^l)^{1-\epsilon}}$$

$$\pi_{ij}^r = \frac{\nu_{ij}^r(\tau_{ij}^r P_i^r)^{1-\rho}}{\sum_{k,l} \nu_{kj}^l(\tau_{kj}^l P_k^l)^{1-\rho}}$$

With financial autarky:

$$P_i^r Y_i^r = \sum_j \sum_s \eta^s \, P_j^s Y_j^s \, \pi_{ij}^r + \sum_j \sum_s (1 - \eta^s) \, P_j^s Y_j^s \, \xi_{ij}^{rs}.$$

Solution

Deviations from steady state created by shocks to transport costs τ_{ij}^r (embargoes):

$$\ln \mathbf{V}_t = \frac{\alpha \psi}{1 + \psi}\left[\ln \mathbf{PY}_t - \ln \mathbf{P}_t^c\right],$$

where

$$\ln \mathbf{PY}_t = (\mathcal{P} + \mathbf{I})\boldsymbol{\Lambda}^{-1} \ln \mathbf{T}_t,$$
$$\ln \mathbf{P}_t^c = [(\mathbf{A}^c)^\top \otimes \mathbf{1}_\mathsf{R}]\mathcal{P}\boldsymbol{\Lambda}^{-1} \ln \mathbf{T}_t.$$

Exact solution from steady state and calibrated values for $\ln \mathbf{T}_t$.

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1. Negligible response of CPI to embargo.
2. Empirical approximation of (%) response of nominal output to embargo.

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$$\ln \widetilde{\mathbf{PY}}_d = \left[(\mathbf{I} - \mathbf{A})^{-1} \, \mathbf{PC} - (\mathbf{I} - \tilde{\mathbf{A}})^{-1} \, \widetilde{\mathbf{PC}}\right] \oslash \left[(\mathbf{I} - \mathbf{A})^{-1} \, \mathbf{PC}\right],$$

$\tilde{\mathbf{A}}$ and $\widetilde{\mathbf{PC}}$ set to zero demand arising from embargoed countries k.
Approximates $\frac{\ln P_{i,t}^r \, Y_{i,t}^r}{\ln \tau_{ik,t}^r}$. Call this HOT.

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$$\ln \widetilde{\mathbf{PY}}_u = \left[(\mathbf{I} - \mathbf{B}^\top)^{-1} \mathbf{PVA} - (\mathbf{I} - \tilde{\mathbf{B}}^\top)^{-1} \mathbf{PVA} \right] \oslash \left[(\mathbf{I} - \mathbf{B}^\top)^{-1} \mathbf{PVA} \right],$$

$\tilde{\mathbf{B}}$ sets to zero intermediate inputs arising from embargoed countries k.
Approximates $\frac{\ln P_{j,t}^s Y_{j,t}^s}{\ln \tau_{kj,t}^r}$. Call this SHOT.

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HOT and SHOT computed using OECD's ICIO in 2018. Later using EXIOBASE 2021 for detailed energy data.

Validation: Embargo on Russia's Oil Exports to EU

Approx. resp. ↓ 1.33%
Avg simul. resp. ↓ 1.37%
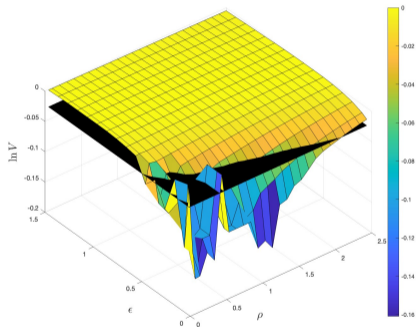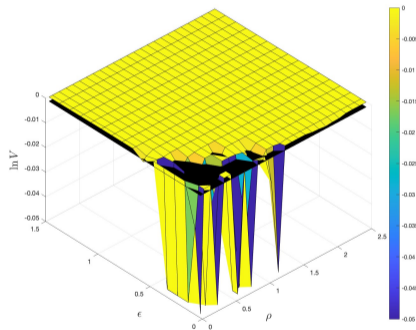
Approx. resp. ↓ 0.08%
Avg. simul. resp. ↓ 0.01%

(a) $\dfrac{\ln V^{OIL}_{RUS,t}}{\ln \tau^{OIL}_{RUS,EUR}}$ vs. $HOT^{OIL}_{RUS,EUR}$

(b) $\dfrac{\ln V^{CHEM}_{DEU,t}}{\ln \tau^{OIL}_{RUS,EUR}}$ vs. $SHOT^{OIL,CHEM}_{RUS,DEU}$

▸ Regressions

Validation: Embargo on all European exports to Russia

Approx. resp. ↓ 0.97%
Avg simul. resp. ↓ 0.6%

Approx. resp. ↓ 0.5%
Avg. simul. resp. ↓ 0.9%

(c) $\frac{\ln V^{CHEM}_{DEU,t}}{\ln \tau^{r}_{EUR,RUS}}$ vs. $HOT^{CHEM}_{DEU,RUS}$

(d) $\frac{\ln V^{OIL}_{RUS,t}}{\ln \tau^{r}_{EUR,RUS}}$ vs. $SHOT^{r,OIL}_{EUR,RUS}$

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Approximate effects of an embargo on Russian Energy Exports (incl. Natural Gas)

Effects on Russia		Effects on European countries			
Energy producing products	10.46	Refined petroleum products	1.47	BGR	1.09
Mining support service activities	2.42	Basic metals	0.50	LTU	0.50
Transport by land & pipelines	1.20	Electricity, gas, steam	0.42	SVK	0.43
Administrative services	1.00	Air transport	0.40	HUN	0.40
Manufacturing nec	0.82	Other non-metallic minerals	0.31	LVA	0.33
Warehouse & transport services	0.78	Non-energy producing products	0.31	CZE	0.30
Water transport	0.71	Chemical products	0.27	POL	0.29
Non-energy producing products	0.64	Transport by land & pipelines	0.25	FIN	0.20
Machinery & equipment, nec	0.45	Water transport	0.23	ROU	0.17
Rubber & plastics products	0.39	Energy producing products	0.20	SVN	0.13
Total Effect	**1.37**		Total effect		**0.08**

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Evenett-Muendler (2022): -0.58% long run effect in Russia of ban on Russian oil and gas.

Approximate effects of an embargo on all Russian Exports

Effects on Russia		Effects on European countries			
Energy producing products	12.30	Refined petroleum products	2.25	BGR	1.82
Air transport	9.21	Basic metals	1.49	LTU	1.22
Mining support service activities	7.63	Air transport	1.19	LVA	1.03
Postal & courier activities	6.40	Water transport	0.80	EST	0.99
Basic metals	6.18	Other non-metallic minerals	0.68	CYP	0.89
Refined petroleum products	6.01	Chemical products	0.66	SVK	0.83
Water transport	5.96	Non-energy producing products	0.66	HUN	0.79
Warehouse & transport services	5.95	Electricity, gas, steam	0.65	POL	0.68
IT	5.65	Fabricated metal products	0.62	FIN	0.68
Transport by land & pipelines	5.65	Transport by land & pipelines	0.62	CZE	0.65
Total effect	**3.62**			Total effect	**0.23**

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- Evenett-Muendler (2022): ban on Russian oil and gas and 35% tariff increase on the rest reduces Russian GDP by 1.06% in the long run.
- Bachmann et al (2022): ban on Russian coal, oil, and gas reduces German GDP by 0.2-0.3%. Here effect on Germany is 0.23%.
- Baqaee et al (2022): ban on Russian coal, oil, and gas reduces French GDP by <0.2%. Here effect on France is 0.13%.

Approximate effects of an embargo on all EU Exports

Effects on European countries		Effects on Russia	
CYP	0.12	Motor vehicles	6.32
LTU	0.06	Rubber & plastics products	5.23
EST	0.06	Machinery & equipment, nec	4.53
LVA	0.04	Other transport equipment	4.33
IRL	0.04	Electrical equipment	3.96
FIN	0.03	Manufacturing nec	3.53
SVK	0.02	Paper products & printing	3.22
CZE	0.02	Air transport	3.05
SVN	0.02	Fabricated metal products	2.96
BGR	0.02	Pharmaceutical products	2.89
Total effect	**0.01**	Total effect	**0.48**

The Availability of Alternatives

Substitution is assumed away in empirical approximation of $\ln V_{i,t}$.

Propose an approximation to availability of substitute markets.

Compute shares of production that historically served alternative markets (HOT) / used alternative inputs (SHOT).

Compare with shares of output lost because of embargo.

Do it for sectors most affected by European embargo on Russian energy / total exports.

Substitute downstream markets for Russia exports (HOT)

European embargo on Russia's Petroleum

Most affected Russian sectors	EUR	Substitute countries		
		USA	CHN	TUR
Refined petroleum products	25.39	4.51	4.30	3.53
Mining support service activities	12.27	2.18	2.08	1.71
Energy producing products	4.35	0.77	0.74	0.60

European embargo on Russia's Energy sectors

Most affected Russian sectors	EUR	Substitute countries		
		CHN	ISR	KOR
Energy producing products	34.02	17.07	2.77	2.75
Mining support services	7.88	3.96	0.64	0.64
Transport by land & pipelines	3.47	1.74	0.28	0.28

European embargo on all Russian sectors

Most affected Russian sectors	EUR	Substitute countries		
		CHN	KOR	ISR
Energy producing products	39.98	18.39	3.44	3.05
Refined petroleum products	29.56	5.98	3.63	1.56
Mining support services	24.80	6.85	2.39	1.39

Substitute upstream markets for Europe imports (SHOT)

European embargo on Russia's Energy	FRA	SAU	KAZ	NOR	
		Substitute countries		
Refined petroleum products	6.59	8.86	4.87	3.23	
Electricity, gas, steam	1.82	2.25	1.24	0.82	
Basic metals	0.64	0.56	0.31	0.21	
	DEU	NOR	KAZ	USA	GBR
Refined petroleum products	6.80	9.48	2.31		2.00
Energy producing products	3.67	5.24	1.28		1.11
Electricity, gas, steam	1.74	1.63	0.40	0.57	
	LVA	GBR	USA	NOR	
Refined petroleum products	32.64	0.03	<0.01	<0.01	
Electricity, gas, steam	13.20	0.02	<0.01	<0.01	
Other non-metallic minerals	12.58	<0.01	<0.01	<0.01	
	BGR	ZAF	TUR	USA	
Refined petroleum products	44.80	0.02	0.02	<0.01	
Electricity, gas, steam	25.69	0.26	0.16	<0.01	
Other non-metallic minerals	23.27	0.06	0.05	<0.01	

Substitute upstream markets for Europe imports (SHOT)

European embargo on all Russian sectors		Substitute countries				
	FRA	SAU	KAZ	USA	CHN	NOR
Refined petroleum products	9.75	8.98	5.75	2.87		3.42
Electricity, gas, steam	2.75	2.30	1.47	1.37		0.89
Basic metals	1.86		2.30		1.36	
	DEU	NOR	USA	KAZ	GBR	CHN
Refined petroleum products	10.80	10.02	2.41	2.74	2.59	
Energy producing products	5.87	5.65	2.16	1.52	1.82	
Basic metals	5.48	2.40	2.69		1.14	1.33
	LVA	USA	CHN	GBR	NOR	
Refined petroleum products	47.99	0.43	0.25	0.20		
Electricity, gas, steam	20.28	0.41	0.23	0.23		
Other non-metallic minerals	19.38	0.37	0.52		0.34	
	BGR	TUR	CHN	GBR	ZAF	
Refined petroleum products	65.37	0.96	0.46	0.29		
Electricity, gas, steam	37.08	0.49		0.18	0.30	
Other non-metallic minerals	34.35	1.46	0.61	0.25		

Direct vs indirect trade - embargo on Russian Petroleum (in %)

Country	HOT	Direct Exports	Ratio	Country	HOT	Direct Exports	Ratio
CZE	0.35	0.01	40.63	HRV	0.05	0.01	4.05
SVK	0.36	0.03	14.32	BEL	0.64	0.16	4.02
LTU	0.29	0.03	9.00	AUT	0.06	0.02	3.93
BGR	0.70	0.08	8.72	DNK	0.96	0.27	3.56
MLT	0.01	<0.01	7.68	IRL	0.24	0.07	3.50
LUX	<0.01	<0.01	6.35	GRC	1.55	0.48	3.23
FIN	0.79	0.15	5.36	EST	0.13	0.04	3.18
POL	2.09	0.40	5.27	ROU	0.38	0.12	3.08
HUN	0.66	0.13	4.96	SVN	0.07	0.03	2.79
SWE	0.84	0.17	4.87	FRA	2.21	0.80	2.76
NLD	1.02	0.24	4.20	DEU	5.79	2.27	2.55
ITA	1.97	0.47	4.19	ESP	0.70	0.28	2.52
PRT	0.25	0.06	4.19	GBR	3.19	1.39	2.30
LVA	0.09	0.02	4.10	CYP	0.01	<0.01	2.10

Direct vs. Indirect Trade

The ratio of indirect to direct trade reflects the intensity of value chains.

Small Eastern European countries are much more integrated with Russia through value chains.

And therefore much more dependent.

Pipelines

We explore the importance of transport infrastructure to account for these enormous asymmetries.

Compute $\text{SHOT}_{i,j}^{r,s}$ for
(i,r) = (Russia, Transport via Pipelines)
(j,s) = (EU country, Production of Electricity using gas).

Estimates how much production of electricity using gas in country j depends on Russian pipelines.

Data comes from EXIOBASE in 2021: 163 industries for 44 countries. Sectors such as "Poultry Farming" or "Reprocessing of secondary wood material".

Dependence on Russian pipelines (Electricity Production)

Country	SHOT	Country	SHOT
SWE	0.023	LUX	0.003
LTU	0.019	SVK	0.002
CZE	0.019	EST	0.002
ROU	0.018	DEU	0.002
HUN	0.015	BGR	0.002
FRA	0.014	ESP	0.002
ITA	0.007	FIN	0.001
HRV	0.005	BEL	0.001
SVN	0.005	GRC	0.001
PRT	0.004	IRL	0.001
DNK	0.004	GBR	0.001
LVA	0.003	NLD	0.001
POL	0.003		
AUT	0.003		

Conclusion

Data-based approximation to effects of trade embargoes. No substitution, and therefore no elasticity calibration.

Not a replacement to precise estimates from GE models - but practical to conduct simple and relevant experiments without a need for calibration.

Document small effects of trade embargoes involving Russia - though enormously asymmetric, especially within the EU.

Show that most affected countries by embargoes (East Europe) are also most dependent on Russia, esp. as far as transport infrastructure.

Illustration of approximation's potential. HOT and SHOT to be made available online.

Thank you
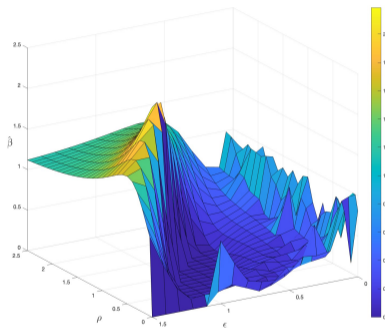
(e) $\hat{\beta}$ from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$
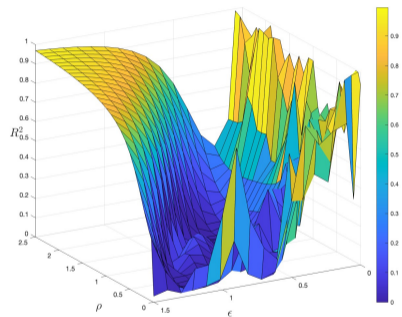
(f) R^2 from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$
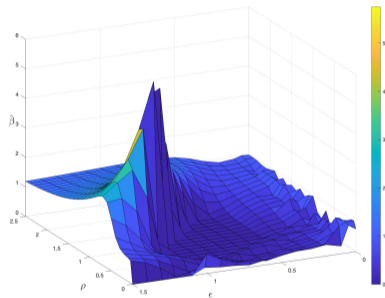
(g) $\hat{\beta}$ from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$
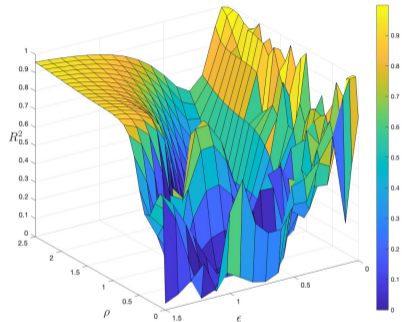
(h) R^2 from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$
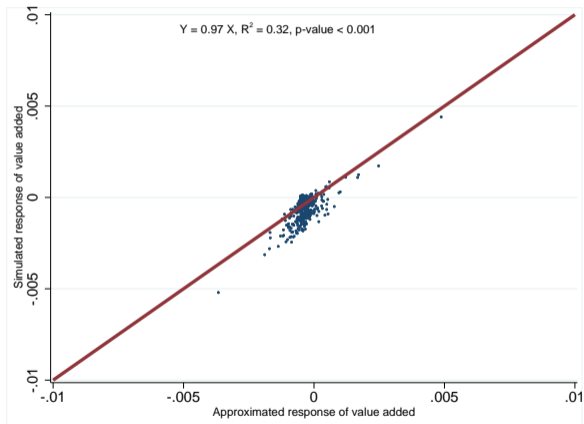
Response of value added to a Russian Oil shock

Y = 1.14 X, R^2 = 0.97, p-value < 0.001

Y = 0.90 X, R^2 = 0.90, p-value < 0.001
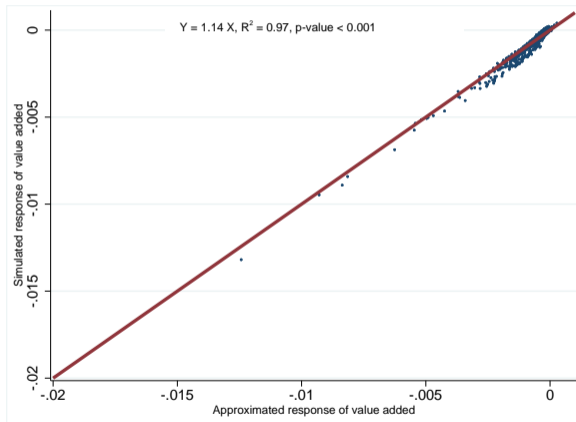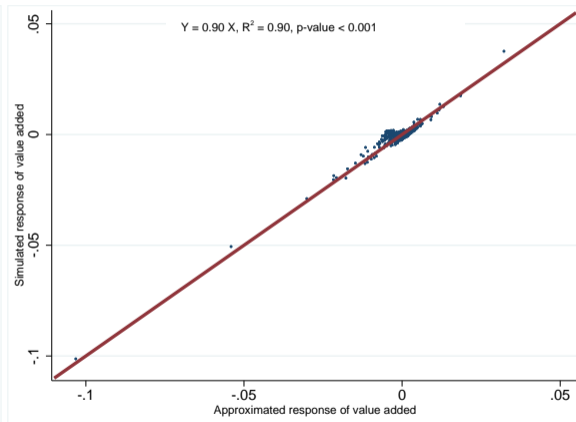
(i) $\rho = 2.5$, $\epsilon = 1.5$, and $\psi = 2$

(j) $\rho = 2.5$, $\epsilon = 0.05$, and $\psi = 2$
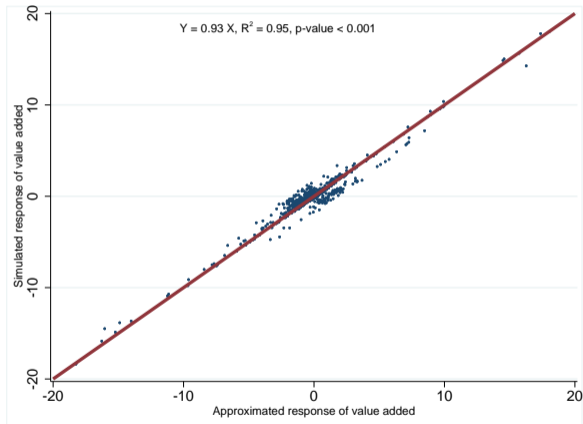
Response of value added to a Russian Oil shock
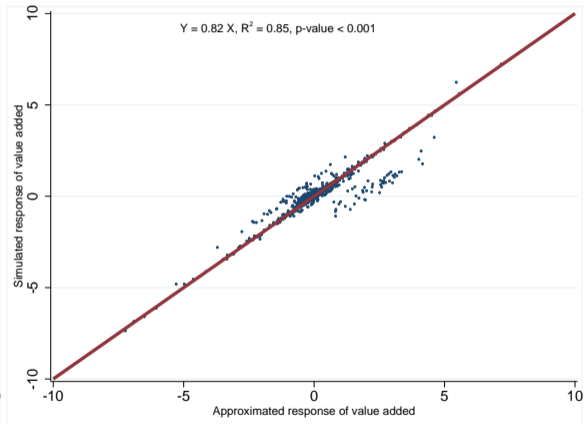

(k) $\rho = 0.05$, $\epsilon = 1.5$, and $\psi = 2$

(l) $\rho = 0.05$, $\epsilon = 0.05$, and $\psi = 2$

Response of value added to a Russian Oil shock

Y = 0.93 X, R² = 0.95, p-value < 0.001

Y = 0.82 X, R² = 0.85, p-value < 0.001

(m) $\rho = 0.05$, $\epsilon = 0.1$, and $\psi = 2$

(n) $\rho = 0.1$, $\epsilon = 0.1$, and $\psi = 2$