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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Direct vs indirect trade - downstream of Russian Petroleum

Country	HOT	Direct Exports	Ratio	Country	HOT	Direct Exports	Ratio
CZE	0.35	0.01	40.71	LVA	0.09	0.02	4.13
SVK	0.36	0.03	14.32	HRV	0.05	0.01	4.11
LTU	0.29	0.03	9.35	AUT	0.06	0.02	4.04
BGR	0.70	0.08	9.19	DNK	0.96	0.27	3.56
MLT	0.01	$<$0.01	7.67	IRL	0.23	0.07	3.38
LUX	$<$0.01	$<$0.01	6.51	GRC	1.52	0.46	3.30
FIN	0.79	0.14	5.45	EST	0.13	0.04	3.23
POL	2.08	0.39	5.31	ROU	0.38	0.12	3.11
HUN	0.66	0.13	5.01	SVN	0.08	0.03	3.06
SWE	0.84	0.17	4.87	FRA	2.23	0.78	2.86
NLD	1.05	0.24	4.47	DEU	5.78	2.19	2.64
BEL	0.64	0.15	4.22	ESP	0.70	0.27	2.55
ITA	1.98	0.47	4.18	GBR	3.18	1.37	2.32
PRT	0.25	0.06	4.14	CYP	0.01	$<$0.01	2.11

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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 sanction;
  Russia much more affected by sanctions on its exports to EU than by sanctions on its imports from EU.
- Within EU, small ex-Soviet Union “satellite” countries much, much more affected by either sanction than large West European countries.

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Consider historical existence of alternative supply chains:

- Alternative to EU for Russia's exports very limited.
- Alternative to Russian imports for large West European economies readily exist.
- Alternative to Russian imports for small ex-satellite East European countries virtually non-existent.
- Appears to happen because East European countries supply chains intimately interlinked with Russian economy, e.g., pipelines.

Plan

1. Model
2. Approximation
3. Validation
4. Effects of Sanctions
5. Conclusion

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:

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

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} (sanctions):

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

where

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

Solution from calibrated steady state (WIOD) and calibrated values for $\ln \mathbf{T}_t$ ($\times$ 100).

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Two steps:

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 sanctioned countries k. Approximates $\frac{\ln P^r_{i,t} Y^r_{i,t}}{\ln \tau^r_{ik,t}}$. 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 r arising from sanctioned countries k. Approximates $\frac{\ln \mathrm{P}^s_{j,t} \mathrm{Y}^s_{j,t}}{\ln \tau^r_{kj,t}}$. Call this SHOT.

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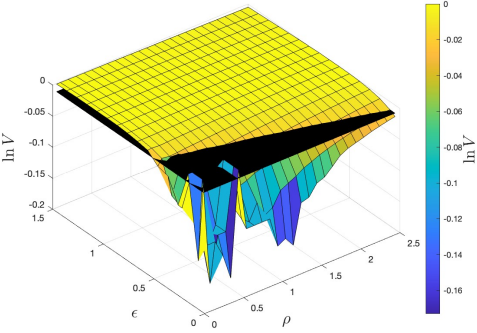
HOT and SHOT computed using OECD's ICIO in 2018.

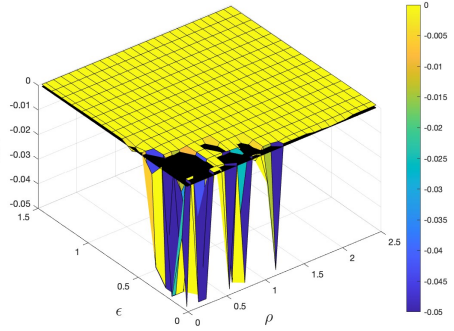
Validation: Sanction on Russia's Oil Exports to EU

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



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

Approx. resp. ↓ 0.08%
Avg. simul. resp. ↓ 0.02%

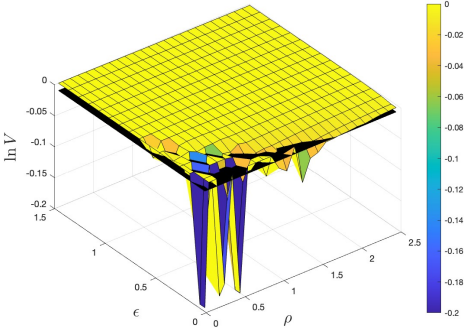


(b) $\frac{\ln V^{CHEM}_{DEU,t}}{\ln \tau^{OIL}_{RUS,EUR}}$ vs. $SHOT^{OIL,CHEM}_{RUS,DEU}$

▸ Regressions

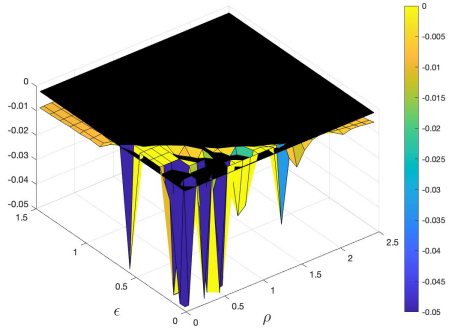
Validation: Sanction on all European exports to Russia

Approx. resp. ↓ 1.18%
Avg simul. resp. ↓ 0.64%



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

Approx. resp. ↓ 0.28%
Avg. simul. resp. ↓ 0.88%



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

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

Effects on Russia		Effects on European sectors		EU countries	
Energy producing products	8.70	Refined petroleum products	1.43	BGR	1.13
Mining support service activities	2.01	Basic metals	0.51	LTU	0.52
Transport by land & pipelines	1.21	Electricity, gas, steam	0.42	SVK	0.43
Administrative services	1.01	Air transport	0.40	HUN	0.40
Manufacturing nec	0.80	Other non-metallic minerals	0.31	LVA	0.33
Warehouse & transport services	0.78	Chemical products	0.28	CZE	0.30
Water transport	0.72	Non-energy producing products	0.26	POL	0.29
Non-energy producing products	0.52	Transport by land & pipelines	0.26	FIN	0.20
Machinery & equipment, nec	0.45	Water transport	0.21	ROU	0.17
Rubber & plastics products	0.40	Rubber & plastics products	0.17	SVN	0.13
Total Effect	**1.17**	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 sanctions on all Russian Exports

Effects on Russia		Effects on European sectors		EU countries	
Energy producing products	10.22	Refined petroleum products	2.19	BGR	1.87
Air transport	9.19	Basic metals	1.51	LTU	1.25
Mining support service activities	6.32	Air transport	1.19	CYP	1.04
Postal & courier activities	6.25	Water transport	0.76	LVA	1.03
Basic metals	6.20	Other non-metallic minerals	0.69	EST	0.99
Warehouse & transport services	6.18	Chemical products	0.69	SVK	0.84
Water transport	6.01	Electricity, gas, steam	0.66	HUN	0.79
Refined petroleum products	5.84	Fabricated metal products	0.63	FIN	0.68
Transport by land & pipelines	5.73	Transport by land & pipelines	0.63	POL	0.68
IT	5.69	Wood products	0.61	CZE	0.65
Total effect	**3.40**	Total effect	**0.23**		

Approximate effects of sanctions on all Russian Exports

Effects on Russia		Effects on European sectors		EU countries	
Energy producing products	10.22	Refined petroleum products	2.19	BGR	1.87
Air transport	9.19	Basic metals	1.51	LTU	1.25
Mining support service activities	6.32	Air transport	1.19	CYP	1.04
Postal & courier activities	6.25	Water transport	0.76	LVA	1.03
Basic metals	6.20	Other non-metallic minerals	0.69	EST	0.99
Warehouse & transport services	6.18	Chemical products	0.69	SVK	0.84
Water transport	6.01	Electricity, gas, steam	0.66	HUN	0.79
Refined petroleum products	5.84	Fabricated metal products	0.63	FIN	0.68
Transport by land & pipelines	5.73	Transport by land & pipelines	0.63	POL	0.68
IT	5.69	Wood products	0.61	CZE	0.65
Total effect	**3.40**	Total effect	**0.23**		

- 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 sanctions on all EU Exports

Effects on EU countries		Effects on Russia	
CYP	2.14	Motor vehicles	6.34
LTU	0.93	Rubber & plastics products	5.26
EST	0.83	Machinery & equipment, nec	4.56
LVA	0.80	Other transport equipment	4.31
BGR	0.71	Electrical equipment	3.97
FIN	0.61	Manufacturing nec	3.49
SVN	0.53	Paper products & printing	3.25
IRL	0.52	Air transport	3.01
SVK	0.52	Fabricated metal products	2.97
CZE	0.50	Pharmaceutical products	2.92
Total effect	**0.24**	Total effect	**1.31**

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Compute $\text{SHOT}^{\text{OIL},s}_{i,\text{EUR}}$. Look in historical data for alternative source *i* for Russian oil used in EU sector *s*.

The Availability of Alternatives

Compute $\text{HOT}^{\text{OIL}}_{\text{RUS},j}$ for next highest market j after EU

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Compute $\text{HOT}^{\text{OIL}}_{\text{RUS},j}$ for next highest market j after EU

Compute $\text{SHOT}^{\text{OIL},s}_{i,\text{EUR}}$ for next highest oil supplier after Russia for EU sector s.

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Compute $\text{HOT}^{\text{OIL}}_{\text{RUS},j}$ for next highest market j after EU

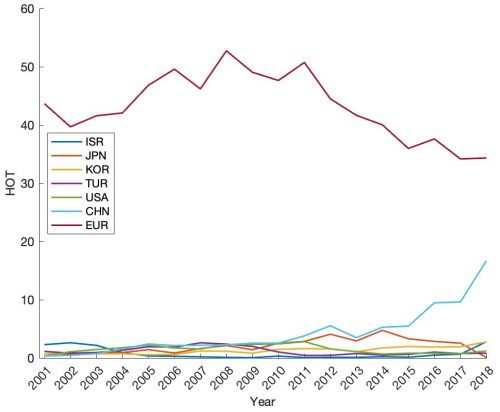
Compute $\text{SHOT}^{\text{OIL},s}_{i,\text{EUR}}$ for next highest oil supplier after Russia for EU sector s.

Compare with shares of output lost because of sanctions. If shares are close, there have been close substitutes in history.

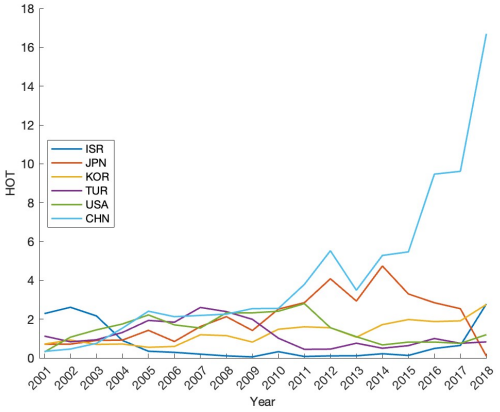
Substitute downstream markets for Russia exports (HOT)

European embargo on Russia's Energy sectors						
		Substitute countries				
Most affected Russian sectors	EUR	CHN	ISR	KOR	USA	TUR
Energy producing products	34.33	16.70	2.78	2.76	1.20	0.83
Mining support services	7.95	3.86	0.64	0.64	0.28	0.19

HOT Russia (in %)

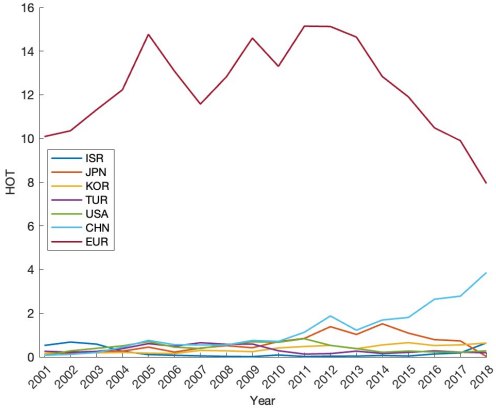


(e) Energy producing products

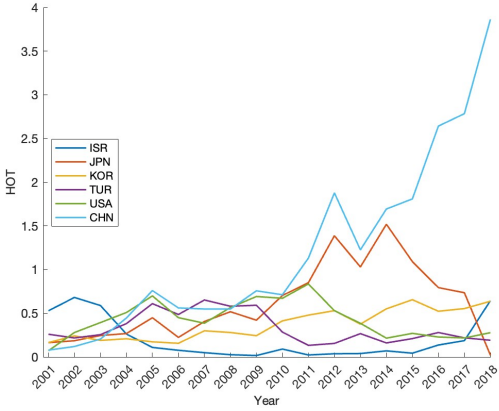


(f) Energy producing products (without Europe)

HOT Russia (in %)



(g) Mining support services

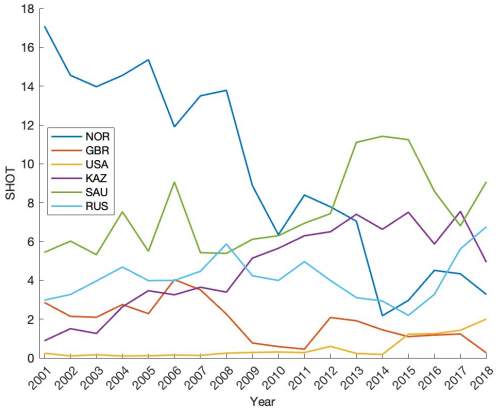


(h) Mining support services (without Europe)

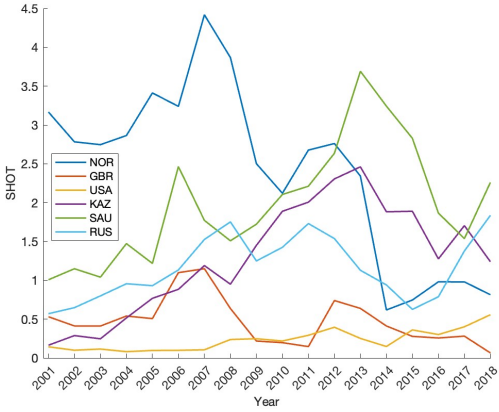
Substitute upstream markets for French and German imports (SHOT)

European embargo on Russia's Energy		Substitute countries				
Most affected French sectors	RUS	SAU	KAZ	CHN	NOR	USA
Refined petroleum products	6.76	9.07	4.93	3.47	3.27	2.01
Electricity, gas, steam	1.84	2.26	1.24	0.87	0.81	0.56
Most affected German sectors	RUS	NOR	KAZ	GBR	USA	SAU
Refined petroleum products	6.73	9.31	2.26	1.97	1.38	0.63
Energy producing products	3.82	5.37	1.31	1.14	0.88	0.36

SHOT France (in %)

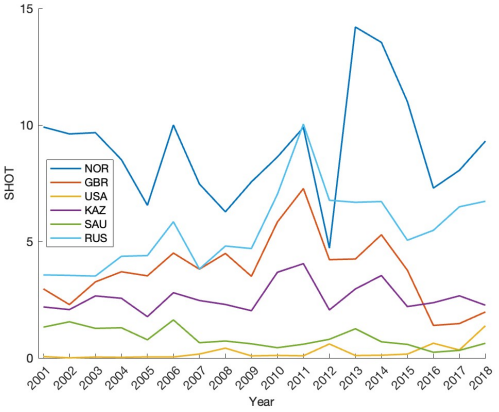


(i) France: Refined petroleum products

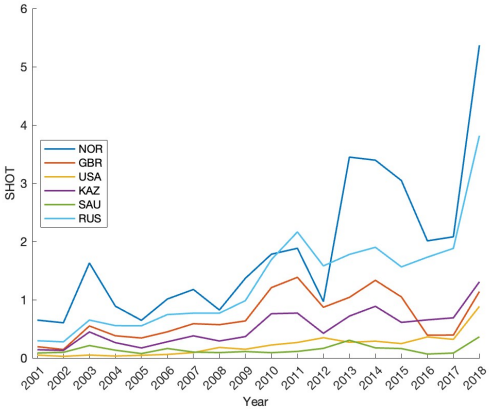


(j) France: Electricity, gas, steam

SHOT Germany (in %)



(k) Germany: Refined petroleum products

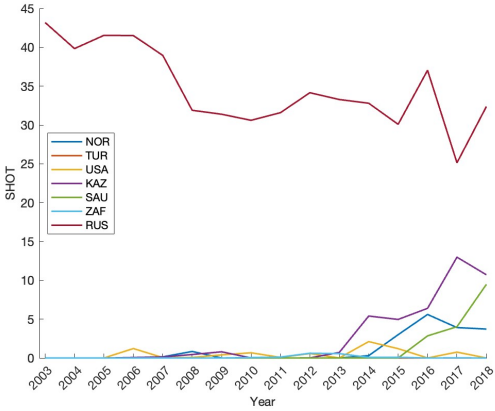


(l) Germany: Energy producing products

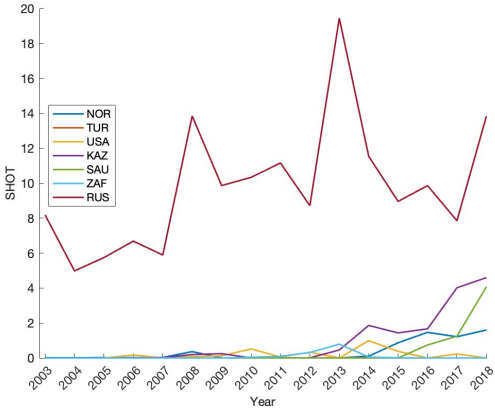
Substitute upstream markets for Bulgarian, Latvian, and Lithuanian imports (SHOT)

European embargo on Russia's Energy		Substitute countries				
Most affected Latvian sectors	RUS	GBR	CHN	NOR	USA	
Refined petroleum products	23.09	0.03	<0.01	<0.01	<0.01	
Electricity, gas, steam	13.59	0.02	<0.01	<0.01	<0.01	
Most affected Lithuanian sectors	RUS	KAZ	SAU	NOR	CHN	ZAF
Refined petroleum products	32.37	10.71	9.48	3.72	0.93	<0.01
Electricity, gas, steam	13.84	4.60	4.07	1.60	0.40	<0.01
Most affected Bulgarian sectors	RUS	ZAF	TUR	CHN	USA	
Refined petroleum products	43.32	0.03	0.02	0.01	<0.01	
Electricity, gas, steam	25.40	0.29	0.15	<0.01	<0.01	

SHOT Lithuania

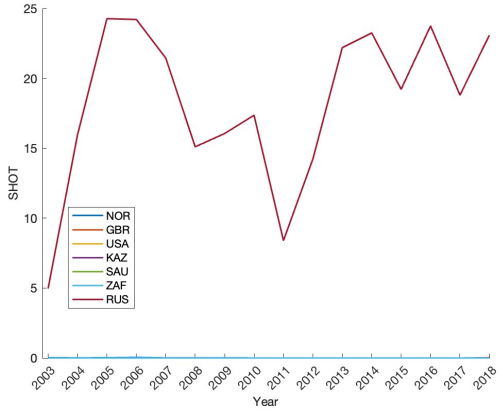


(m) Lithuania: Refined petroleum products

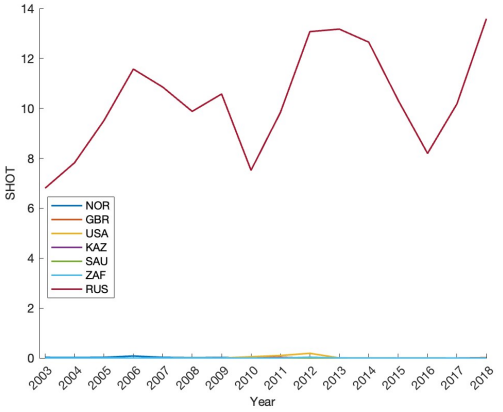


(n) Lithuania: Electricity, gas, steam

SHOT Latvia

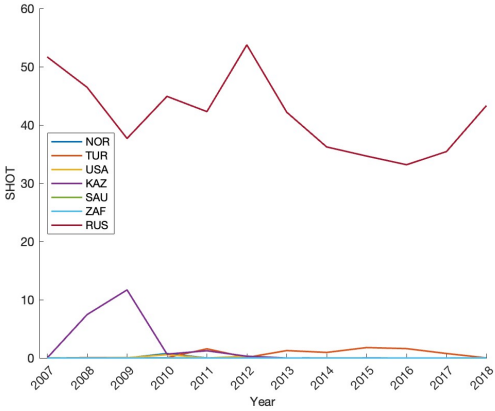


(o) Latvia: Refined petroleum products

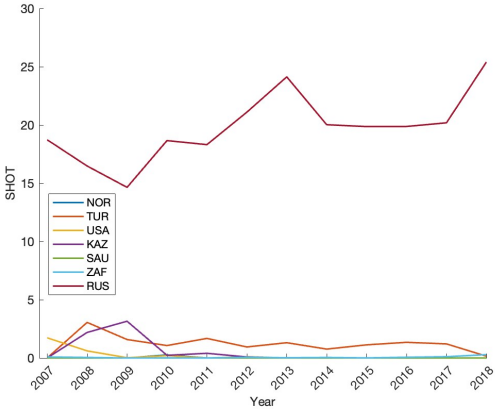


(p) Latvia: Electricity, gas, steam

SHOT Bulgaria



(q) Bulgaria: Refined petroleum products



(r) Bulgaria: Electricity, gas, steam

Energy Infrastructure

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The importance of transport infrastructure

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Oil Refinery opens in Lithuania in 2006. Receives oil from Norway and Kazakhstan. Liquefied Natural Gas Terminal in Klaipeda opens in 2014. Imports LNG from Norway and Qatar instead of Yamal-Europe pipeline.

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Bulgaria plans to connect to Azerbaijan-Georgia-Romania Interconnector pipeline project. Too recent for our data.

Conclusion

Data-based approximation to effects of trade sanctions. 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.

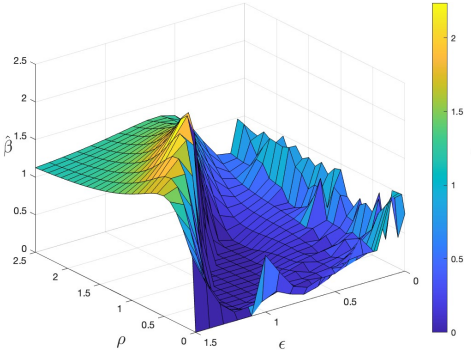
Document small effects of trade sanctions involving Russia - though enormously asymmetric, especially within the EU.

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

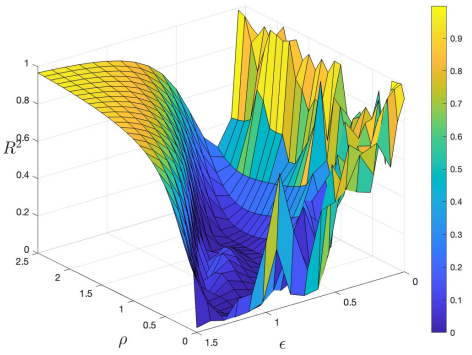
Illustration of approximation's portability `https://exposure.trade`

Thank you

Validation: Embargo on Russia's Oil Exports to EU



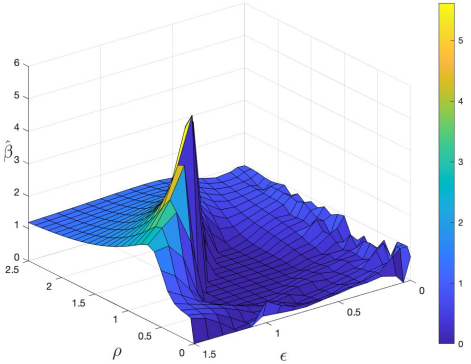
(s) $\hat{\beta}$ from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$



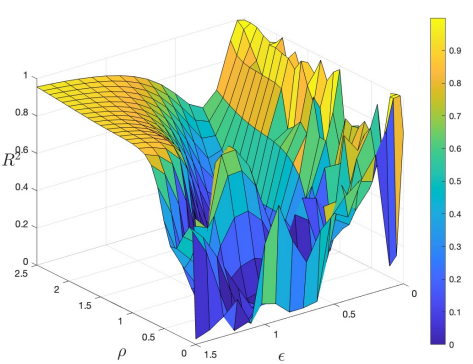
(t) R^2 from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$

Back

Validation: Embargo on all European exports to Russia



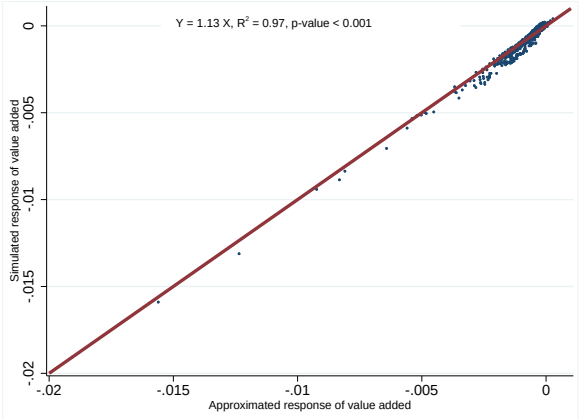
(u) $\hat{\beta}$ from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$



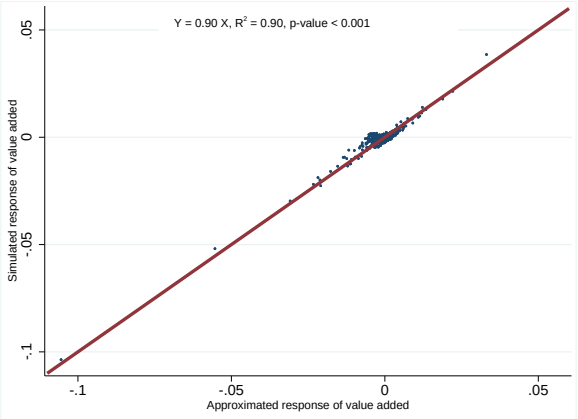
(v) R^2 from regressing $\ln \mathbf{V}_t$ on $\frac{\alpha^r \psi}{1+\psi} \ln \mathbf{PY}_t$

Back

Response of value added to a Russian Oil shock

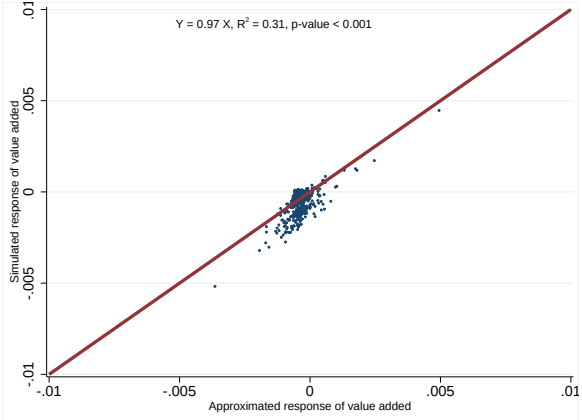


(w) $\rho = 2.5$, $\epsilon = 1.5$, and $\psi = 2$

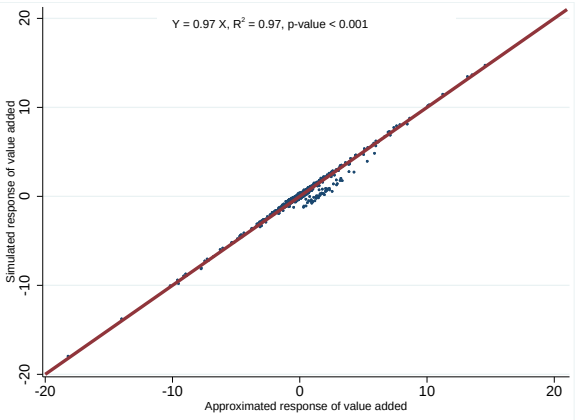


(x) $\rho = 2.5$, $\epsilon = 0.05$, and $\psi = 2$

Response of value added to a Russian Oil shock



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



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

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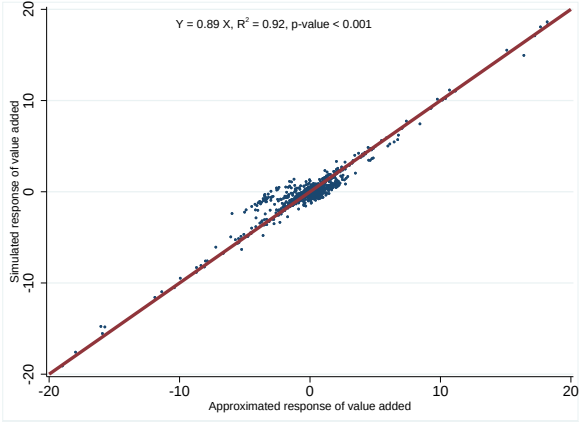
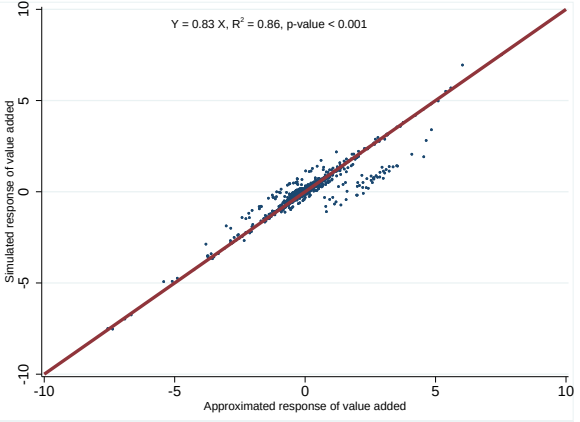


() $\rho = 0.05$, $\epsilon = 0.1$, and $\psi = 2$



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