Assessing the supply security – a compound indicator

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Motivation

Supply security as a crucial concept; some examples

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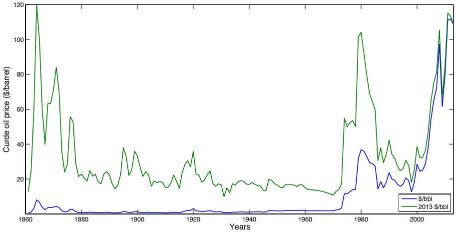
- Oil price spikes



Motivation

Supply security as a crucial concept; some examples

- Shortages of gasoline
- Oil price spikes
- Food import dependency

Lettuce 'black market' emerges amid national salad shortage

The Telegraph 3 FEBRUARY 2017 • 1:23PM

Motivation

Supply security as a crucial concept; some examples

- Shortages of gasoline
- Oil price spikes
- Food import dependency

However, not an easy to define and measure one...

Motivation

Supply security often associated to energy (oil, gas, electricity).
IEA's definition:

- Energy security is the uninterrupted availability of energy sources at an affordable price

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Yet other definitions are broader and encompass several dimensions (see e.g. Kruyt et al., 2009):

- Availability (physical/geographical)
- Accessibility (geopolitical elements)
- Affordability (price)
- Acceptability (social, environmental)

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$\Rightarrow$ Supply security is a multi-dimensional and context-dependent notion

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Supply security has a strong link to the notion of “diversity” $\Rightarrow$ broader relevance in economics:

- Hedge against “ignorance”
- Driver for innovation and growth

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Related applications:

- Finance: portfolio diversification
- International trade: foreign trade balance
- Agricultural economics: food security

Current measurement approaches

Four categories:

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Simple metrics:

- Import dependency, resource estimates, reserve-to-production ratios, etc.
- Limitations: one-dimensional crude assessments, narrow coverage

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Diversity-based indicators:

- Assessing diversification of supplier-mix with Shannon-Wiener or Herfindhal-Hirschamnn indexes. Extensions: accounting for self-sufficiency, political or transit risks, etc.
- Limitations: "static" diversification $\rightarrow$ disregarding potential substitution alternatives; no relation to market capability/capacity

Current measurement approaches

Analyses of short-term resilience:

- Model-based assessment: scenario analyses based on simulations or IEA's model: political/technical risk of disruption & system resilience
- Limitations: choices of scenarios, no integration of demand-side reaction

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EU's approach

- N-1 rule: capability to cope with disruption of largest infrastructure
- Limitations: static assessment $\rightarrow$ disregarding market dynamics, notably on the supply side (e.g. global shortage)

Methodology

We propose a novel approach to assess the supply security of network-based industries

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Our aims:

- Assessment tool for supply security
- Comprehensive view on supply security (multi-dimensional)
- Flexible approach: application to various network-based markets (energy, international trade, ...)
- Overcoming limitations of current methodologies

Methodology

Main principles:

- Putting the market in a stress situation (shock) and evaluating reaction its to the crisis (i.e. capability to cope with it) by measuring the impact on consumer surplus
- Shocks: interruption / collapse of the network components.
- Consumer surplus impact allows to cover both the quantity (deliveries interruption, consumer reaction, etc.) and price effect of the crisis.

Methodology

Relation to existing methodologies:

- Takes the market dynamics (demand & supply reaction) into account
- Multi-dimensional approach (4 A's)
- Broader stance than current methodolgies (blending diversification, system resilience, etc.)
- Probabilistic-like methodology

Methodology

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4. Evaluate the impact on consumer surplus in each iteration:

$$\phi_{i,n} = \frac{CS_n^{crisis}}{CS_n^{base}}$$

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4. Evaluate the impact on consumer surplus in each iteration:

$$\phi_{i,n} = \frac{CS_n^{crisis}}{CS_n^{base}}$$

5. Weight $\phi_{i,n}$ by a risk factor (political, technical, etc.; depending on each scenario) and build arithmetic mean:

$$\Phi_n = \frac{\sum_i^I \omega_i \, \phi_{i,n}}{\sum_i^I \omega_i}$$

Exemplary application

First application: European natural gas market

Our model:

- Partial equilibrium model depicting the main interactions along the supply chain
- Producers, pipeline & LNG transport, storage, disaggregated demand
- Worldwide coverage; seasonal dynamics; monthly resolution
- Calibration with market data for 2012-2014
- Accomodates both a short-term and medium-term perspective

Exemplary application

Three sets of shock scenarios and weighting:

- Technical pipeline failures (82): failure rate (length)
- Geopolitical pipeline failure (16): political stability index
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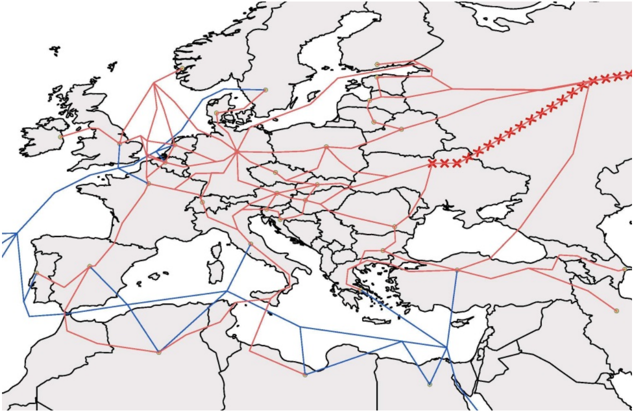
Time frame: for a thorough assessment, we run the scenarios in two different time frames (with corresponding elasticities):

- Short-term: 4 months, December to March
- Medium-term: 12 months, December to November

Exemplary application

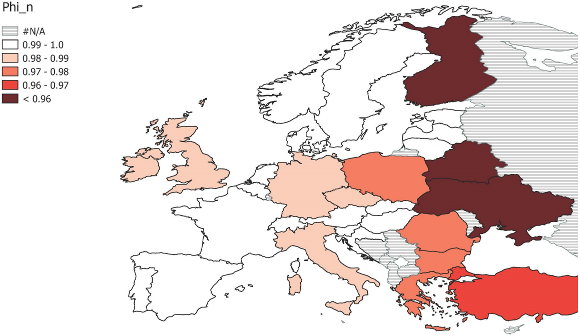
Example of shock: (geopolitical) interruption of network service: Russia-Ukraine pipeline disruption



Results I

Baseline results (short-term): $\Phi_n = \frac{\sum_i^I \omega_i \frac{CS_n^{crisis}}{CS_n^{base}}}{\sum_i^I \omega_i}$

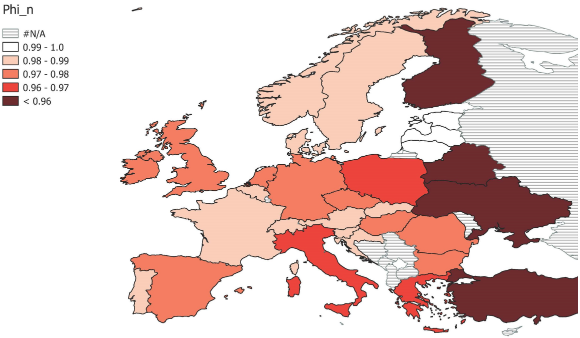
	Φ_n^{ST}
AUT	0.983
BEL	0.998
CHE	0.997
CZE	0.990
DNK	0.991
ESP	0.995
FIN	0.953
FRA	0.997
GBR	0.988
GER	0.989
GRC	0.975
IRL	0.987
ITA	0.989
NLD	0.991
POL	0.974
PRT	0.994
SWE	0.992
TUR	0.967
UKR	0.951
av.	*0.976*
std. dev.	*0.011*



Results I

Baseline results (mid-term): $\Phi_n = \frac{\sum_i^I \omega_i \frac{CS_n^{crisis}}{CS_n^{base}}}{\sum_i^I \omega_i}$

	Φ_n^{MT}
AUT	0.983
BEL	0.989
CHE	0.983
CZE	0.979
DNK	0.982
ESP	0.980
FIN	0.955
FRA	0.986
GBR	0.978
GER	0.976
GRC	0.969
IRL	0.973
ITA	0.964
NLD	0.979
POL	0.965
PRT	0.990
SWE	0.984
TUR	0.948
UKR	0.954
av.	*0.985*
std. dev.	*0.014*



Results I

Comparison with other indicators

Clustered values of Φ_n and of various supply security indicators: [1: worst achievable value $\rightarrow$ 5: best one]

	Φ_n	HHI	SWIN2	N-1
AUT	5	2	2	4
BEL	5	2	4	5
CHE	5	5	5	4
DNK	3	1	1	4
ESP	4	2	3	3
FIN	1	1	1	2
FRA	4	3	5	3
GBR	2	3	4	3
GER	3	4	5	5
GRC	2	5	3	1
IRL	2	4	5	4
ITA	2	5	4	2
POL	1	1	1	2
PRT	4	3	4	2
SWE	3	3	3	1
TUR	1	4	2	N/A
UKR	1	1	1	N/A

- For some countries: all four are rather unanimous (e.g. Finland, Poland, Switzerland, Ukraine). In other cases, some discrepancies.
- Between Φ_n and N-1: rather good alignment (e.g. Austria, Belgium, Greece) $\rightarrow$ largest difference: $+/-2$ (e.g. Ireland, Portugal, Sweden)

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GRC	2	5	3	1
IRL	2	4	5	4
ITA	2	5	4	2
POL	1	1	1	2
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TUR	1	4	2	N/A
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- Between Φ_n and N-1: rather good alignment (e.g. Austria, Belgium, Greece) $\rightarrow$ largest difference: $+/-2$ (e.g. Ireland, Portugal, Sweden)

$\Rightarrow$ All indicators do not measure the same things

Results II

Assessment of projects and policies

Testing currently discussed infrastructure projects and policies:

- Investment into LNG import capacity (currently planned terminals)
- Nord Stream 2
- Southern Gas Corridor
- Strategic reserve policy (minimum filling of 30 %)

Results II

Assessment of projects and policies

Testing currently discussed infrastructure projects and policies:

	Base	LNG	NrdStrm	SGC
AUT	0.983	0.983	0.989	0.983
BEL	0.989	0.989	0.994	0.989
CHE	0.983	0.983	0.990	0.984
DNK	0.982	0.983	0.983	0.983
ESP	0.980	0.980	0.982	0.982
FIN	0.955	0.955	0.954	0.955
FRA	0.986	0.985	0.991	0.987
GBR	0.978	0.978	0.982	0.978
GER	0.976	0.976	0.984	0.976
GRC	0.969	0.970	0.973	0.974
IRL	0.973	0.973	0.978	0.973
ITA	0.964	0.964	0.971	0.964
POL	0.965	0.966	0.972	0.966
PRT	0.990	0.989	0.990	0.990
SWE	0.984	0.986	0.985	0.985
TUR	0.948	0.950	0.951	0.969
UKR	0.954	0.954	0.955	0.955
av.	*0.974*	*0.974*	*0.977*	*0.976*

- Overall, low effect of infrastructure; NordStream 2 has the largest
- Effect on directly concerned countries (e.g. Turkey for SGC)

Results II

Special case strategic storage policy:

- So far: comparison within same “market conditions” (e.g. ConsSurpl. crisis with NordStream vs. ConsSurp no-crisis with NordStream)
- Storage obligation is welfare-decreasing policy (forces more storage than optimal)
- Storage obligation is released during crisis $\Rightarrow$ a crisis might be welfare enhancing!

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	w/in	across
AUT	1.035	0.996
BEL	1.011	0.998
CHE	1.013	0.999
DNK	1.053	0.992
ESP	0.995	0.998
FIN	0.957	0.989
FRA	1.025	0.997
GBR	1.001	0.989
GER	1.004	0.991
GRC	1.018	0.994
IRL	0.994	0.994
ITA	1.002	0.987
POL	0.991	0.990
PRT	0.996	0.999
SWE	1.068	0.999
TUR	0.984	0.989
UKR	0.996	0.974
av.	*1.008*	*0.993*

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$\Rightarrow$ Hence, comparison to "normal" base case? (i.e. "across")
$\Rightarrow$ But, "across" comparisons is an apples and pears comparison

Conclusions

We propose a novel methodology for the assessment of supply security

- Broader and more comprehensive approach (multi-dimensional)
- Overcoming limitations of current approaches, notably via incorporation of market dynamics
- Exemplary application to the European natural gas market and policy evaluation

Conclusions

Limitations of the methodology:

- Focusing on consumer surplus has a drawback: crisis might also cause increase of producer surplus. Hence, we might oversee an overall "positive" impact.
- For policy evaluation: within or across comparison?
- Generalization of methodology to non-energy markets (e.g. social networks, etc.) is still up for debate

Thank you for your attention!