What Do Sectoral Output and Price Data Say about Propagation of Oil Supply Shocks?

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Abstract

In this study, we analyse how gross output and price respond to oil supply shocks at the industry-level in the European countries. Using the consistent data from the EU KLEMS database, we establish a considerable variation in the sign and the magnitude of the industry responses. In particular, we find that many industries experience oil supply shocks mainly through the demand channels, and not through the traditional supply channels. Further, we investigate the role of the costs shares of energy and materials in explaining the pattern of industry responses. We reject the hypothesis that a higher energy share leads to a larger output decline after an adverse oil supply shock. Consistent with the previous literature, our results suggest that the diect cost channel is not the main channel through which oil shocks affect the economy. We also find some support the intermediate input channel.

Key words: oil shocks, sectoral output, sectoral price, KLEMS.

Introduction

This study contributes to the research agenda aimed at understanding the importance of production linkages across industries as an amplification and propagation mechanism of oil price shocks. Oil price shocks have been traditionally viewed as *supply side* phenomena. Yet, this view has been recently challenged. Following the work of Kilian (2009), a consensus has been emerging in the empirical literature that oil price changes have different origins. That is, the world oil prices respond to demand changes, not only reflect disruptions of oil supply. Further, oil shocks with different origins trigger distinct aggregate output and price responses.

At the industry level, the responses to oil price shocks are even more complex. Lee and Ni (2002) document a systematic pattern in industry responses in the US economy. These authors estimate the responses of industry gross output and prices to an exogenous oil price shock, identified within the structural vector autoregression framework. Lee and Ni (2002) find that an exogenous increase in the price of oil tends to decrease industrial production in all sectors, but to generate different price responses. In particular, prices tend to increase in more oil-intensive industries, but to decrease in less oil-intensive ones. It follows that in oil-intensive industries, like petroleum refineries and chemicals, oil price shocks act mostly like *supply shocks.* In contrast, less oil intensive industries, like the automobile industry, tend to experience oil price shocks as *demand shocks.*

Economic theory can provide an explanation for the observed heterogeneity in industry responses. An exogenous increase in the price of oil can affect output and prices in a particular industry through different channels (e.g. Hamilton 2008 and Kilian 2008). On the supply side, higher oil prices push up production costs of industries that use oil and energy (the direct cost channel). The higher energy costs can push the costs of energy-intensive intermediate inputs, thereby creating a secondary round of effects through the intermediate input channel (e.g. Linn 2009). Oil price changes can also generate demand effects by changing the patterns of consumers' and firms' expenditures on energy-sensitive products (e.g. Hamilton 2003 and Kilian 2009), as well as altering the input demands of energy-intensive producers. Whether a particular industry experiences oil price changes as a supply or as a demand shock will depend on the relative strengths of the different channels.

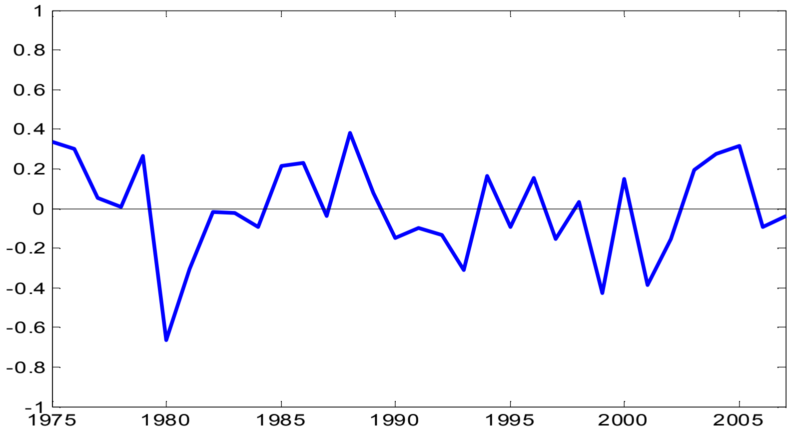
The current study investigates whether the pattern of industry responses to oil price shock, found in the US manufacturing industries, can be generalized to other industries and countries. Our focus is on the effects of supply shocks to the global oil market, constructed by Kilian (2009). We estimate the effects of these shocks on gross output and prices, using the consistent industry-level data from for the 24 industries of the 11 European countries. We classify the industry responses as mainly driven by supply or demand changes, depending on the signs of the peak output and price responses. We then examine how the peak responses depend on the industry-specific characteristics, such as production costs shares of energy and material inputs.

Data Description

Kilian (2009) proposed an explicit empirical model of the world market for crude oil. Using this model, he decomposed oil price changes into oil supply shocks, aggregate demand shocks, and oil-specific demand shocks. In this paper, we focus on oil supply shocks. To be consistent with the frequency of industry data, we construct measures of the annual shocks by averaging the monthly series of oil shocks from Kilian (2009). The resulting series is plotted on Figure 1.

The industry-level information is obtained from the KLEMS database for the European Union. The database is described in detail in O'Mahony & Timmer (2009). The database is accessible at http://www.euklems.net/. Our main series are the volume and the price indices of gross output. We also use the information on the costs of energy and material inputs, and the value of gross output to construct the shares of energy and materials in production.

Figure 1. Oil Supply Shock (1975-2007).



Notes: The series is constructed by averaging monthly oil supply shocks, identified by Kilian (2009).

The time period of observations included into EU KLEMS database varies by countries. We restrict the sample to 11 countries, for which the information is available for the longest period and for all series of our interest. The countries are: Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, and the United Kingdom. In addition, we restrict the analysis to the industries, reported for all countries in the sample. There are 24 industries in total. The industries include 11 manufacturing industries,[1] 11 service industries,[2] agriculture, hunting, forestry and fishing, and mining and quarrying. The sample runs from 1975 to 2005. The first period is restricted by the starting date of the series of oil supply shocks in Kilian (2009). The last period is determined by the last available year in the EU KLEMS database.

Empirical Methodology

The empirical methodology follows a two-step process. At the first stage, we estimate the responses of each industry's output and price to oil supply shocks. To this end, we follow the method similar to the one used by Kilian (2009) to estimate the empirical responses of real GDP and inflation. In particular, we project the growth rate of output and prices, $\Delta Y_{j,t}$ and $\Delta PY_{j,t}$ for each industry j, on the current and past values of oil supply shocks ε:

$$\Delta Y_{j,t} = a_j + b_{j0}\, \varepsilon_t + b_{j1}\, \varepsilon_{t-1} + b_{j3}\, \varepsilon_{t-2} + b_{j4}\, \varepsilon_{t-3} + b_{j5}\, \varepsilon_{t-4} + b_{j0}\, \varepsilon_{t-5} + u_{jt} \quad (1)$$

and

$$\Delta PY_{j,t} = c_j + d_{j0}\, \varepsilon_t + d_{j1}\, \varepsilon_{t-1} + d_{j3}\, \varepsilon_{t-2} + d_{j4}\, \varepsilon_{t-3} + d_{j5}\, \varepsilon_{t-4} + d_{j0}\, \varepsilon_{t-5} + v_{jt} \quad (2)$$

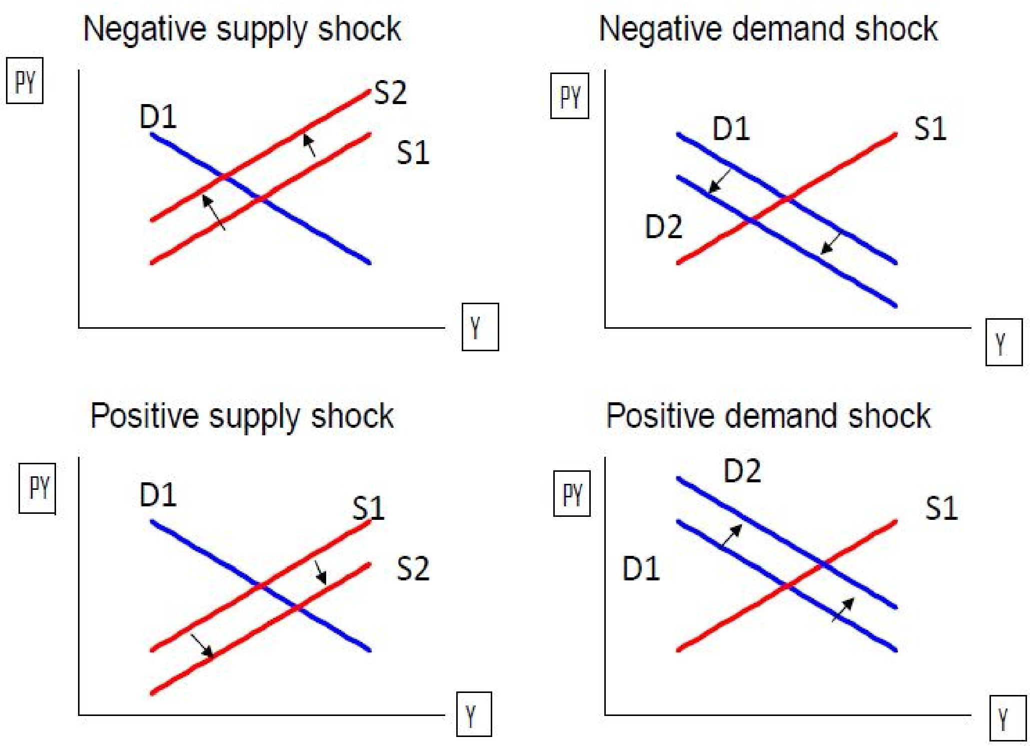
The error terms u_{jt} and v_{jt} are potentially serially correlated. The estimated coefficients in this regression model are used to construct the impulse responses of the levels of output and prices. We estimate the equations (1) and (2) by the ordinary least squares.

[1] FOOD, BEVERAGES AND TOBACCO; TEXTILES, TEXTILE, LEATHER AND FOOTWEAR; WOOD AND OF WOOD AND CORK; PULP, PAPER, PAPER, PRINTING AND PUBLISHING; CHEMICAL, RUBBER, PLASTICS AND FUEL; OTHER NON-METALLIC MINERAL; BASIC METALS AND FABRICATED METAL; MACHINERY, NEC; ELECTRICAL AND OPTICAL EQUIPMENT TRANSPORT EQUIPMENT; MANUFACTURING NEC & RECYCLING.

[2] ELECTRICITY, GAS AND WATER SUPPLY; CONSTRUCTION; WHOLESALE AND RETAIL TRADE; HOTELS AND RESTAURANTS; TRANSPORT AND STORAGE AND COMMUNICATION; FINANCIAL INTERMEDIATION; REAL ESTATE, RENTING AND BUSINESS ACTIVITIES; COMMUNITY SOCIAL AND PERSONAL SERVICES; EDUCATION; HEALTH AND SOCIAL WORK; OTHER COMMUNITY, SOCIAL AND PERSONAL SERVICES.

We then compute the peak responses of output and prices during the five year period following the oil supply shock. The signs of the output and price responses indicate whether oil supply shocks have mainly demand or supply effects in each industry. The intuition for our classification can be understood from Figure 2. This figure represents an equilibrium view on the industry's output and price determination. For simplicity, the diagrams are drawn for a single supply or demand shock. Thus, there are four possible combinations of the demand and supply effects on the industry's output and price. In the reality, of course, an oil supply shock will affect an industry through both the demand and supply channels, leading to shift in both the demand and supply curves. However, the observed peak responses will signal whether the demand or supply effects were dominant.

Figure 2. Industry Output and Price Responses to Demand and Supply Shocks.



If the adverse oil supply shock changes output and price of an industry in the same directions, we classify this industry as having the dominant demand effects. The demand effects are negative if the industry's output falls, and positive if output increases. If output and prices move in different directions, then the supply effects dominate in that industry. The supply effects are negative if output falls, and positive if output increases.

The second stage of the analysis aims at explaining the magnitude and the sign of the peak output and price responses. We link the estimated peak responses of output and prices to several variables. Frist, the energy share in total costs (eshare) represents the importance of energy in production. It is an indicator of the direct cost channel. Through the direct cost channel, we expect to find that industries with higher energy shares should experience a stronger decline in output after the increase in the prices of energy.

Second, an industry can experience negative supply effects through the intermediate input channel. An increase in the price of oil will push up prices of materials produced by oil-intensive industries. These higher material costs will increase production costs of downstream industries further, thereby amplifying the negative supply effects on production. For example, production of paper is energy-intensive. An oil price increase will increase the price of paper. The higher price of paper will in turn raise the production costs and lower output in the publishing industry that uses paper (e.g. Linn 2009). Ideally, one would like to have a measure of energy-intensity of the intermediate inputs, used by an industry to study the intermediate input channel. Unfortunately, the KLEMS database does not have this information. The database does report the value and the volume of the material inputs. In this study, we use the share of the intermediate material inputs in production costs as an imperfect indicator of the intersectoral linkages. This variable is denoted by mshare. Through the intermediate input channel, the higher share of material inputs should have a stronger impact on output responses.

Third, it has been argued in the literature that the reaction of central banks to oil price shocks can have significant impacts on propagation of oil shocks throughout the economy. This is because an increase in the oil price will like increase aggregate price level. The central bank, whose objective is to maintain price stability, can implement a pre-emptive contractionary monetary policy to curb down the expected inflation. In this study, we include a country-specific indicator to control for the country-specific characteristics, including the differences in the monetary policy regimes. Finally, we expect positive spillovers on other sectors from the energy-producing industries in the countries that are oil-exporters. In our sample, oil exporters include Denmark, Germany, Greece, the Netherlands and the United Kingdom.

To be precise, in the second stage of the analysis we consider two separate empirical models for output and prices:

$$\text{Peak } Y_i = \alpha_0 + \alpha_1 \text{ eshare}_i + \alpha_2 \text{ mshare}_i + \alpha_3 \text{ country}_i + \alpha_4 \text{ oil\_exporter}_i + \text{ey}_i \quad (3)$$

$$\text{Peak } PY_i = \beta_0 + \beta_1 \text{ eshare}_i + \beta_2 \text{ mshare}_i + \beta_3 \text{ country}_i + \beta_4 \text{ oil\_exporter}_i + \text{ep}_i \quad (4)$$

In each regression, we pool the peak responses of either output or prices across all the countries and all the industries (264 observations in total). We also consider the sample of manufacturing industries only (132 industry-country observations). For each sample, we estimate three regressions. The first two regressions include the energy share or the share of the material inputs alone. The last regressions include all four variables indicated in the equations (3) and (4).

Based on the equations (3) and (4), we test the following hypotheses:

1. Are output responses to oil supply shocks negatively related to the average energy share in production? That is, does higher energy share leads to a stronger output decline?
2. Are output responses negative related to the average share of the intermediate material inputs?
3. Do price responses systematically depend on the energy and materials shares?

The inference on the statistical significance of the regression coefficients is based on the heteroskedasticity and serial correlation robust variance-covariance matrix, based on the Newey-West estimator.

Finally, we use a product of the peak responses of output and prices as an indicator whether oil supply shocks are experienced as a supply or a demand phenomenon by a particular industry. Our goal is to test whether such effects are linked to the energy-intensity of production, as discussion in Lee and Ni (2002) may suggest. To this end, we estimate the regressions

$$\text{Peak } Y_i * \text{Peak } PY_i = \gamma_0 + \gamma_1 \text{ eshare}_i + \gamma_2 \text{ mshare}_i + \gamma_3 \text{ country}_i + \gamma_4 \text{ oil\_exporter}_i + \text{epy}_i \quad (5)$$

As it was the case with the models described by equations (3) and (4), we estimate (5) with the data for all industries, and for manufacturing industries alone.

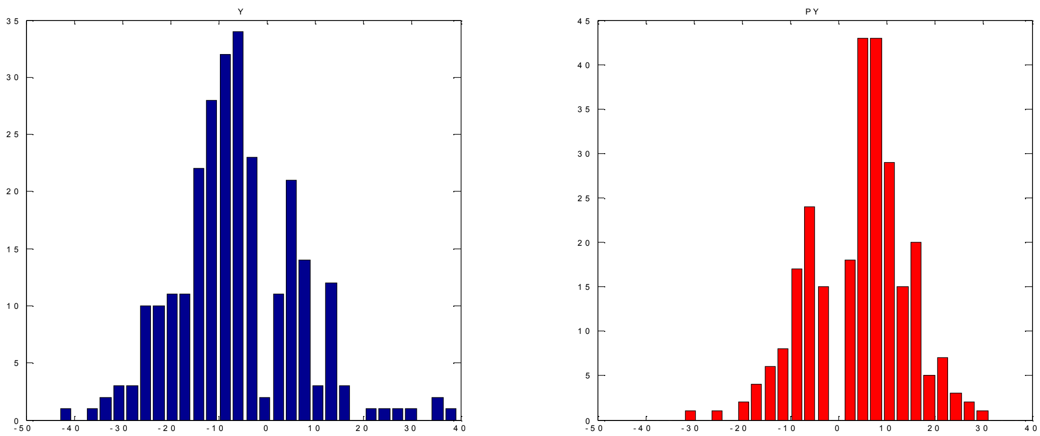
Results

In discussing the results, we first characterize the distribution of peak responses of output and prices to oil supply shocks across the pooled sample. We then turn to the analysis of the regression results from the second stage, based on the equations (3), (4) and (5).

Distribution of Output and Price Responses

Figure 3 plots the histogram of the estimated peak responses of output (the left panel) and prices (the right panel). This figure demonstrates a significant variation in the sign and the magnitude of the industry responses. Table 1 reports the statistics, characterizing the joint behavior of output and prices. We find that a majority of industries (73%) experience a decline in production after the adverse oil supply shock. However, the decline in output is largely driven by the supply changes only in 53% of the industries. The other 20% of the industries experience negative demand effects, which lead to a fall in the output price. Somewhat surprisingly, 27% of the industries benefit from the adverse oil shock, either through demand or supply channels. It should be noted that many of these cases occur in oil-exporting countries, and in the service sectors.

Figure 3. Histogram of Peak Output and Price Responses.



Notes: The peak responses of industrial gross output (the left panel) and price (the right panel) are estimated by the author, based on the sample of 264 industry-country observations.

Table 1. Classification of Industry Responses to an Adverse Oil Supply Shocks.

Negative supply effects: ↓Y, ↑P **141 cases (53%)**	Negative demand effects : ↓Y, ↓P **52 cases (20%)**
Positive supply effects: ↑ Y, ↓ P **26 cases (10%)**	Positive demand effects: ↑ Y, ↑ P **45 cases (17%)**

Explaining Peak Output and Price Responses

Table 2 and 3 summarize the estimation results for the equations (3) and (4).

The first observation to note is that there is a strong rejection of the hypothesis that the direct cost channel plays an important role in explaining industry responses to oil shocks. In the multi-variate specification (column 3 of Table 2), the energy share is not significant in the sample of all industries. In other specifications, the energy share has a positive impact on output responses. The absence of the strong links between the energy share and the peak output responses is consistent with the previous findings in the literature. For example, Lee and Ni (2002) find that the automobile industry, which is relatively small oil share, has experienced the largest decline in output during the oil crises of the 1970s and during the post 1970s period overall. Table 3 indicates that the energy share is not important in explaining the peak price responses at all. Thus, our results with respect to the energy share confirm the consensus in the literature that one needs to go beyond the direct production cost channel to understand how oil shocks affect the economy.

The second observation relates to the role of the share of the intermediate material inputs. This captures the strength of the interesectoral input-output linkages, to some degree. If it is positively correlated with the energy-intensity of the intermediate inputs, then higher values of this share should have a stronger negative impact on output. This is exactly the result that we find for the overall sample of industries. However, it should be noted that the explanatory power of the "mshare" variable, as measured by Rbar2 statistics is very small. Our results suggest that a better indicator of the energy-intensity of the intermediate inputs is required to identify more precisely the role of the intermediate input channel in propagation of oil supply shocks. Constructing such indicators may be possible from the detailed input-output tables produced by individual countries.

Finally, the results in Tables 2 and 3 point to the importance of the country-specific indicator and of the indicator whether or not a country is an oil-exporter. The "country" variable has a positive impact on the prices and output in the pooled industry sample. However, it has a negative impact on the output of manufacturing industries, and no significant impact on manufacturing prices. To the extent that the "country" variable proxies the effects of the monetary policy, the results can be interpreted to indicate that the real effects of oil shocks on the economy may be of a greater concern to the policy makers relative to their effects on inflation. The "oil-exporter" variables matters significantly in explaining the price responses, but not output responses. In particular, the oil-exporting countries tend to have falling industry prices, with the larger effects present in the sample of the manufacturing industries.

Demand versus Supply Effects

Table 4 reports the estimation results, based on the equation (5). The dependent variable in this specification is the product of the peak responses of output and prices. If this variable is negative, the industry experiences oil supply shocks mainly as supply shocks. If this variable is positive, then the oil supply shocks act mostly like demand shocks. Note that this approach does not allow us to separate negative and positive demand and supply effects.

The only variable that is statistically significant in the pooled sample of all industries is the country-specific indicator. It suggests that oil supply shocks act like supply shocks on an average industry in a country, moving output and prices in the opposite directs. This is consistent with the statistics in Table 1. More interesting conclusions can be made about the sample of manufacturing industries. Our results suggest that manufacturing industries with higher energy share and higher share of the material inputs tend to experience oil supply shocks through demand channels. This conclusion differs from the hypothesis of Lee and Ni (2002), based on the selected US manufacturing industries.

Table 2. Peak Output Responses.

	Y, All industries			Y, Manufacturing industries		
eshare	12.12*		9.99	13.99*		35.20**
	(1.70)		(1.43)	(1.76)		(2.22)
mshare		-11.18***	-9.24**		-4.369	18.61
		(-2.50)	(-2.14)		(-0.56)	(1.37)
country			0.67***			-0.72**
			(-3.45)			(-2.34)
oil_exporter			1.39			0.45
			(0.84)			(0.19)
Rbar2	0.003	0.026	0.057	0.008	-0.01	0.033
DW stat	1.96	2.02	2.07	2.04	2.04	2.13
Nobs	264	264	264	132	132	132

The table reports the estimated coefficients with t-statistics, computed with the Newey-West heteroskedasticity and serial correlation robust variance-covariance. The starts ***, ** and * indicate the significance at the 1%, 5% and 10%. All specifications include constant (not reported).

Table 3. Peak Price Responses.

	PY, All industries			PY, Manufacturing industries		
eshare	17.64		15.93	9.89		-13.60
	(1.56)		(1.59)	(0.85)		(-0.80)
mshare		2.04	1.97		-5.77	-19.79*
		(0.60)	(0.59)		(-0.82)	(-1.85)
country			0.64***			1.10
			(3.63)			(5.00)
oil_exporter			-4.84***			-7.35***
			(-3.77)			(-4.08)
Rbar2	0.018	-0.002	0.101	0.005	-0.001	0.187
DW stat	1.84	1.80	1.90	1.87	1.84	1.91
Nobs	264	264	264	132	132	132

The table reports the estimated coefficients with t-statistics, computed with the Newey-West heteroskedasticity and serial correlation robust variance-covariance. The starts ***, ** and * indicate the significance at the 1%, 5% and 10%. All specifications include constant (not reported).

Table 4. Joint Responses of Output and Prices.

	Y*PY All industries			Y*PY, Manufacturing		
eshare	0.31		0.37	0.73		3.01**
	(0.48)		(0.54)	(0.99)		(2.27)
mshare		-0.47	-0.33		-0.07	2.01*
		(-1.49)	(-0.99)		(-0.11)	(1.86)
country			-0.06***			-0.07***
			(-2.92)			(-3.92)
oil_exporter			0.21			0.22
			(1.50)			(1.37)
Rbar2	-0.003	0.005	0.045	-0.001	-0.008	0.059
DW stat	1.86	1.88	1.96	1.89	1.90	1.90
Nobs	264	264	264	132	132	132

The table reports the estimated coefficients with t-statistics, computed with the Newey-West heteroskedasticity and serial correlation robust variance-covariance. The starts ***, ** and * indicate the significance at the 1%, 5% and 10%. All specifications include constant (not reported).

Conclusion

In this study, we have analysed how gross output and price respond to oil supply shocks at the industry-level in the European countries. Using the consistent data from the EU KLEMS database, we have established a considerable variation at the industry level. In particular, we have found that many industries experience oil supply shocks as *demand* type, and *not* as a *supply* type phenomenon.

We have also investigated the importance of the costs shares of energy and of the intermediate material inputs in explaining the pattern of industry output and price responses. We have rejected the hypothesis that a higher energy share leads to a larger output decline after an adverse oil supply shock. Consistent with the previous literature, our results suggest that the diect cost channel is not the main channel through which oil shocks affect the economy.

We have found some support for the role of the intermediate input channel. In particular, in the pooled industry-country sample of industries, the material input was negatively and significantly related to the peak output responses. However, the explanatory power of this variable was rather low. Our results suggest that a better indicator of the energy-intensity of the intermediate inputs is required to identify more precisely the role of the intermediate input channel in propagation of the energy supply shocks. Constructing such indicators may be possible from the detailed input-output tables produced by individual countries.

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