

Critical Minerals: Estimating Price Elasticity of Supply Using Mine-Level Data

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Introduction

IEA (2021) : Limiting global warming to $+2^{\circ}\text{C}$ requires a $\times 4$ increase in demand for critical minerals by 2040 \Rightarrow need for an increase in mineral supply, both in the short- and long-run.

Medium- to long-run : Main determinants of supply are geological discoveries and technological innovation.

Short-run : Importance of price elasticity of supply and ability of mines to adapt their production.

\Rightarrow What is the short-run impact of global price shocks on critical mineral supply ?

Related Literature

Large interest in the 1970s-1980s for mineral supply elasticity :
Fisher et al. (1972), Suan Tan (1977), Chhabra et al. (1979),
Fisher & Owen (1981), Gupta (1982)... but shift in interest towards
demand elasticity since the early 2000s.

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Very few recent articles :

- Fernandez (2019) : bauxite, copper, lead, nickel, tin, and zinc.
 - Boer et al. (2024) : copper, nickel, cobalt, and lithium.
 - Bogmans et al. (2024) : copper, lead, tin, and zinc.
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However, all used **macroeconomic data** \Rightarrow risk of an “aggregation bias” (as identified by Bjørnland et al., 2021, for oil supply).

Results and Contribution

Focus of the study :

- 8 minerals defined as critical for the energy transition : cobalt, copper, lead, molybdenum, nickel, platinum, silver, and zinc.
- We distinguish global price shocks from mineral demand driven price shocks (following Boer et al., 2024).
- Mine-level data for 318 mines in 43 countries over 2000-2019.
- We investigate the determinants of supply elasticity.

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- We investigate the determinants of supply elasticity.

Main Results :

- Price elasticity ranging from 0.5 to 1 in the baseline setting.
- The impact of the shock is largest after 3 years.
- High heterogeneity across minerals and mine characteristics.

Mine-Level Data (1)

Main raw dataset : Jasansky et al. (2023) \Rightarrow annual mineral production for 1,171 mines and 80 minerals over 2000-2020.

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We keep only minerals that respect three criteria :

- 1 Defined as “strategic” for the energy transition in at least one of the two lists (World Bank, 2020 ; IEA, 2021).
- 2 With ≥ 50 observations in the dataset.
- 3 Data represent $\geq 20\%$ of total global production (US Geological Survey).

Finally, we drop the year 2020 (Covid-19).

Mine-Level Data (2)

Main refined dataset : Annual mineral production (in tons) for :

- 8 minerals : copper (34.3% of sample), silver (23.2%), zinc (13.9%), lead (10.2%), nickel (8.1%), molybdenum (4.4%), platinum group metals (4.1%), and cobalt (1.7%).
- 318 mines located in 43 countries.
- 6,068 observations at the mine-mineral-year level.

▶ Descriptive statistics

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We also include additional variables for robustness/heterogeneity :

- Reserves by mines (ETM dataset).
- Geo-localization of conflicts (UCDP GED).
- Gridded GDP (Kummu et al., 2018).
- Geo-localization of transport infrastructure (UNECE).
- Existence of export restrictions (OECD).

Global Series

Global annual series between 1912 and 2019 :

- Global annual production for each mineral (US Geological Survey).
- Real global price for each mineral \Rightarrow ratio of nominal global mineral price (USGS) to US CPI (Officer, 2025).
- Real global GDP (Jacks and Stuermer, 2020 ; and IMF data).

All series are normalized to 100 in 1912.

Step 1 : Isolating Mineral-Specific Demand Shocks

We follow Boer et al. (2024) and build for each mineral a structural VAR which includes : (i) real global activity, (ii) global mineral production, and (iii) real global mineral price.

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We then identify 3 types of shocks through sign restrictions :

	Real global GDP	Global mineral production	Real mineral price
Aggregate demand shock (AS)	+	+	+
Mineral-specific supply shock (MS)	+	+	-
Mineral-specific demand shock (MD)	-	+	+

Step 1 : Isolating Mineral-Specific Demand Shocks

We can decompose real mineral prices as :

$$\ln P_{jt} = ad_{jt}^P + ms_{jt}^P + md_{jt}^P + r_{jt}^P \quad (1)$$

with :

- P_{jt} the real global price of mineral j at time t
- ad_{jt}^P the contribution of aggregate demand shocks to P_{jt}
- ms_{jt}^P the contribution of mineral-specific supply shocks to P_{jt}
- md_{jt}^P the contribution of mineral-specific demand shocks to P_{jt}
- r_{jt}^P the residual

▶ Graphs

Step 2 : Estimating Price Elasticity of Supply

Using the local projection approach (Jordà, 2005), we can estimate the reaction of mineral production between $t-1$ and $t+h$ to a global price variation occurring between $t-1$ and t (baseline regression) :

$$\Delta_h Q_{ijt} = \alpha_h + \theta_h \Delta_0 md_{jt}^P + \rho_t + \mu_{ij} + \omega_{ijt} \quad (2)$$

with :

- Δ_h the operator indicating the difference in a variable between $t-1$ and $t+h$. Here we select $h = [0,5]$
- Q_{ijt} the quantity of mineral i produced in mine j at time t
- md_{jt}^P the mineral specific demand shock estimated in (1)
- ρ_t the year fixed-effects
- μ_{ij} the mine-mineral fixed-effects

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- 2 The cumulated impact of a mineral-demand shock on mineral supply (“horizon-h projection”) :

$$\Delta_h \ln Q_{ijt} = \alpha_h + \tilde{\theta}_h \Delta_h md_{jt}^P + \rho_t + \mu_{ij} + \omega_{ijt} \quad (4)$$

Baseline Results

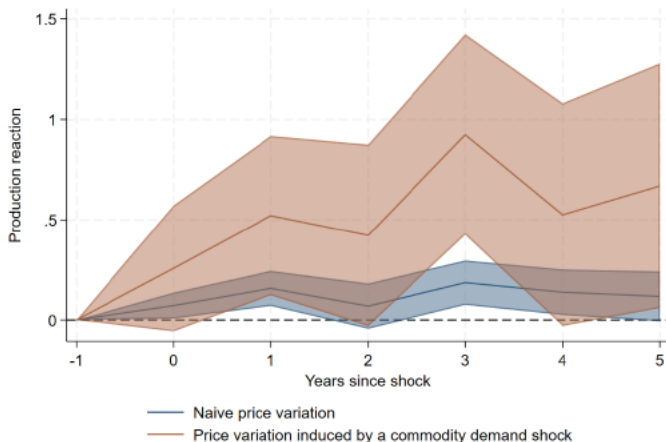
Table 1 – Impact of price shocks on mineral supply at different horizons

	Naive regression	Baseline regression	Horizon-h projection
h=0	0.071* (0.039)	0.258 (0.191)	0.258 (0.192)
h=1	0.157*** (0.053)	0.521** (0.242)	0.595** (0.277)
h=2	0.069 (0.060)	0.422 (0.276)	0.716 (0.470)
h=3	0.186*** (0.067)	0.924*** (0.304)	1.450*** (0.484)
h=4	0.138** (0.069)	0.525 (0.338)	0.848 (0.552)
h=5	0.117 (0.075)	0.669* (0.371)	1.571* (0.886)

Note : Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Baseline Results

Figure 1 – Average production reaction to mineral price shocks



Robustness

Table 2 – Mineral supply response to a mineral-specific demand shock

Horizon	Control for cotton in VAR	Control for trends in VAR	Control for mineral supply shocks	Keep if ≥ 5 years of obs.	Drop market making countries	Control for chinese imports	Drop booms and busts
h=0	0.150 (0.186)	0.199 (0.184)	0.222 (0.204)	0.630** (0.286)	0.424* (0.255)	0.234 (0.191)	0.342 (0.268)
h=1	0.649*** (0.243)	0.493** (0.239)	0.458* (0.250)	0.813*** (0.338)	0.667** (0.316)	0.494** (0.244)	0.408 (0.300)
h=2	0.247 (0.264)	0.389 (0.270)	0.446 (0.280)	0.533 (0.342)	0.435 (0.339)	0.385 (0.274)	0.302 (0.329)
h=3	0.703** (0.296)	0.938*** (0.301)	0.897*** (0.307)	1.002*** (0.352)	1.094*** (0.366)	0.878*** (0.306)	1.076*** (0.384)
h=4	0.524 (0.331)	0.597* (0.329)	0.496 (0.346)	0.449 (0.362)	0.642 (0.424)	0.483 (0.340)	0.808* (0.428)
h=5	0.641* (0.389)	0.759** (0.368)	0.649* (0.379)	0.669* (0.371)	0.738* (0.447)	0.628 (0.371)	0.951* (0.492)

Note : Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Heterogeneity : Type of Mineral

Table 3 – Mineral-Specific Estimation Results

Horizon	Cobalt	Copper	Lead	Molyb.	Nickel	PGM	Silver	Zinc
h=0	0.067 (0.469)	1.298* (0.697)	-0.788 (0.603)	0.502 (0.405)	-0.109 (0.637)	-0.447* (0.239)	0.782* (0.467)	0.242 (0.487)
h=1	-0.198 (0.849)	0.750 (0.855)	-0.799 (0.820)	0.413 (0.536)	0.893 (0.846)	-0.190 (0.301)	1.398*** (0.535)	0.554 (0.557)
h=2	0.857 (1.271)	0.300 (0.779)	-0.934 (0.835)	0.360 (0.590)	1.331 (1.096)	0.212 (0.527)	1.080* (0.585)	0.151 (0.644)
h=3	3.458* (1.956)	1.785** (0.826)	-0.824 (0.869)	0.575 (0.630)	2.150** (1.012)	0.333 (0.607)	1.431** (0.663)	0.691 (0.633)
h=4	2.864 (2.122)	-0.010 (1.039)	-1.184 (0.989)	0.408 (0.590)	3.461*** (1.062)	-0.438 (0.563)	0.988 (0.834)	0.538 (0.668)
h=5	2.155 (2.036)	1.669* (0.894)	-1.175 (1.198)	0.332 (0.707)	2.837** (1.258)	-0.252 (0.508)	1.303 (0.851)	0.219 (0.742)
Share of obs.	2%	34%	10%	4%	8%	4%	23%	14%
Nb of obs.	105	2,084	616	270	494	250	1,405	844

Note : Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Heterogeneity : Mine and Market Characteristics

Table 4 – Heterogeneity Results at Horizon h=1

Interaction variable	Characteristics of the mine						
	The mine produces only 1 minerals	The mine produces 1 or 2 minerals	The mineral is the main of the mine (in volume)	The mineral is the main of the mine (in value)	The mine is held by a single firm	High mineral reserves	Small producers
Shock	1.533** (0.775)	1.149** (0.516)	0.149 (0.256)	0.073 (0.280)	-0.240 (0.367)	1.389** (0.569)	0.617* (0.345)
Shock # interaction	-1.179 (0.807)	-0.958* (0.564)	1.041** (0.509)	1.051** (0.478)	1.221* (0.618)	-1.507** (0.677)	-0.187 (0.481)
N	4,747	4,747	4,747	4,747	3,107	2,467	4,747
Type Time-varying	Characteristics of the interaction variable						
	Binary No	Binary No	Binary No	Binary No	Binary No	Binary No	Binary No

Note : Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Conclusion

Main results :

- Larger price elasticity of supply than in previous studies, suggesting a possible aggregation bias.
- High heterogeneity across minerals, the results being mainly driven by copper, nickel, and silver.
- High heterogeneity across mines, depending on their characteristics and on mineral markets.

Conclusion

Thank You for Your Attention !

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Descriptive Statistics

Table 6 – Observations by mineral and country (revised dataset) [▶ Back](#)

Mineral	Obs.	Mines	Three Main Countries
Copper	2,084	195	Chile (18.2%) Canada (13.2%) Peru (11.1%)
Silver	1,405	163	Peru (24.2%) Mexico (14.7%) Kazakhstan (10.4%)
Zinc	844	90	Peru (20.1%) Mexico (14.4%) Australia (10.1%)
Lead	616	65	Peru (27.9%) Mexico (19.6%) Australia (13.0%)
Nickel	494	45	Canada (40.3%) Russian Fed. (10.5%) South Africa (8.7%)
Molybdenum	270	21	Chile (36.7%) Peru (27.4%) USA (21.9%)
PGM	250	16	South Africa (71.2%) Russian Fed. (11.2%) Canada (7.2%)
Cobalt	105	12	DR Congo (36.2%) Cuba (19.1%) South Africa (14.3%)

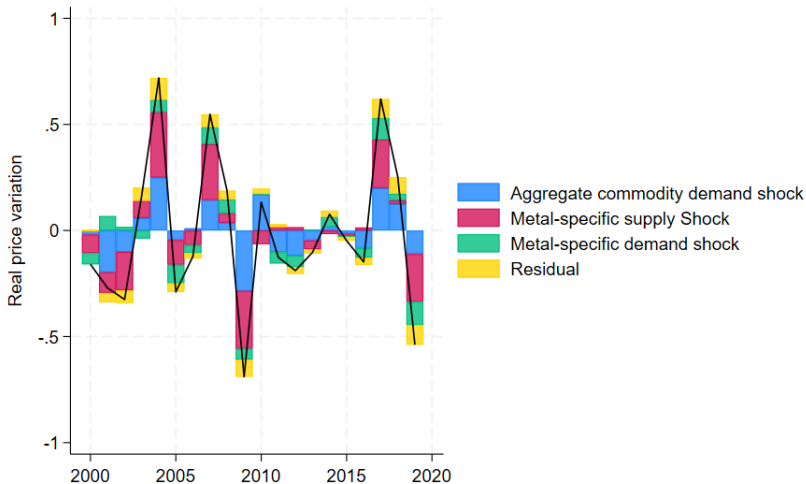
Data sources

Table 7 – List of sources by variable [▶ Back](#)

Variable	Source
Mineral production by mine	Jasansky et al. (2023)
Global mineral production	US Geological Survey
Real global mineral prices	US Geological Survey; Officer (2025)
Real global GDP	Jacks and Stuermer (2020); IMF
Real cotton prices	Jacks and Stuermer (2020); IMF
Reserves	Owen et al. (2022)
Geolocalized conflict	UCDP Georeferenced Event Dataset
Gridded GDP data	Kummu et al. (2018)
Geolocalized transport infra.	UNECE-LOCODE
Export restrictions	OECD industrial raw materials restrictions

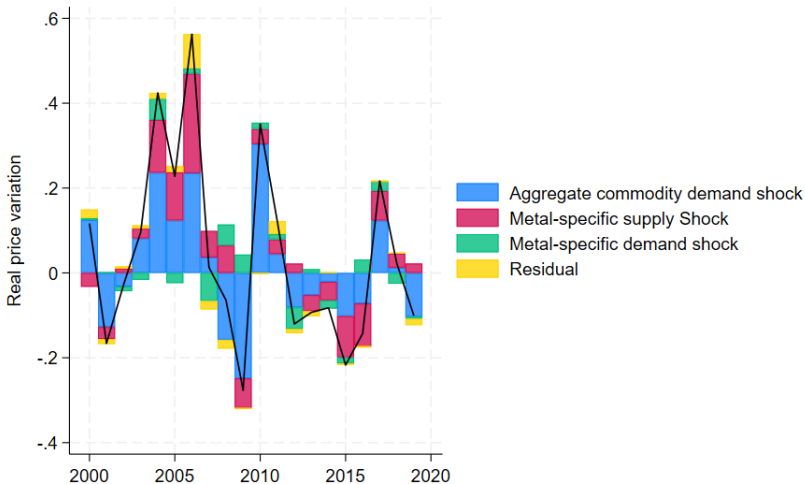
Decomposition of the real price variation (2000-2019)

Figure 2 – Evolution of the price of cobalt [▶ Back](#)



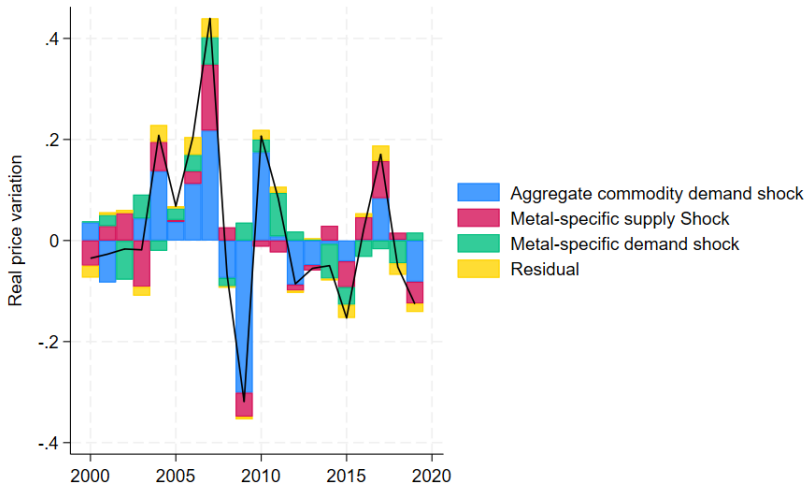
Decomposition of the real price variation (2000-2019)

Figure 3 – Evolution of the price of copper [▶ Back](#)



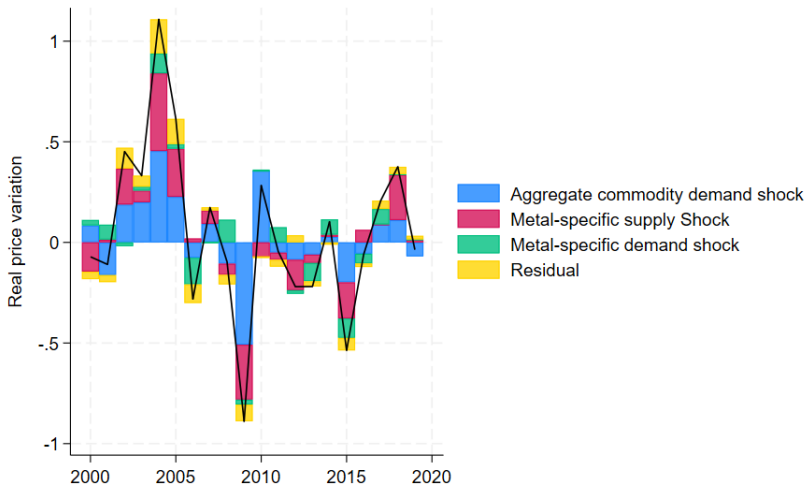
Decomposition of the real price variation (2000-2019)

Figure 4 – Evolution of the price of lead [▶ Back](#)



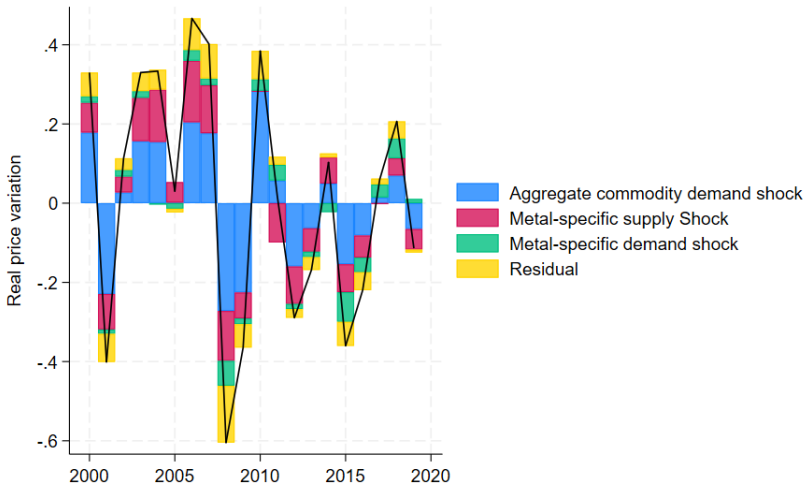
Decomposition of the real price variation (2000-2019)

Figure 5 – Evolution of the price of molybdenum [▶ Back](#)



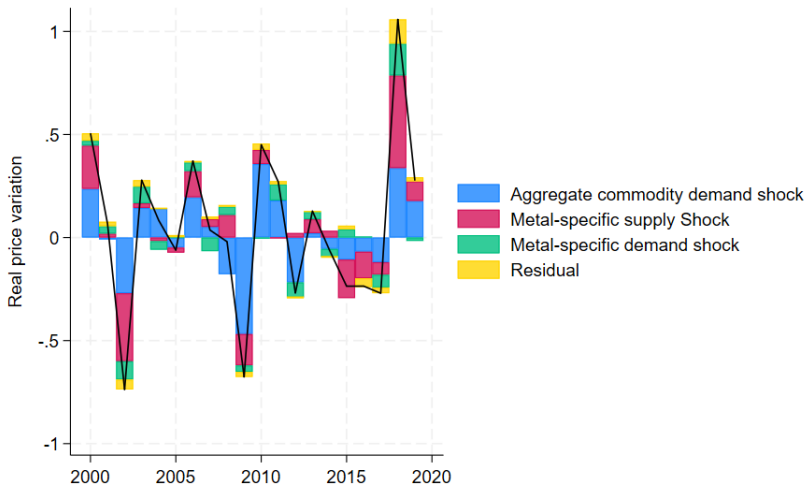
Decomposition of the real price variation (2000-2019)

Figure 6 – Evolution of the price of nickel [▶ Back](#)



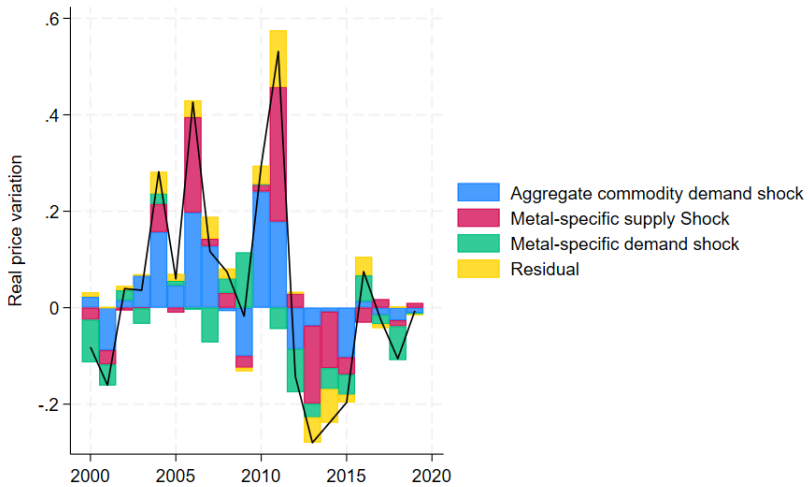
Decomposition of the real price variation (2000-2019)

Figure 7 – Evolution of the price of platinum-group-metals [▶ Back](#)



Decomposition of the real price variation (2000-2019)

Figure 8 – Evolution of the price of silver [▶ Back](#)



Decomposition of the real price variation (2000-2019)

Figure 9 – Evolution of the price of zinc [▶ Back](#)

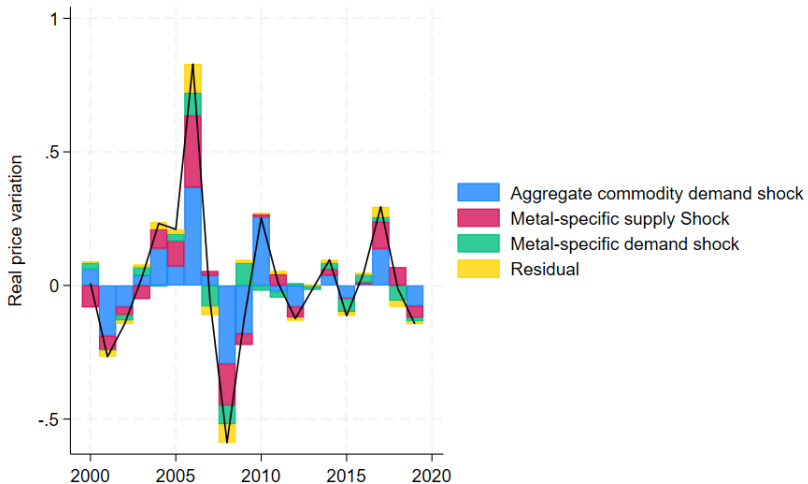


Table 8 – Heterogeneity Results at horizon h=3 [▶ Back](#)

Interaction variable	Characteristics of the mine						
	The mine produces only 1 minerals	The mine produces 1 or 2 minerals	The mineral is the main of the mine (in volume)	The mineral is the main of the mine (in value)	The mine is held by a single firm	High mineral reserves	Small producers
Shock	2.209** (0.971)	1.963*** (0.516)	0.512 (0.326)	0.419 (0.343)	0.405 (0.485)	1.535** (0.655)	0.814** (0.395)
Shock # interaction	-1.501 (0.992)	-1.579** (0.624)	1.084* (0.589)	1.257** (0.571)	1.329* (0.690)	-1.001 (0.702)	0.229 (0.548)
N	3,662	3,662	3,662	3,662	2,432	1,950	3,662
Type Time-varying	Characteristics of the interaction variable						
	Binary No	Binary No	Binary No	Binary No	Binary No	Binary No	Binary No

Note : Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 9 – Heterogeneity Results at horizon h=3 (continued) [▶ Back](#)

Interaction variable	Location of the mine					Market characteristics	
	Distance to closest conflict in t-1 (km)	Log GDP in t-1	GDP change in the 5 previous years	Distance to closest transport infra. (km)	Mine is in Africa	Herfindahl-Hirschmann Index	New global restrictions on exports in t-1
Shock	0.408 (0.451)	2.052 (1.425)	1.401** (0.451)	0.778** (0.367)	0.868*** (0.319)	1.092*** (0.388)	0.739 (0.645)
Interaction variable	-0.0001** (0.0000)	0.020 (0.137)	0.145 (0.127)			0.0000 (0.0000)	-0.002* (0.001)
Shock # interaction	0.0004 (0.0003)	-0.069 (0.087)	-3.013 (2.255)	0.002 (0.002)	0.640 (0.954)	-0.0001 (0.0001)	-0.009 (0.020)
N	3,617	3,385	3,385	3,617	3,662	3,662	2,063
Characteristics of the interaction variable							
Type	Continuous	Continuous	Continuous	Continuous	Binary	Continuous	Continuous
Time-varying	Yes	Yes	Yes	No	No	Yes	Yes

Note : Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 10 – Heterogeneity Results at Horizon h=5 [▶ Back](#)

Interaction variable	Characteristics of the mine						
	The mine produces only 1 minerals	The mine produces 1 or 2 minerals	The mineral is the main of the mine (in volume)	The mineral is the main of the mine (in value)	The mine is held by a single firm	High mineral reserves	Small producers
Shock	1.585 (1.270)	1.728** (0.738)	0.147 (0.388)	-0.009 (0.413)	-0.0137 (0.555)	0.815 (0.802)	0.274 (0.505)
Shock # interaction	-1.058 (1.286)	-1.588** (0.777)	1.363* (0.716)	1.656** (0.680)	1.085 (0.821)	-0.344 (0.871)	0.869 (0.658)
N	2,717	2,717	2,717	2,717	1,847	1,488	2,717
Type Time-varying	Characteristics of the interaction variable						
	Binary No	Binary No	Binary No	Binary No	Binary No	Binary No	Binary No

Note : Robust standard errors are in parentheses. * p<0.10, ** p<0.05, *** p<0.01.

Table 11 – Heterogeneity Results at Horizon h=5 (continued) [▶ Back](#)

Interaction variable	Location of the mine					Market characteristics	
	Distance to closest conflict in t-1 (km)	Log GDP in t-1	GDP change in the 5 previous years	Distance to closest transport infra. (km)	Mine is in Africa	Herfindahl-Hirschmann Index	New global restrictions on exports in t-1
Shock	-0.107 (0.558)	1.224 (1.661)	0.865* (0.512)	0.691 (0.440)	0.758* (0.392)	1.063** (0.462)	-0.249 (0.787)
Interaction variable	-0.00001*** (0.00003)	0.012 (0.174)	-0.093 (0.141)			(0.0001*** (0.0000))	-0.001 (0.002)
Shock # interaction	0.0006* (0.0004)	-0.037 (0.101)	-1.481 (2.534)	-0.000 (0.003)	-0.951 (1.096)	-0.0003** (0.0001)	0.045 (0.030)
N	2,699	2,699	2,699	2,699	2,717	2,717	1,249
Characteristics of the interaction variable							
Type	Continuous	Continuous	Continuous	Continuous	Binary	Continuous	Continuous
Time-varying	Yes	Yes	Yes	No	No	Yes	Yes

Note : Robust standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.