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Copper's Double-Edged Sword: Asymmetric Impact on Taiwan's Stock Market

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Abstract
This paper provides empirical evidence of asymmetric impacts of copper futures on Taiwan's stock indices. Using the Nonlinear Autoregressive Distributed Lag model, we reveal that initially negative impact of copper futures transitions into positive influence in the long term. Lithium prices contribute to short-term dynamics with inconsistencies and lagged effects but do not have significant long-term influence.

Keywords: Asymmetry, Commodity Prices, Stock Market Returns, Taiwan, NARDL
JEL classification: F41, G10, C32

Introduction
Recent commodity price fluctuation emphasizes its effect on stock market returns, especially for advanced open economies dependent on commodity imports. Taiwan aptly exemplifies such an economy: Taiwan Semiconductor Manufacturing Company (TSMC) is a global semiconductor powerhouse that contributes 15% to Taiwan's GDP (The Economist, 2023) and 38.4% to its export revenue (Ai and Huang, 2023). High-tech industries heavily rely on critical commodities like copper and lithium. Copper is a pivotal component in electrical wiring and electronic devices (Transparency Market Research, 2023), while lithium in lithium-ion batteries powers a broad range of electronic devices and electric vehicles (Garside, 2023). Consequently, changes in commodity prices could substantially affect Taiwan's economy via its tech sector.

Prior research (Guo, 2018; Kang et al., 2019) validates copper prices' influence on stock performance. However, the exploration of asymmetric effects is lacking, barring a few studies of the Chinese (Hu et al., 2017) and Mongolian markets (Badamvaanchig et al., 2021). This study bridges this gap, examining the asymmetric impact of copper price changes on stock market returns, a critical yet understudied aspect in commodity-dependent, high-tech export economies. Taiwan's case is particularly instructive, given its dominance in semiconductor material purchases with 27.6% of global spending (Chang and Huang, 2023) and being a leading exporter of semiconductors, with TSMC accounting for 58.5% of the global semiconductor foundry market (Alsop, 2023).

Data
Our dataset includes monthly prices for Copper Futures (CF), Taiwan Stock Exchange Capitalization Weighted Stock Index ($TWII$), Taipei Exchange 50 Index ($TPEX50$), and Lithium carbonate 99% purity ($Li99$) spot prices. The data spans from June 2009 to May 2023 for copper futures, TWII, and lithium carbonate prices, and from June 2010 to May 2023 for TPEX. To ensure consistency, all values have been converted to United States Dollars (USD) and the models were estimated within the timeframe from June 2010 to May 2023. The data was obtained from investing.com. Additionally, we sourced Consumer Price

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Indices (CPI) with a base year of 2021 (equivalent to 100) from the National Statistics of Taiwan. A statistical summary of logged variables and exchange rates is provided in Table 1.

Table 1
Descriptive statistics

	$ln(TPEX50)$	$ln(TWII)$	$ln(CF)$	$ln(Li99)$	$ln(CPI)$	USD_TWD	USD_CNY
Mean	1.74	5.80	1.15	9.24	4.56	30.32	6.57
Median	1.69	5.73	1.14	8.84	4.56	30.29	6.57
Maximum	2.41	6.49	1.56	11.28	4.66	33.48	7.30
Minimum	1.35	5.28	0.72	8.44	4.49	27.52	6.05
Std. Dev.	0.23	0.29	0.21	0.79	0.04	1.34	0.30
Skewness	0.94	0.83	-0.04	1.11	0.18	0.07	0.15
Kurtosis	3.37	2.82	2.29	3.23	2.50	2.58	1.94
Jarque-Bera	24.05	19.65	3.53	35.07	2.66	1.37	8.48
Probability	0.00	0.00	0.17	0.00	0.26	0.51	0.01
Observations	158	168	168	168	168	168.00	168.00

Note: USD_TWD, and USD_CNY correspond to exchange rates

Methods

This study seeks to validate a primary hypothesis: Copper futures have an asymmetric impact on the returns of $TPEX50$ and $TWII$. To evaluate this hypothesis, our initial step is to separate the variations in copper futures into their positive and negative components: $\Delta ln\left(CF_j^{+}\right)$ for positive changes, and $\Delta ln\left(CF_j^{-}\right)$ for negative changes. This allows creating two distinct variables that represent the cumulative sum of these positive and negative changes:

$$CF^{+} = \sum_{j=1}^{t} \Delta ln\left(CF_j^{+}\right) = \sum_{j=1}^{t} max\left(\Delta ln\left(CF_j, 0\right)\right);\ CF^{-} = \sum_{j=1}^{t} \Delta ln\left(CF_j^{-}\right) = \sum_{j=1}^{t} min\left(\Delta ln\left(CF_j, 0\right)\right)$$

We then implement the following Nonlinear Autoregressive Distributed Lag (NARDL) model (model 1):

$$\begin{aligned}\Delta ln(TPEX50) = a_0 &+ \sum_{j=1}^{n_1} a_1 \Delta ln(TPEX50)_{(t-j)} + \sum_{j=1}^{n_2} a_2 \Delta ln(LI99)_{(t-j)} + \sum_{j=1}^{n_3} a_3 \Delta ln(CPI)_{(t-j)} \\ &+ \sum_{j=1}^{n_4} a_4 \Delta CF^{+}{}_{(t-j)} + \sum_{j=1}^{n_5} a_5 \Delta CF^{-}{}_{(t-j)} + \beta_1 ln(TPEX50)_{(t-1)} + \beta_2 ln(CPI)_{(t-1)} \\ &+ \beta_3 ln(Li99)_{(t-1)} + \beta_4 ln(CF^{+})_{(t-1)} + \beta_5 ln(CF^{-})_{(t-1)} + \varepsilon_t,\end{aligned}$$

where the short-run dynamics are represented by the coefficients $a_1 \dots a_5$. The long-run effects are inferred from the ratios $\beta_i/{-\beta_1}$ $(i = 2, \dots 5)$, $n_1 \dots n_5$ represent lags and ε_t is the error term.

This equation is also used to predict $TWII$ returns, replacing $TPEX50$ with $TWII$ throughout, forming model 2. To enhance the robustness of our findings, we estimate this equation both excluding the CPI (model 1.1 for $TPEX50$, and model 2.1 for $TWII$) and omitting the $Li99$ factor (models 1.2 for $TPEX50$, and model 2.2 for $TWII$ respectively).

Results

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Our investigation first confirms the stationarity of logged variables within the NARDL framework (Shin et al., 2014). We expected the variables to exhibit either $I(0)$ or $I(1)$ integration orders and ruled out $I(2)$. A group unit root test (Table 2) shows that all variables stationary at the first difference.

Table 2
Unit Root Test Results

Method	$ln(TPEX50)$, $ln(CPI)$, $ln(Li99)$ and $ln(CF)$		$ln(TWII)$, $ln(CPI)$, $ln(Li99)$ and $ln(CF)$	
	in Levels	in First Differences	in Levels	in First Differences
Levin, Lin & Chu t	1.168 (0.878)	-23.556 (0.000)	0.925 (0.823)	-28.376 (0.000)
Im, Pesaran and Shin W-stat	0.639 (0.739)	-25.893 (0.000)	0.619 (0.732)	-29.707 (0.000)
ADF-Fisher Chi-square	6.111 (0.635)	338.139 (0.000)	7.268 (0.699)	436.612 (0.000)
PP-Fisher Chi-square	6.397 (0.603)	320.588 (0.000)	7.512 (0.676)	418.925 (0.000)

Note: H_0 assumes the presence of a unit root. P-values in parenthesis.

We then proceed to the estimation of NARDL models. The explanatory power of models is solid (see Table 3), as indicated by their adjusted R-squared values. Model diagnostic tests validate robustness and stability, revealing no autocorrelation, heteroskedasticity, or specification issues. Stability over time is further confirmed by CUSUM and CUSUM2 tests (see Fig 1-2).

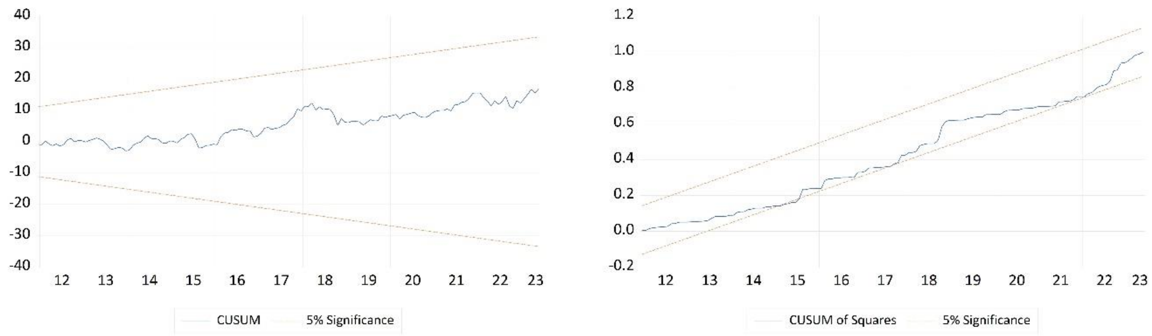

Fig. 1 Stability over time (Model 1)

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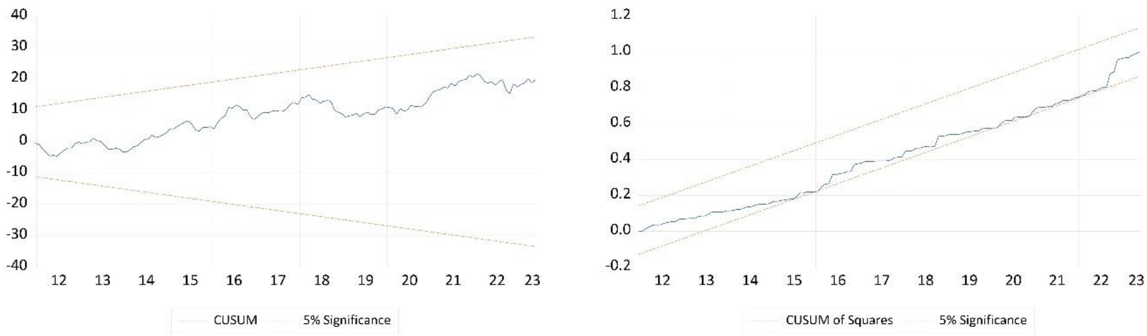

Fig. 2 Stability over time (Model 2)

Both Bounds test and Wald long-run tests provide evidence of cointegration and asymmetry at the 1% significance level, implying the stable and asymmetric long-term relationships among the variables. Short-term asymmetry is also present at the 5% significance level.

Table 3
Diagnostics statistics

Test	Model 1	Model 1.1	Model 1.2	Model 2	Model 2.1	Model 2.2
$adj.R^2$	0.426	0.381	0.388	0.512	0.483	0.470
RESET	0.077	0.553	0.206	0.361	0.449	0.427
(F-stat)	(0.782)	(0.458)	(0.650)	(0.549)	(0.504)	(0.514)
LM	0.162	0.079	0.531	0.915	0.805	1.352
(F-stat)	(0.851)	(0.924)	(0.589)	(0.403)	(0.449)	(0.262)
BPG	1.573	1.229	1.302	1.155	1.184	0.919
(F-stat)	(0.088)	(0.268)	(0.247)	(0.310)	(0.288)	(0.504)
Bounds test	5.537***	4.121**	4.812***	5.627***	4.858***	5.751***
(F-stat)						
$Wald_{LR}$	17.615***	14.248***	14.961***	22.396***	17.389***	21.752***
(Chi-sq)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Wald_{SR}$	5.680**	0.428	1.025	5.036**	2.033	4.386**
(Chi-sq)	(0.017)	(0.514)	(0.311)	(0.025)	(0.154)	(0.036)

Note: *** p < 0.01, ** p < 0.05. Ramsey RESET test: H_0 the model has no omitted variables; Breusch-Godfrey Serial Correlation LM Test: H_0: No serial correlation at up to 2 lags; Breusch-Pagan-Godfrey Test H_0: Homoskedasticity, The 5% critical values for the Bounds test are 2.560 (stationary bound) and 3.490 (non-stationary bound); $Wald_{LR}$ H_0: no long-run asymmetry and $Wald_{SR}$ H_0: no short-run asymmetry.

Analyzing Table 4 and narrowing the focus to models 1 and 2 we can state that the enduring impact of CPI on returns in the long-run is significant. Meanwhile, CPI doesn't appear to influence the short-term market dynamics. An interesting asymmetry is observed where TPEX50 and TWII are more reactive to positive shifts in CF in the long-run. The short-run analysis reveals the complex dynamics of the lithium prices, exhibiting inconsistent impacts and a lagged effect.

Table 4
NARDL Models

Variable	Model 1	Model 1.1	Model 1.2	Model 2	Model 2.1	Model 2.2
Long-run estimates						
$lnCPI$	-9.480***	-	-10.313***	-6.317***	-	-7.651***
	(0.004)		(0.001)	(0.005)		(0.000)
$ln(Li99)_{t-1}$	-0.029	-0.126**	-	-0.043	-0.105***	-
	(0.551)	(0.019)		(0.201)	(0.000)	
$ln(CF^{+})_{t-1}$	0.896***	0.659***	0.929***	0.781***	0.602***	0.835***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$ln(CF^{-})_{t-1}$	0.419***	0.467***	0.429***	0.315***	0.330***	0.336***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	43.441***	2.616***	47.997	34.223***	6.312***	39.862***
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Short-run estimates						
ECM_{t-1}	-0.229***	-0.187***	-0.202***	-0.215***	-0.182***	-0.200***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\Delta ln(CPI)_t$	-	-	-2.645***	-	-	-
			(0.004)			
$\Delta ln(CPI)_{t-1}$	-	-	1.628	-	-	-
			(0.079)			
$\Delta ln(Li99)_t$	0.073	0.069	-	0.046	0.042	-
	(0.149)	(0.182)		(0.164)	(0.216)	
$\Delta ln(Li99)_{t-1}$	-0.096	-0.065	-	-0.048	-0.022	-
	(0.181)	(0.375)		(0.309)	(0.648)	
$\Delta ln(Li99)_{t-2}$	0.006	0.031	-	-0.048	-0.041	-
	(0.937)	(0.694)		(0.347)	(0.433)	
$\Delta ln(Li99)_{t-3}$	0.186**	0.177**	-	0.145***	0.159***	-
	(0.021)	(0.029)		(0.006)	(0.004)	
$\Delta ln(Li99)_{t-4}$	-0.227***	-0.210**	-	-0.133**	-0.142***	-
	(0.005)	(0.010)		(0.011)	(0.009)	
$\Delta ln(Li99)_{t-5}$	0.188***	0.180	-	0.134***	0.138***	-
	(0.004)	(0.000)		(0.002)	(0.002)	
$\Delta CF^{+}{}_{t}$	0.531***	0.573***	0.513**	0.521***	0.526***	0.491***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\Delta CF^{-}{}_{t}$	0.767***	0.727***	0.747***	0.549***	0.533***	0.535***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$\Delta CF^{+}{}_{t-1}$	-0.199	-	-	-0.076	0.016	-0.008
	(0.129)			(0.381)	(0.854)	(0.349)
$\Delta CF^{-}{}_{t-1}$	0.128	-	-	0.073	0.037	0.083
	(0.310)			(0.380)	(0.664)	(0.322)
$\Delta CF^{+}{}_{t-2}$	-0.142	-	-	-0.133	-0.060	-0.114
	(0.277)			(0.121)	(0.481)	(0.197)
$\Delta CF^{-}{}_{t-2}$	0.329***	-	-	0.322***	0.306***	0.279***
	(0.009)			(0.000)	(0.000)	(0.001)

Note: *** $p < 0.01$, ** $p < 0.05$.

Fig 3 illustrates the evolution of a CF shock on TPEX50 and TWII returns over a 15-month span. Early negative effects, possibly from market anticipation of higher production costs for copper-reliant firms could erode profits and investor gains. Yet, the influence turns positive after the 6th month.

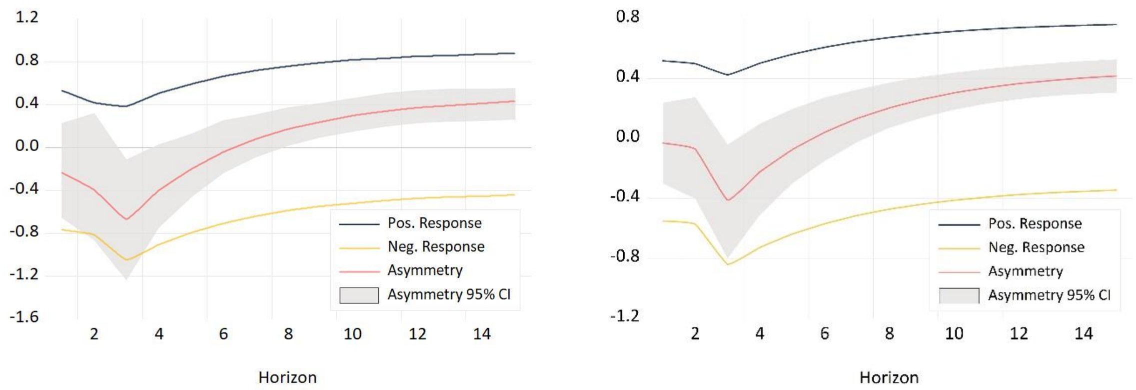

Fig. 3. Evolution of CF Shocks on TPEX50 (Left) and TWII (Right)

Several economic factors could explain this pivot. Firms may optimize their hedging strategies against copper price hikes, thus ensuring investor returns. Stock markets more accurately mirror future profitability projections. Sustained high copper prices could be perceived as a sign of strong global economic activity and expected growth, fostering a market optimism that positively impacts stock returns. Companies might manage to pass the increased costs onto their customers over time, safeguarding their profit margins and ensuring steady or even improved returns for investors.

The initial negative but eventual positive impact of CF shocks on TPEX50 and TWII returns is consistent with Hu et al. (2017), who found CF shock effects are often transitory, flipping to positive over time.

Conclusion

This study effectively validates the hypothesis that copper futures exert an asymmetric influence on TPEX50 and TWII returns, shifting from an initial negative impact to a positive one in the longer term. While lithium prices do not significantly sway stock market returns, they contribute to a short-term dynamic marked by inconsistent and lagged effects.

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Declarations of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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