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How Oil Prices Impact the Japanese and South Korean Economies: Evidence from the Stock Market and Implications for Energy Security

Willem Thorbecke

Research Institute of Economy, Trade and Industry, 1-3-1 Kasumigaseki, Chiyoda-ku, Tokyo 100-8901, Japan; willem-thorbecke@rieti.go.jp; Tel.: +81-3-3501-0230; Fax: +81-3-3501-8414

Abstract: Oil prices are volatile. How does this affect Japanese and South Korean firms? Since they import almost all of their oil, oil price increases may harm their economies. To investigate these issues, this paper examines how oil prices affect sectoral stock returns. Using Hamilton's method to decompose oil price changes into portions driven by global demand and by oil supply, the results indicate that many sectors in both countries benefit from increases in global aggregate demand that raise oil prices. Many industrial firms in Japan that produce advanced products also benefit from supply-driven oil price changes. The finding that many firms benefit from higher oil prices indicates that blanket subsidies to compensate for oil price increases are unnecessary. Targeted subsidies would be more economical and eco-friendly. Many sectors in Japan and Korea that produce for the domestic economy are harmed by oil price increases. Large oil price swings will continue due to wars, tariffs, geopolitical events, and climate change. These will whipsaw sectors in both countries. To shield their economies from oil price changes, Japan and Korea should invest in technologies to improve wind, solar, and hydro power and should facilitate intra-regional trade in renewables. They should also encourage individual sectors such as airlines, cosmetics, agriculture, hotels, semiconductors, and automobiles to reduce their exposure to fossil fuels and to choose environmentally friendly production methods. In addition, both countries should expedite their targets for achieving carbon neutrality. This paper considers ways to achieve these goals.

Keywords: crude oil prices; stock returns; Japan; South Korea

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1. Introduction

Fossil fuels dominate Japan and South Korea's energy supplies. For Japan, 85% of energy came from fossil fuels in 2023, and for Korea, 79% came from fossil fuels. Oil was the largest source, with 38% of the energy supply for Japan and 37% for Korea coming from oil. As Table 1 reports, half of both countries' energy consumption comes from petroleum products. Oil thus plays a vital role in their energy matrices.

Both countries also wrestle with energy security. For Japan, 99.6% of the crude oil supply came from imports in 2023, and for Korea, 98.9% came from imports. Figure 1 shows the percentage of petroleum products in Japan and Korea's total imports. On average, over the 2000 to 2022 period, 20% of Japan's imports and 21% of Korea's imports were petroleum products. Petroleum is by far the leading import category for both countries. Figure 2 shows the U.S. dollar (USD) value of petroleum imports. On average, over the 2000 to 2022 period, Japan imported USD 113 billion per year and Korea imported USD 77 billion per year.

Table 1. Total final energy consumption in 2022.

Country	Unit	Oil Products	Coal	Natural Gas	Electricity	Other
Japan	Terajoules	5,346,282	746,387	1,161,807	364,210	95,578
Japan	Percent of Total Energy Consumption	49.4%	6.9%	11.7%	30.1%	2.9%
South Korea	Terajoules	3,903,514	366,746	962,194	1,950,218	388,708
South Korea	Percent of Total Energy Consumption	51.5%	4.8%	12.7%	25.7%	5.3%

Source: International Energy Agency.

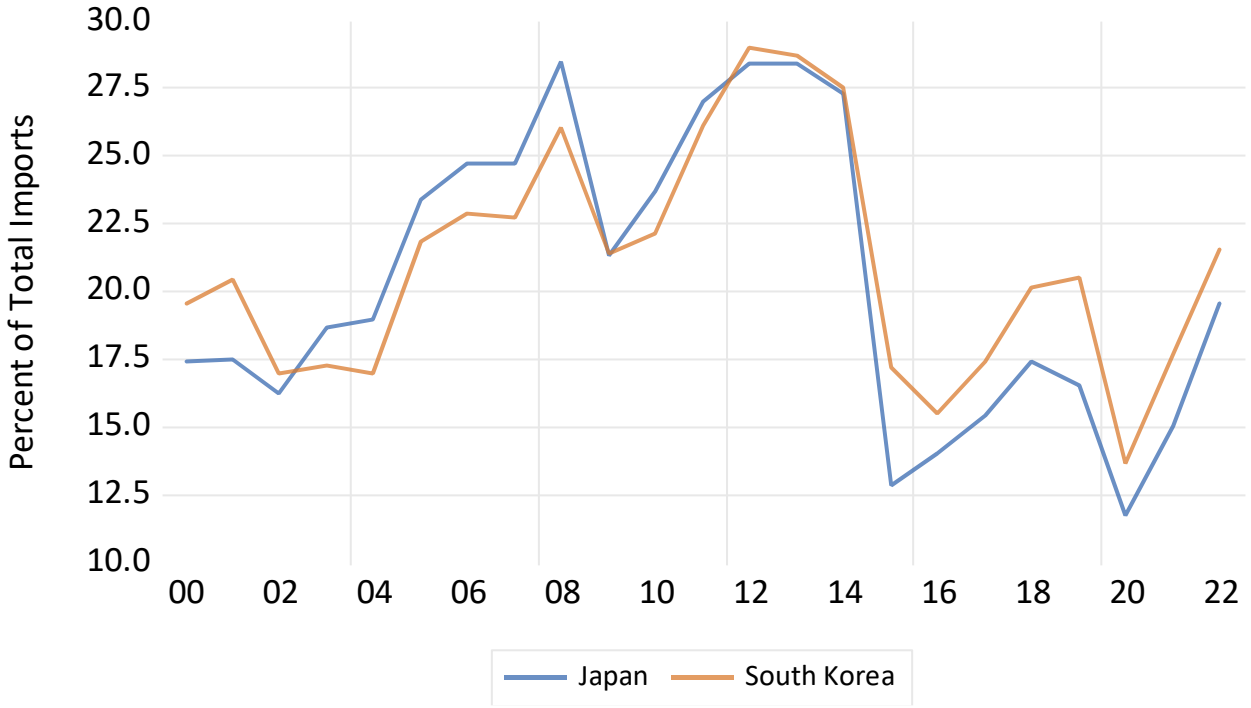


Figure 1. Percent of petroleum imports in total imports. *Notes:* Petroleum imports include crude and refined petroleum oil and petroleum gases. *Source:* https://atlas.hks.harvard.edu (accessed 25 March 2025) and calculations by the author.

Figure 3 shows that oil prices are volatile. Fernald and Trehan [1] noted that, unlike for domestically produced oil, an increase in prices for imported oil shifts income from domestic users to foreign oil producers. They thus argued that price increases for imported oil act like a tax on domestic users. Golub [2] similarly observed that oil price increases transfer wealth from oil-importing countries such as Japan and Korea to oil exporters. High oil prices can thus harm firms in these countries.

Oil is crucial to Japan and Korea's energy mixes and oil prices have fluctuated violently. Oil price volatility will continue as wars, trade wars, economic shocks, natural disasters, and other factors buffet oil markets. It is thus important to examine how oil prices impact their economies.

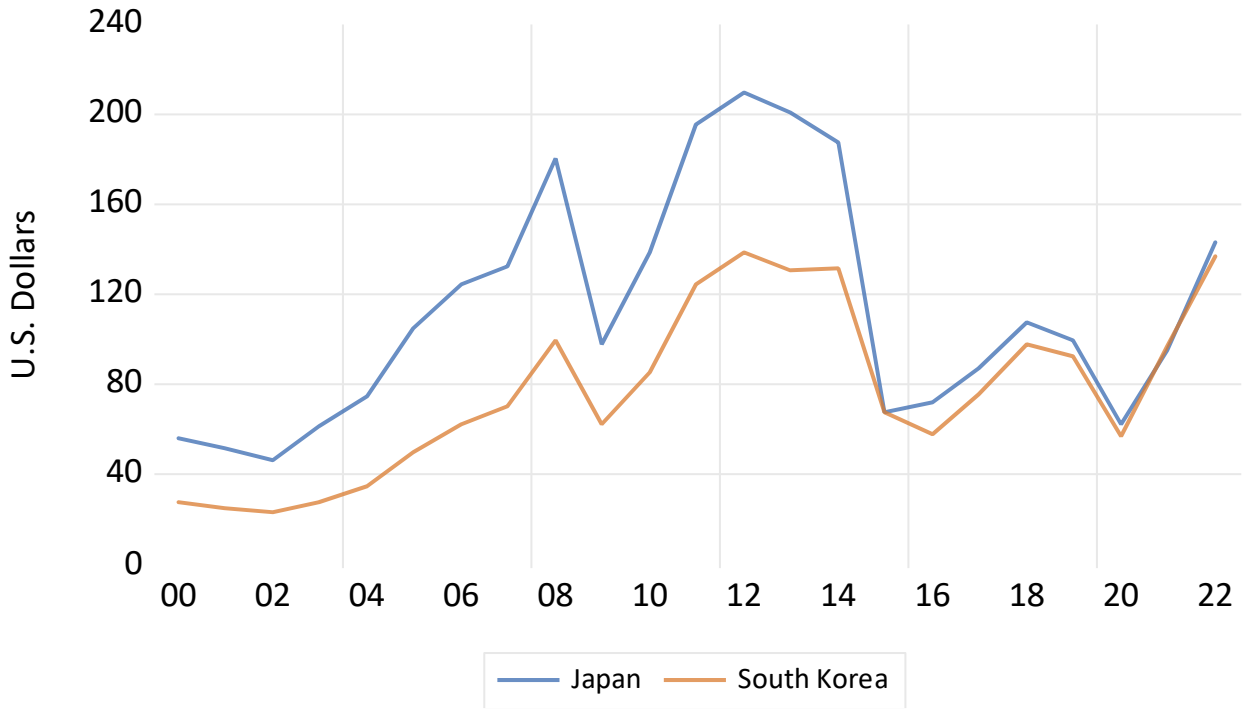


Figure 2. USD value of petroleum imports. *Notes:* Petroleum imports include crude and refined petroleum oil and petroleum gases. *Source:* https://atlas.hks.harvard.edu (accessed 25 March 2025) and calculations by the author.



Figure 3. Price of Dubai crude oil. *Source:* Federal Reserve Bank of St. Louis Fred Database.

As Hamilton [3] noted, changes in oil prices can be driven by changes in global aggregate demand or in global oil supply and other factors. Hamilton presented a method for decomposing oil price changes into components driven by demand and by other factors. The evidence presented in Section 3 lends credence to his approach. This paper uses Hamilton's technique to investigate how the demand- and supply-driven oil price changes affect the Japanese and Korean economies.

To do this, this paper examines how they impact sectoral stock returns. Black [4] reported that sectoral changes in stock prices presage sectoral changes in output, profits,

and investment. Since oil prices are determined in global markets, changes in both global aggregate demand and global oil supply should affect individual sectors in Japan and Korea, but causality flowing in the other direction should be second-order. This is the econometric identifying assumption underlying this study. Thus, examining the relationship between demand- and supply-driven oil price changes and sectoral stock returns should shed light on how oil price shocks impact sectoral sales, earning, and spending.

The next section surveys the related literature. It reveals that there is a gap in the literature. Previous work has not used reliable methods such as Hamilton's [3] to investigate how shocks to aggregate demand and oil supply affect Japanese and Korean stock returns. Instead it has used approaches such as Kilian's [5] to decompose oil price changes into supply and demand components. As discussed below, Kilian's decomposition is problematic. Much of the previous research has also examined how oil prices affect aggregate stock returns or many sectors aggregated together. This paper provides much more disaggregated results and consider how these could provide impetus to governments and affected sectors to expedite the shift to renewable energy sources.

The results indicate that Japanese sectors that compete in world markets such as machinery, electronic components, and consumer electronics benefit from oil price increases driven by global aggregate demand. Sectors oriented towards the domestic market such as food producers, railroads, hotels, restaurants, and delivery services suffer from oil price increases driven by global demand. Japanese industrial and engineering sectors gain from oil price increases driven by supply factors. This may reflect Fukunaga et al.'s [6] findings that Japanese firms provide crucial products that agents demand when oil prices increase. Japanese sectors such as airlines, construction, and tires that depend on oil and energy suffer from higher oil prices driven by supply factors.

Similarly, for Korean sectors benefiting from global demand such as iron and steel and shipbuilding gain from oil price increases due to aggregate demand increases. The commercial vehicle sector also benefits from higher oil prices due to demand increases as this increases the usage of public transportation relative to private vehicles. As with Japan, sectors relying on oil such as airlines and food producers are harmed by oil price increases.

The next section reviews the literature. Section 3 discusses the materials and methods. Section 4 contains the results. Section 5 considers how Japan and Korea can transition from fossil fuels to sustainable energy sources. Section 6 concludes.

2. Literature Review

Previous research has found a link between stock prices and subsequent economic activity. Liu et al. [7] found that industry valuations obtained from earnings data track stock prices well in several industries across several countries. Chatelais et al. [8] reported that sectoral equity variables in the context of a factor model forecast industrial production better than other predictors. McMillan [9] found that stock prices help predict GDP growth across several countries. Croux and Reusens [10] reported that the slowly fluctuating components of stock prices obtained from the frequency domain predict economic activity well. Barro [11], Schwert [12], Velinov and Chen [13], and others also found that stock prices help predict economic activity.

This paper thus examines the response of stock returns to oil price changes to shed light on how oil prices impact economic activity across sectors in Japan and Korea. The results indicate that many sectors in both countries are exposed to oil price changes.

Fukunaga et al. [6] reported that oil price increases raise production for several Japanese sectors. They used Kilian's [5] decomposition to investigate how shocks to oil production, global aggregate demand, and oil market-specific price shocks affect stock returns. They followed Kilian in using bulk dry cargo freight rates to measure global

demand for industrial commodities and thus global economic activity. They estimated structural vector autoregressions (VARs) over the January 1973–December 2008 period to investigate how oil price shocks affect American and Japanese industries. They found that positive oil market-specific price shocks not explained by global economic activity or oil production decrease aggregate and sectoral production across several industries in the U.S. and increase aggregate and sectoral production across several industries in Japan. They interpreted their findings by noting that Japanese products in sectors such as automobiles tend to be more energy-efficient than American products in the same sectors. An increase in oil prices would thus switch demand from American to Japanese products. This would stimulate production in other industries such as steel and precision instruments that provide inputs to Japanese final goods.

Abhyankar et al. [14] found that oil price shocks primarily affect the cash flows of Japanese companies. Using Kilian's [5] decomposition and structural VARs, they reported that positive innovations in their measure of global economic activity produced a positive and statistically significant response of Japanese aggregate stock returns. They also found that oil market-specific price shocks not explained by global economic activity or oil production were associated with declines in Japanese aggregate stock returns. The response of stock returns to oil-market-specific shocks was not different from zero; however, this was with using two standard error bands. Finally, using the methodology of Campbell [14], they reported that oil price shocks primarily affected Japanese stock returns by affecting expected cash flows.

Batten et al. [15] examined whether stock markets in China, Hong Kong, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand are integrated with an energy portfolio. They uncovered two regimes, one where stock markets are not integrated with energy stocks and a second where they are. They reported positive energy-related risk premia during high-integration regimes. These results indicate that oil and other energy sources impact Asian stock markets.

Kotsompolis et al. [16] employed daily data and an autoregressive distributed lag framework to examine how oil price shocks impacted stock prices in China, Japan, Indonesia, Malaysia, the Philippines, and South Korea. Using impulse response techniques, they found that positive shocks to West Texas Intermediate oil prices raised stock returns in all six countries over the January to June 2020 period and in all countries except China in the June 2020 to May 2023 period. They reported larger responses during the first period.

Researcher have uncovered a positive relationship between the prices of oil and other commodities and global aggregate demand. Delle Chiaie et al. [17], using commodity price data over the 1981–2020 period, divided commodity prices into a commodity-specific factor, a category-specific factor (e.g., all commodities in the metals category), and a global factor. They reported that the lion's share of price movements can be explained by the global factor. The global component is closely related to world industrial production. They interpret this component as a measure of global aggregate demand.

Matsumoto et al. [18], using data on commodity prices and global industrial production over the 1957 to 2017 period, found that commodity prices commove with global economic activity. They also reported that latent factors derived from commodity prices helped forecast global industrial production and GDP over the January 1980 to December 2018 period.

Kilian [5] constructed a measure of global activity to explain oil price changes. He used a VAR with crude oil prices, global crude oil production, and an index of real economic activity to capture global commodity demand. He used data on dry cargo bulk freight rates to measure the world economic activity. He employed recursive ordering in the VAR

with the crude oil supply coming first, dry cargo bulk freight rates second, and crude oil prices third.

Hamilton [19], Demirer et al. [20], and others have recently presented cogent criticisms of Kilian's [5] decomposition. Hamilton noted that Kilian used the questionable approach of taking the log of a log when calculating bulk dry cargo freight rates. This implies that the initial value used influences the value of the series. Hamilton showed that initializing the series at different dates produced strikingly different values for the index. Hamilton also showed that Kilian's proxy for global economic activity had strange properties, such as indicating that the global economy in 2015 suffered a more severe downturn than during the 1974–1975 recession or the 2008–2009 global financial crisis. Examining industrial production over these periods reveals that the global downturns were far more severe in 1974–1975 and 2008–2009 than in 2015. Demirer et al. argued that the Kilian decomposition assigns too much weight to oil price shocks not explained by global economic activity or oil production.

Hamilton [3] presented an alternative method to decompose oil price changes into the portion driven by aggregate demand and the portion driven by oil supply and other factors. To capture the effect of the aggregate demand on oil prices, he regressed the change in the log of oil prices on the changes in the log of copper prices, the ten-year Treasury constant maturity interest rate, and the log of the trade-weighted USD exchange rate. He then measured the change in oil prices driven by the oil supply and other factors as the residuals from this regression. Bernanke [21] used Hamilton's approach to examine how aggregate demand and oil supply shocks affect stock returns. The evidence presented below indicates that Hamilton's method provides a good measure of global economic activity.

3. Materials and Methods

To examine how oil price shocks affect individual sectors, their impact on stock prices is examined. Finance theory indicates that stock prices equal the expected present value of future cash flows. Abhyankar et al. [14], using the variance decomposition methodology of Campbell [22], reported that oil price shocks primarily affect the cash flows of Japanese firms. By examining how oil prices impact stock prices, we can infer how they impact firms' profitability.

To understand why oil price changes driven by global aggregate demand might impact firms' profits differently from oil price increases driven by oil supply it is helpful to begin with micro-theoretic foundations. Without distinguishing between the sources of oil price changes, a firm seeking to maximize profits faces the optimization problem:

$$\text{Max}_{Q,L,K,O}\ \text{Profit} = PQ - wL - rK - P_O O \text{ s.t. } Q = f(L,K,O) \quad (1)$$

where Q is output, L is labor, K is capital, and O is oil with respective prices P, w, r, and P_O. It follows from the envelope theorem that an increase in the price of oil decreases profits and also share prices (since share prices equal the expected present value of future earnings). To distinguish between the sources of oil price changes, assume that output depends positively on global aggregate demand (AD) and that oil prices depend positively on global aggregate demand and negatively on oil supply (SS), viz. Q = f(L,K,O,AD) and P_O = g(AD,SS). An increase in AD now increases both Q, which raises profits and share prices, and also P_O, which lowers profits and share prices. The net effect on profits and stock prices depends on which channel is stronger. An increase in SS will not affect Q, but will lower P_O, raising profits and share prices. The situation can be still more complicated. For instance, if a firm supplies the oil industry, an increase SS can also increase Q.

Hamilton's [3] method is used to decompose oil price changes into the portion driven by global aggregate demand and the portion driven by oil supply. Following Hamilton, the

monthly change in the log of Dubai oil prices is regressed on the change in the log of copper futures prices, the change in the log of the U.S. nominal effective exchange rate, and the change in the ten-year constant maturity U.S. Treasury interest rate. The values predicted by this regression represent oil price changes driven by aggregate demand. The residuals from this regression represent oil price changes driven by the oil supply and other factors.

As Delle Chiaie et al. [17] and Matsumoto et al. [18] noted, the portion of commodity prices driven by global aggregate demand should be related to global production. The correlation coefficient between Hamilton's measure of oil price changes driven by demand factors and the growth of OECD industrial production over the February 2001 to December 2019 period is 0.20 and the associated *t*-statistic is 3.09 (probability value equals 0.002). Since stock prices equal the expected present value of future cash flows, there should also be a strong relationship between Hamilton's measure and world stock returns. The correlation coefficient between these two variables over the February 2001 to December 2019 period is 0.59 and the associated *t*-statistic is 10.95 (probability value equals 0.0000). When compared with the correlation between demand-driven oil price shocks and industrial production, the stronger correlation between demand-driven oil price shocks and world stock returns reflects the fact that both of the latter variables are strongly influenced by speculative behavior. They thus respond more quickly than industrial production to new information. Investors price in a close relationship between times when they expect global demand to raise oil prices and times when they expect world stocks to perform well. This finding lends confidence that Hamilton's approach provides a good measure of oil price changes driven by aggregate demand.

As Kilian and Park [23], Hamilton [3], Bernanke [21], and others have noted, oil price changes driven by global aggregate demand have very different implications for stock prices than oil price changes driven by oil supply. Sectors that gain from aggregate demand increases that happen to raise oil prices do not necessarily benefit from higher oil prices. Sectors that gain because supply factors raise oil prices are benefitting from the oil price increases themselves. On the other hand, sectors that are harmed by demand- or supply-driven oil price increases are suffering from the price increases themselves.

Many have examined stock returns' exposure to exchange rates. This involves regressing a firm or sector's stock return on the return in the country's stock market and exchange rate (see, e.g., Ito et al. [24] or Dominguez and Tesar [25]). In this paper, stock returns on 57 Japanese sectors and 64 Korean sectors are included as left-hand-side variables and changes in the log of oil prices are included as an additional right-hand-side variable, along with the return on the country's aggregate stock market and changes in the log of the country's exchange rate relative to the USD.

In one specification, the change in the log of the spot price of Dubai crude oil is included as a regressor. In the other specification, the log of the spot price of Dubai crude oil is decomposed using the method of Hamilton [3] into the portion driven by global aggregate demand and the portion driven by oil supply.

As columns (7), (8), and (9) of Tables A1 and A2 in Appendix A report, in every case, augmented Dickey–Fuller tests permit rejection of the null hypothesis that the series have unit roots. The equations are thus estimated using least squares. When the spot price of Dubai oil is used as a regressor, the equations take the form:

$$\Delta R_{i,c,t} = \alpha_0 + \alpha_1 \Delta R_{m,c,t} + \alpha_2 \Delta \left(\frac{currency}{dollar} \right)_{c,t} + \alpha_3 \Delta Dubai_t + \mu_{i,c,t}, \quad (2)$$

where $\Delta R_{i,c,t}$ is the monthly stock return for sector i in country c (either Japan or Korea), $\Delta R_{m,c,t}$ is the monthly stock return for country c's aggregate market, $\Delta(\text{currency/USD})_{c,t}$ is

the change in the log of the nominal exchange rate in country c relative to the USD, and $\Delta Dubai_t$ is the change in the log of the spot price for Dubai crude oil.

When Dubai oil price changes are divided into the parts driven by global aggregate demand (Oildd) and by oil supply (Oilss), the equations take the form:

$$\Delta R_{i,c,t} = \beta_0 + \beta_1 \Delta R_{m,c,t} + \beta_2 \Delta \left(\frac{currency}{dollar} \right)_{c,t} + \beta_3 Oildd_t + \beta_4 Oilss_t + \nu_{i,c,t} \quad (3)$$

This paper follows Chen et al. [26] in assuming that causality flows from the macroeconomic variables on the right-hand side of Equations (2) and (3) to the sectoral variables on the left-hand side, and that any causality flowing in the other direction is of second-order. Consider for instance oil prices. They are determined in global markets and influenced by world demand, geopolitical events, OPEC policy, and many other factors. What happens to individual Japanese or Korean sectors are only minor factors in global oil markets. Thus, for a first approximation, causality should flow from world oil markets to individual Japanese or Korean sectors and any causality flowing the other way is second-order.

The sample period extends from February 2001 to December 2019. It ended before the COVID-19 pandemic began because volatile movements in the variables during this period might cloud inference. During the pandemic, oil prices could change by more than 70% in a single month. There were also days when oil prices were negative. These unprecedented movements in oil prices while the pandemic was also causing dislocation could distort inference. Data on sectoral and aggregate stock returns, Dubai crude oil spot prices, and nominal exchange rates come from the Refinitiv Datastream database. Data on copper futures come from investing.com. The other data come from the FRED database provided by the Federal Reserve Bank of St. Louis.

4. Results

Tables 2 and 3 report the results for sectoral and firm returns for Japan and Table 4 presents the results for sectoral returns for Korea. As column (2) of Tables A1 and A2 in Appendix A reports, the models perform well. The adjusted R-squared average is 0.52 for sectoral returns in Japan and 0.33 for sectoral returns in Korea. In Tables 2–4, column (2) presents the coefficients of oil price changes driven by aggregate demand shocks (from Equation (3)), column (4) presents the coefficients of oil price changes driven by supply factors (from Equation (3)), column (6) presents the coefficients of total oil price changes (from Equation (2)), and column (8) presents the coefficients of the exchange rate relative to the USD (from Equation (3)). The columns to the right of columns (2), (4), (6), and (8) present the associated heteroskedasticity and autocorrelation consistent (HAC) standard errors. The results of Breusch–Godfrey serial correlation LM tests with two lags and Breusch–Pagan–Godfrey heteroskedasticity tests, reported in columns (3) and (4) of Tables A1 and A2 in Appendix A, do not permit rejection in most cases of the maintained hypotheses of no serial correlation or heteroscedasticity. In those cases where the null hypothesis is rejected, the HAC method should help provide consistent estimates of the standard errors.

Table 2. The exposure of Japanese sectors to oil price changes and the JPY/USD exchange rate.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sector	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on JPY/USD Exchange Rate**	**S.E.**
Airlines	−0.235 ***	0.082	−0.087 *	0.049	−0.124 ***	0.044	−0.206	0.159
Aluminum	0.041	0.108	0.008	0.064	0.017	0.051	−0.521 **	0.209
Automobiles	0.123 **	0.055	0.009	0.033	0.038	0.028	0.870 ***	0.106
Auto Parts	0.155 ***	0.053	0.003	0.031	0.041	0.034	0.674 ***	0.102
Banks	−0.114 *	0.063	0.059 *	0.038	0.015	0.030	−0.301 **	0.123
Biotechnology	0.079	0.200	−0.030	0.123	−0.002	0.099	0.147	0.411
Cement	−0.077	0.112	0.062	0.066	0.027	0.081	−0.085	0.217
Chemicals	0.092 **	0.037	−0.005	0.022	0.020	0.023	0.089	0.072
Construction	−0.079	0.077	−0.119 ***	0.046	−0.109 ***	0.040	−0.420 ***	0.150
Consumer Electronics	0.315 ***	0.087	0.004	0.052	0.082 *	0.044	0.529 ***	0.169
Consumer Staples	0.045	0.031	0.011	0.018	0.019	0.016	0.483 ***	0.060
Cosmetics	−0.134 *	0.076	0.029	0.046	−0.013	0.040	−0.301 **	0.148
Delivery Services	−0.211 ***	0.077	−0.041	0.046	−0.084 **	0.037	−0.113	0.150
Electronic and Electrical Equipment	0.191 ***	0.043	−0.001	0.025	0.048 **	0.023	0.394 ***	0.083
Electronic Equipment: Controls	0.051	0.096	0.025	0.057	0.032	0.526	−0.133	0.186
Electronic Equipment: Gauges	0.146 ***	0.047	−0.012	0.028	0.028	0.025	0.345 ***	0.092
Electronic Equipment: Pollution	0.107	0.097	0.016	0.058	0.039	0.049	−0.197	0.189
Electronic Office Equipment	0.179 ***	0.060	−0.061 *	0.036	−0.000	0.033	0.685 ***	0.117
Electricity	−0.253 ***	0.095	−0.104 *	0.056	−0.141 ***	0.044	−0.088	0.184
Electronic Component	0.213 ***	0.050	0.011	0.030	0.062 **	0.026	0.324 ***	0.096

Table 2. *Cont.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sector	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on JPY/USD Exchange Rate**	**S.E.**
Fishing and Farming	−0.065	0.069	0.013	0.040	−0.007	0.041	0.094	0.130
Fertilizers	−0.216 *	0.129	−0.035	0.077	−0.081	0.075	0.507 **	0.250
Food Producers	−0.154 ***	0.046	−0.022	0.027	−0.056 **	0.027	−0.119	0.089
Food Retail and Wholesale	−0.273 ***	0.066	−0.054	0.039	−0.109 ***	0.036	−0.249 *	0.128
Gas Distribution	−0.233 ***	0.057	−0.040	0.034	−0.089 **	0.035	−0.121	0.111
General Industrials	0.184 ***	0.061	0.026	0.036	0.066 **	0.033	−0.086	0.118
Healthcare	−0.133 ***	0.043	0.013	0.026	−0.023	0.020	−0.140 *	0.084
Home Furnishings	−0.271***	0.066	−0.021	0.039	−0.083 **	0.033	−0.189	0.127
Home Construction	−0.141 **	0.060	−0.082 **	0.036	−0.097 ***	0.032	−0.224 *	0.116
Hotels	−0.285 ***	0.083	−0.035	0.050	−0.098 **	0.045	−0.223	0.162
Industrial Engineering	0.215 ***	0.043	0.060 **	0.026	0.099 ***	0.023	0.151 *	0.084
Industrial Suppliers	0.426 ***	0.065	0.148 ***	0.038	0.219 ***	0.031	−0.021	0.127
Industrial Materials	−0.181 **	0.085	0.123 **	0.050	0.046	0.060	−0.414 **	0.164
International Oil and Gas	0.310 ***	0.085	0.186 ***	0.051	0.217 ***	0.049	0.031	0.166
Iron and Steel	0.227 ***	0.071	0.062	0.042	0.103 ***	0.030	0.133	0.137
Leisure Goods	0.150 ***	0.054	0.024	0.032	0.056 *	0.032	0.287 ***	0.105
Luxury Items	0.303 ***	0.094	−0.028	0.056	0.055	0.074	0.684 ***	0.183
Machinery: Agriculture	−0.068	0.094	0.033	0.056	0.007	0.055	0.221	0.183
Machinery: Construction	0.622 ***	0.083	0.090 *	0.049	0.225 ***	0.043	0.589 ***	0.160
Machinery: Industrial	0.183 ***	0.049	0.053 *	0.029	0.086 ***	0.027	0.046	0.096
Machinery: Specialized	0.167 **	0.068	0.006	0.040	0.047	0.039	0.109	0.131
Machinery: Tools	0.224 ***	0.078	0.009	0.047	0.063	0.043	0.224	0.152

Table 2. *Cont.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sector	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on JPY/USD Exchange Rate**	**S.E.**
Marine Transport	0.172 *	0.097	0.101 *	0.058	0.119 **	0.050	0.055	0.188
Medical Equipment	0.022	0.069	0.075 *	0.041	0.061 *	0.037	0.102	0.134
Nonferrous Metals	0.455 ***	0.084	0.031	0.050	0.138 ***	0.044	−0.043	0.163
Oil Equipment and Services	0.283 **	0.139	0.299 ***	0.088	0.295 ***	0.063	−0.600	0.282
Oil Refining and Marketing	0.220 **	0.096	0.199 ***	0.057	0.204 ***	0.055	−0.022	0.187
Oil: Crude Production	0.298 ***	0.083	0.289 ***	0.049	0.291 ***	0.047	0.194	0.161
Pharmaceuticals	−0.163 ***	0.050	0.007	0.030	−0.036	0.023	−0.162 *	0.097
Railroads	−0.229 ***	0.047	−0.018	0.028	−0.071 ***	0.021	−0.267 ***	0.091
Restaurants and Bars	−0.251 ***	0.049	−0.048 *	0.029	−0.100 ***	0.025	−0.373 ***	0.094
Semiconductors	0.166 *	0.086	−0.027	0.051	0.022	0.043	0.343 **	0.168
Technology Hardware	0.167 ***	0.055	−0.012	0.033	0.034	0.026	0.192 *	0.108
Tires	−0.025	0.080	−0.119 **	0.048	−0.096 **	0.042	0.855 ***	0.156
Transport Services	−0.191 ***	0.061	−0.015	0.037	−0.059 *	0.034	−0.307 ***	0.119
Travel and Leisure	−0.264 ***	0.046	−0.031	0.027	−0.090 ***	0.020	−0.285 ***	0.089
Trucking	−0.202 ***	0.055	−0.032	0.033	−0.075 **	0.031	−0.202 *	0.107

Notes: The coefficients in columns (2), (4), and (8) represent the regression parameters from a regression of stock returns for the sectors listed in column (1) on: (1) the change in the log of Dubai spot crude oil prices driven by global aggregate demand (column (2)), (2) the change in the log of Dubai spot crude oil prices driven by supply (column (4)), (3) the JPY/USD nominal exchange rate (column (8)), and (4) the return on the Japanese stock market (not reported). The coefficients in columns (6) represent the regression parameters from a regression of stock returns for the sectors listed in column (1) on: (1) the change in the log of Dubai spot crude oil prices (column (6)), (2) the return on the Japanese stock market (not reported), and (3) the JPY/USD nominal exchange rate (not reported). Following Hamilton [3], the change in crude oil prices driven by aggregate demand factors is captured by regressing the change in the log of oil prices on the change in the log of future copper prices, the change in the ten-year Treasury constant maturity interest rate, and the change in the log of the trade-weighted USD exchange rate. The change in oil prices driven by oil supply and other factors is measured as the residuals from this regression. The regressions are all run over the February 2001 to December 2019 period. Columns (3), (5), (7), and (9) report heteroskedasticity and autocorrelation-consistent standard errors. *** (**) [*] denote significance at the 1% (5%) [10%] levels.

Table 3. The exposure of Japanese industrial firms to oil price changes and the JPY/USD exchange rate.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Company	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on JPY/USD Exchange Rate**	**S.E.**
Daio Paper	−0.352 **	0.145	0.155 **	0.075	0.027	0.081	−0.303	0.264
Japan Steel Works	0.218	0.168	0.201 **	0.084	0.206 **	0.084	−0.700 *	0.383
Komatsu	0.696 ***	0.133	0.107 **	0.045	0.256 ***	0.041	0.626 ***	0.187
Marubeni	0.345 ***	0.107	0.185 ***	0.065	0.224 ***	0.050	−0.497 *	0.257
Mitsui	0.496 ***	0.061	0.169 ***	0.037	0.252 ***	0.036	−0.039	0.115
Nikkiso	0.029	0.148	0.190 ***	0.069	0.149 **	0.072	0.036	0.237
Nitto Boseki	0.041	0.149	0.184 **	0.084	0.147 *	0.078	−0.145	0.231
Oji Holdings	−0.112	0.108	0.153 **	0.070	0.086	0.067	−0.260	0.219
Tadano	−0.044	0.114	0.186 **	0.077	0.128 **	0.058	0.229	0.212

Notes: The coefficients in columns (2), (4), and (8) represent the regression parameters from a regression of stock returns for the firms listed in column (1) on: (1) the change in the log of Dubai spot crude oil prices driven by global aggregate demand (column (2)), (2) the change in the log of Dubai spot crude oil prices driven by supply (column (4)), (3) the JPY/USD nominal exchange rate (column (8)), and (4) the return on the Japanese stock market (not reported). The coefficients in columns (6) represent the regression parameters from a regression of stock returns for the firms listed in column (1) on: (1) the change in the log of Dubai spot crude oil prices (column (6)), (2) the return on the Japanese stock market (not reported), and (3) the JPY/USD nominal exchange rate (not reported). Following Hamilton [17], the change in crude oil prices driven by aggregate demand factors is captured by regressing the change in the log of oil prices on the change in the log of future copper prices, change in the ten-year Treasury constant maturity interest rate, and the change in the log of the trade-weighted USD exchange rate. The change in oil prices driven by oil supply and other factors is measured as the residuals from this regression. The regressions were all run over the February 2001 to December 2019 period. Columns (3), (5), (7), and (9) report heteroskedasticity and autocorrelation-consistent standard errors. *** (**) [*] denote significance at the 1% (5%) [10%] levels.

Table 4. The exposure of Korean sectors to oil price changes and the KRW/USD exchange rate.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sector	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on SKW/ USD Exchange Rate**	**S.E.**
Airlines	−0.163	0.171	−0.30 ***	0.106	−0.278 ***	0.085	−0.427	0.311
Asset Managers	−0.081	0.075	0.056	0.042	0.021	0.038	−0.092	0.069
Auto Parts	−0.200	0.140	0.038	0.057	−0.012	0.053	0.206	0.190
Automobiles	−0.031	0.127	0.013	0.055	0.004	0.050	0.295	0.187
Banks	0.230 ***	0.074	0.010	0.061	0.060	0.057	−0.142	0.139

Table 4. *Cont.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sector	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on SKW/ USD Exchange Rate**	**S.E.**
Basic Materials	0.282 ***	0.075	0.003	0.035	0.061 **	0.031	−0.262 ***	0.083
Basic Resources	0.377 ***	0.093	0.036	0.045	0.107 ***	0.038	−0.321 ***	0.116
Biotechnology	0.128	0.354	0.308	0.293	0.262	0.274	−0.105	0.498
Casinos/Gambling	−0.151	0.108	0.038	0.078	−0.001	0.064	−0.577 **	0.236
Cement	−0.437 **	0.208	−0.063	0.111	−0.141	0.111	−0.838 **	0.385
Chemicals	0.236 *	0.142	−0.048	0.062	0.011	0.052	−0.029	0.142
Commercial Vehicles and Parts	0.364 **	0.154	0.052	0.073	0.117 *	0.067	0.298	0.173
Computer Hardware	−0.061	0.128	0.009	0.079	−0.008	0.064	0.247	0.238
Computer Services	−0.235	0.187	0.015	0.071	−0.027	0.065	0.040	0.426
Consumer Digital Services	0.009	0.167	−0.013	0.095	−0.009	0.077	0.090	0.173
Construction and Materials	0.052	0.102	0.007	0.054	0.016	0.045	−0.178	0.173
Construction	0.073	0.135	−0.000	0.067	0.015	0.056	−0.120	0.211
Consumer Discretionary	−0.176 **	0.058	0.023	0.026	−0.019	0.023	0.011	0.080
Consumer Electronics	−0.027	0.118	−0.031	0.063	−0.030	0.056	0.246	0.204
Consumer Products and Services	−0.189 ***	0.064	0.014	0.034	−0.028	0.029	−0.023	0.087
Consumer Staples	−0.222 ***	0.072	−0.006	0.033	−0.051 *	0.028	0.139	0.102
Cosmetics	−0.380 **	0.153	0.035	0.080	−0.051	0.070	−0.220	0.205
Diversified Industrials	0.086	0.112	0.033	0.060	0.044	0.054	−0.047	0.150
Diversified Retail	0.031	0.113	0.058	0.045	0.052	0.040	−0.078	0.198
Drug/Grocery Stores	−0.407 ***	0.131	0.021	0.072	−0.068	0.058	−0.252	0.161

Table 4. *Cont.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sector	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on SKW/ USD Exchange Rate**	**S.E.**
Electronic Entertainment	0.104	0.237	−0.156	0.109	−0.102	0.095	0.118	0.281
Electricity	−0.057	0.095	−0.130 **	0.052	−0.115 **	0.047	−0.427 ***	0.153
Electronic Components	−0.076	0.116	−0.086	0.073	−0.084	0.059	0.173	0.132
Energy	0.283 **	0.141	0.075	0.069	0.118 *	0.062	−0.135	0.147
Financial Data Providers	0.008	0.187	−0.001	0.063	0.001	0.059	−0.248	0.299
Food Producers	−0.196 **	0.090	−0.000	0.049	−0.041	0.041	−0.454 ***	0.171
Healthcare	−0.196	0.198	0.139	0.085	0.069	0.091	0.109	0.211
Household Equip. Production	−0.530 ***	0.145	0.147 *	0.084	0.004	0.063	−0.192	0.211
Industrial Engineering	0.250 **	0.121	0.034	0.065	0.079	0.056	0.039	0.158
Industrial Goods and Services	0.039	0.069	0.015	0.034	0.020	0.027	0.049	0.096
Industrial Metals and Mines	0.376 ***	0.093	0.036	0.045	0.107 ***	0.038	−0.319 ***	0.116
Industrial Support Svstems	0.156	0.113	0.108 *	0.064	0.118 **	0.058	−0.183	0.168
Industrial Transport	−0.057	0.141	−0.158 **	0.070	−0.137 **	0.055	−0.046	0.164
Insurance	0.056	0.087	−0.009	0.055	0.004	0.042	0.146	0.165
Investment Banks and Brokers	−0.161	0.123	−0.054	0.065	−0.077	0.050	−0.219	0.174
Iron and Steel	0.375 ***	0.101	0.054	0.049	0.121 ***	0.041	−0.304 **	0.132
Leisure Goods	−0.079	0.110	−0.015	0.051	−0.028	0.050	0.127	0.169
Life Insurance	0.197 *	0.119	−0.009	0.062	0.026	0.056	0.307	0.272
Machinery: Industrial	−0.021	0.191	0.120	0.099	0.091	0.091	−0.143	0.235
Marine Transport	0.334 **	0.145	−0.008	0.071	0.063	0.060	0.022	0.227
Nonlife Insurance	0.089	0.092	−0.026	0.055	−0.002	0.043	0.112	0.168

Table 4. *Cont.*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sector	**Coefficient on Dubai Oil Price Changes Driven by Aggregate Demand**	**S.E.**	**Coefficient on Dubai Oil Price Changes Driven by Oil Supply**	**S.E.**	**Coefficient on Total Dubai Oil Price Changes**	**S.E.**	**Coefficient on SKW/ USD Exchange Rate**	**S.E.**
Oil Refining and Marketing	0.212	0.161	0.092	0.072	0.117 *	0.067	−0.147	0.186
Personal Goods	−0.422 ***	0.129	0.055	0.061	−0.045	0.051	−0.267 *	0.153
Personal Product	−0.423 ***	0.134	0.020	0.073	−0.072	0.058	−0.262	0.160
Pharmaceutical and Biotech	−0.194	0.198	0.138	0.085	0.069	0.091	0.110	0.211
Pharmaceuticals	−0.532 *	0.319	−0.150	0.122	−0.216 *	0.110	−1.473 ***	0.553
Precious Metals and Mines	0.528 ***	0.160	−0.077	0.076	0.049	0.077	−0.121	0.278
Retailers	−0.017	0.109	0.069	0.047	0.051	0.042	−0.117	0.188
Software and Computer Services	0.073	0.140	0.018	0.085	0.030	0.076	0.085	0.155
Security Systems	−0.017	0.127	0.041	0.060	0.029	0.058	0.073	0.212
Semi-conductors	−0.459	0.309	−0.054	0.148	−0.139	0.108	0.426	0.269
Technology Hardware	−0.218	0.138	−0.005	0.064	−0.050	0.057	0.402 **	0.171
Telecommunication Equipment	−0.485	0.344	−0.218	0.153	−0.274 *	0.141	−1.253 ***	0.419
Telecommunication Service Providers	−0.101	0.099	−0.054	0.053	−0.064	0.049	−0.094	0.118
Tires	−0.101	0.150	−0.043	0.060	−0.055	0.052	0.213	0.204
Tobacco	−0.107	0.088	0.079	0.065	0.040	0.052	0.178	0.129
Transport Services	−0.239	0.227	−0.080	0.073	−0.120 *	0.064	−0.118	0.185
Travel and Leisure	−0.215 **	0.101	0.034	0.058	−0.018	0.054	−0.424 ***	0.163
Trucking	−0.117	0.294	−0.039	0.105	−0.059	0.098	0.050	0.276

Notes: The coefficients in columns (2), (4), and (8) represent the regression parameters from a regression of stock returns for the sectors listed in column (1) on: (1) the change in the log of Dubai spot crude oil prices driven by global aggregate demand (column (2)), (2) the change in the log of Dubai spot crude oil prices driven by supply (column (4)), (3) the KRW/USD nominal exchange rate (column (8)), and (4) the return on the Korean stock market (not reported). The coefficients in column (6) represent the regression parameters from a regression of stock returns for the sectors listed in column (1) on: (1) the change in the log of Dubai spot crude oil prices (column (6)), (2) the return on the Korean stock market (not reported), and (3) the KRW/USD nominal exchange rate (not reported). Following Hamilton [17], the change in crude oil prices driven by aggregate demand factors is captured by regressing the change in the log of oil prices on the change in the log of future copper prices, the change in the ten-year Treasury constant maturity interest rate, and the change in the log of the trade-weighted USD exchange rate. The change in oil prices driven by oil supply and other factors is measured as the residuals from this regression. The regressions were all run over February 2001 to December 2019 period. Columns (3), (5), (7), and (9) report heteroskedasticity and autocorrelation-consistent standard errors. *** (**) [*] denote significance at the 1% (5%) [10%] levels.

4.1. Results for Japan

Table 2 presents the results for 57 Japanese sectors. Column (2) presents the coefficients on oil price changes driven by global aggregate demand shocks (Oildd) and column (3) presents the associated HAC standard errors. Of the 57 sectors, 24 exhibit positive and statistically significant exposures to Oildd and 17 exhibit negative and statistically significant exposures. Those exhibiting positive exposures are largely those Japanese sectors that compete in global markets. These sectors include four different types of machinery industries (construction, industrial, specialized, and tools), consumer electronics, industrial engineering, industrial suppliers like Japanese trading companies (*sogo shosha*), electronic and electrical equipment, luxury items (primarily watches), electronic components, automobiles, and auto parts. In addition, sectors related to the oil industry gain from increases in Oildd. For all of these sectors, the benefits of the increased global demand offset the costs arising from higher oil prices.

The sectors harmed by increases in Oildd are those that focus on the domestic market. These include home furnishings, railroads, transport services, delivery services, electricity, restaurants and bars, and food producers. These sectors do not gain from increases in global aggregate demand, but suffer from higher costs as oil prices increase. For instance, higher oil prices increase the cost of running tractors and thus the cost of producing food. As Taghizadeh-Hesary et al. [27] noted that oil and other fossil fuels are essential inputs to agricultural production. In addition, as Ready [28] noted, higher oil prices reduce consumers' discretionary income and thus their ability to spend on domestic goods. Higher oil prices also harm the cosmetics industry by increasing input costs and decreasing consumers' capacity to purchase non-essential items.

Column (4) presents the coefficients on oil price changes driven by supply factors (Oilss) and column (5) presents the associated HAC standard errors. Of the 57 sectors, 7 exhibit positive and statistically significant exposures to Oilss and three exhibit negative and statistically significant exposures. Four of those exhibiting positive exposures are related to the oil industry. In addition, the industrial engineering, industrial suppliers, and industrial materials sectors benefit from oil price increases driven by supply factors. Japanese industrial firms excel at providing goods and services that are needed when energy prices increase, and the beneficial effect of increases in Oilss reflects the increased demand for Japanese products that arises when oil prices increase.

The sectors harmed by increases in Oilss are tires, construction, and home construction. Oil is one of the largest costs for tire manufacturers and they lose when supply factors drive up oil prices. The costs of moving items to construction sites and paying for electricity rise as oil prices increase. Thus the construction industry suffers from higher oil prices. The coefficients on electricity and airlines are also large and statistically significant at the 10% level. The electricity industry uses various energy sources including oil and suffers when oil prices increase. Airlines also depend on oil and are harmed by oil price increases.

Column (6) presents the coefficients on the total oil price changes and column (7) presents the associated HAC standard errors. Fourteen sectors gain from oil price increases and fifteen sectors lose. Many of these sectors exhibit the same responses to Oildd and Oilss and to overall oil price changes. Three industrial sectors (industrial engineering, industrial suppliers, and machinery: industrial) have positive exposures to Oildd and Oilss and also to overall oil prices. In addition, several oil-related sectors (crude oil production, oil equipment and services, and international oil and gas) benefit from increases in Oildd and Oilss and from increases in overall oil prices. Electricity, home construction, and airlines have negative coefficients on Oildd and Oilss and on overall oil price changes. The betas to total oil price changes in column (6) are closely related to the betas to Oildd and Oilss in columns (2) and (4). Regressing the total oil price betas on the Oildd betas yields a

coefficient of 0.40 with a *t*-statistic of 11.44 and regressing the total oil price betas on the Oilss betas yields a coefficient of 1.10 and a *t*-statistic of 16.71.

Column (8) presents the coefficients on the JPY/USD exchange rate and column (9) presents the associated HAC standard errors. Those exhibiting positive exposures (implying that a JPY depreciation raises returns) are largely those Japanese sectors that compete in global markets. These include automobiles, auto parts, construction machinery, and consumer electronics. The sectors that benefit from a weaker JPY exchange rate overlap with the sectors that benefit from an increase in oil prices driven by global aggregate demand. Regressing the coefficients on Dubai oil price changes driven by aggregate demand in column (2) on the coefficients on the JPY/USD exchange rate in column (8) yields a coefficient of 0.31 with a *t*-statistic of 3.67.

To shed further light on why increases in oil prices due to supply factors as reported in column (4) of Table 2 benefit Japanese industrial sectors, Table 3 reports elasticities for individual Japanese industrial companies with statistically significant exposures to Oilss. Out of 81 firms in the categories of industrial engineering, industrial suppliers, industrial materials, and machinery: industrial, 9 benefit from increases in oil prices driven by supply factors and none are harmed.

4.2. Results for South Korea

Table 4 presents the results for 64 Korean sectors. Column (2) presents the coefficients on oil price changes driven by global aggregate demand shocks (Oildd) and column (3) presents the associated HAC standard errors. Of the 64 sectors, 10 exhibit positive and statistically significant exposures to Oildd and 11 exhibit negative and statistically significant exposures. In column (2) of Table 4, sectors benefiting from global demand such as iron and steel and marine transport (i.e., shipbuilding) gain. The commercial vehicle sector gains as higher oil prices increase the demand for public transportation as opposed to using private vehicles. As with Japan, sectors related to the food industry such as food producers and drug and grocery stores are hurt by higher oil prices. As discussed above, higher oil prices increase the cost of producing food and also decrease the discretionary income of consumers. As with Japan, higher oil prices also harm the cosmetics industry by increasing the costs of inputs and reducing the ability of consumers to purchase non-essentials.

In column (4) of Table 4 for Korea, the sectors harmed from oil price increases driven by supply factors are airlines, industrial transportation, and electricity. Fuel costs are paramount for airlines and industrial transportation, and higher oil prices raise their costs. Oil is also one input to electricity generation. No sectors benefit from oil price increases driven by supply side factors.

Columns (6) and (8) of Table 4 for Korea present the betas to total oil price changes and the KRW/USD exchange rate. Again the betas to total oil price changes in column (6) are closely related to the betas of Oildd and Oilss in columns (2) and (4). Regressing the total oil price betas on the Oildd betas yields a coefficient of 0.26 with a *t*-statistic of 7.31 and regressing the total oil price betas on the Oilss betas yields a coefficient of 0.89 and a *t*-statistic of 14.13. Also, there is again a positive relationship between sectors that gain from increases in global demand in column (2) and sectors that gain from a weaker currency in column (8). Regressing the Oildd betas on the KRW/USD betas yields a coefficient of 0.22 with a *t*-statistic of 2.68.

One important implication of these results is that several sectors in Korea gain during times of high oil prices if price increases are driven by increases in global demand. These include iron and steel, shipbuilding, and commercial vehicles. Another implication is that several sectors are harmed by oil price increases, whether driven by aggregate demand or by supply side factors. These include airlines, drug and grocery stores, consumer

staples, food producers, industrial transportation, and cosmetics. No sectors benefit from supply-driven oil price increases.

5. Discussion

The results indicate that many sectors in Japan and Korea are exposed to oil price changes. Figure 1 shows that oil prices can fluctuate violently. Hari [29] noted that tariffs, trade wars, and geopolitical shocks will continue disrupting oil markets. The findings in Tables 2–4 indicate that the resulting oil price changes will whipsaw the economy. As Hari argued, governments should respond by expediting the shift to renewable energy sources.

Japan in 2025 approved a plan to reduce greenhouse gas emissions by 63% by 2035 and 73% by 2040 relative to 2013 levels. The plan involves raising solar energy sources from 9.8% in 2023 to between 22% and 29% in 2040, raising nuclear power sources from 8.5% to 20%, and reducing fossil fuel sources from over 80% to between 30% and 40%. Korea plans to decrease greenhouse gas emissions by 40% by 2030 compared to 2018 levels. As so many firms are exposed to oil price changes, Japan and Korea should be more ambitious in switching from fossil fuels to renewables. Investing in technologies to improve wind, hydro, and solar power would not only help them to reach their climate goals, but also reduce firms' exposures to oil price changes.

One problem is that renewable energy sources can be more expensive and unpredictable than fossil fuels. Clean energy relies on sunshine, wind, and other intermittent sources. If Japan and Korea and other northeast Asian neighbors could partner together, they could develop more affordable and reliable sources of renewable energy (the Korea Energy Foundation [30]). If they could strengthen infrastructure for receiving, storing, and distributing power produced by their neighbors, they could reduce the volatility associated with clean energy (Xiangchengzhen and Yilmaz [31]). Hama [32] reported that the Korean government rejected an offshore wind farm because there was an insufficient grid capacity. Europe and southeast Asia share energy across countries. Northeast Asia should learn from them.

Another problem is that Japan and Korea are mountainous. As Dempsey [33] discussed, this means that there is less room for solar farms. One solution would be to use perovskite cells. These are 20 times thinner than regular solar panels and can be used in smaller spaces. Governments should continue sponsoring research into this technology.

Individual sectors and firms should also reduce their exposure to oil prices. Tables 2 and 4 indicate that airlines in both Japan and Korea are harmed by higher oil prices. As Russell [34] reported, airlines aim to achieve carbon neutrality by 2050. A major step would be to replace fossil fuels with sustainable aviation fuel (SAF). While SAF could cut the carbon dioxide output by 80%, Russell noted that it is four times more expensive than fossil jet fuels. For this reason, Japan Airline's SAF use in 2023 was 0.012%, All Nippon Airways' SNF use was less than 0.1%, and Korean Airlines' use was also miniscule. In addition to using SAF, airlines could reduce emissions by reorganizing flight plans, adjusting flap angles during takeoff, releasing the landing gear later, and adjusting other procedures. They could also employ newer fuel-efficient planes. These steps are costly. However, tourists visiting Japan have increased from 25 million in 2023 to 36.8 million in 2024, to projections of more than 40 million in 2025 (the Japanese tourist statistics are available at https://statistics.jnto.go.jp/en/ and forecasts for 2025 come from Naoya Haraikawa, Commissioner of the Japan Tourism Agency (see Terada [35]). Tourists visiting Korea increased from 11 million in 2023 to 16.4 million in 2024 to projections of 19 million in 2025 (these data come from *Straits Times* [36] and from Yanolja Research [37]). If governments levied a small surcharge on tourists, they could help fund airlines' decarbonization efforts.

The results indicate that cosmetics sectors in both Japan and Korea are exposed to oil price increases. Many cosmetic products rely on petrochemicals. These could be replaced by environmentally friendly products. For instance, petrochemicals could be replaced by oleochemicals derived from vegetable oils and other renewable materials. As oleochemicals contain fewer carcinogens than petrochemicals, they are not only more sustainable, but also healthier for consumers in the long run (see Nogueria et al. [38]).

Food producers are exposed to oil price increases. Both countries should provide incentives for the adoption of smart farms. These use information and communication technology (ICT) and data to grow food more sustainably. Mi et al. [39] found that people who graduated from specialized schools and vocational colleges were more likely to adopt smart farming and ICT methods. Subsidizing education at these institutes could help promote sustainable farming practices.

The travel and leisure sectors in both Japan and Korea are harmed by oil price increases. Hotels could switch to renewable energy sources. For instance, Japan's Super Hotels have achieved carbon neutrality across their 173 hotels in Japan (Tanimoto [40]). This not only reduces their exposure to fossil fuel prices, but also helps attract customers, as 73% of people surveyed said that they wanted to travel in a sustainable manner in 2025 (Tanimoto [40]). A small surcharge on tourists could help to fund this transition.

Promoting the use of electric vehicles (EVs) instead of internal combustion engine vehicles could also reduce countries' dependence on oil. Research has indicated that increasing the number of charging facilities and ensuring their full functioning is more cost-effective than providing consumers with subsidies (Kim [41]). It is also important to raise the quantity and quality of charging infrastructure at travel hubs such as highway rest stops. Governments in Japan and Korea are working in these areas, and to promote decarbonization and protect their economies from shocks arising from oil price changes, they should redouble their efforts.

Semiconductor manufacturing requires massive amounts of energy. Within the electronics supply chain, Gupta et al. [42] found that the majority of the carbon output of electronic goods such as smartphones and computers comes from manufacturing the semiconductors inside the electronic devices. To be more environmentally friendly, semiconductor producers in Japan and Korea should decrease the share of high global-warming potential gases used in manufacturing, reduce the energy requirements of their furnaces, clean rooms and other machines, and transport their final products to customers in fuel-efficient ways (McKinsey [43]). In addition, by consciously designing chips that employ less energy, such as by layering integrated circuits on top of each other in a 3D manner, they could slash their carbon footprints (Salata Institute [44]).

Unlike Japan, Korea has no sectors in Table 4 that gain from oil price increases driven by supply side factors. Several Japanese industrial firms excel at providing goods and services that are needed when energy prices increase, and supply-driven increases in oil prices raise the demand for Japanese products. Korean firms could become more resilient by following Japanese firms up the technology ladder and producing products that are needed as oil prices increase.

Japan has often resorted to blanket subsidies to offset the burden of high energy prices. For instance, starting in 2022, it provided subsidies to oil wholesalers in order to lower gasoline and fuel prices for final users. It also provided subsidies to reduce electricity and gas bills. By August 2023, it had spent JPY 6.3 trillion on fuel subsidies (Kishida [45]). Starting in 2025, it provides subsidies when gasoline prices exceed JPY 185 per liter. Subsidies encourage fossil fuel consumption, work against decarbonization, and impose large fiscal costs. The findings that many Japanese sectors gain from higher oil prices indicate that the Japanese government should not provide universal subsidies,

but rather target subsidies only towards those sectors and individuals that suffer from oil price hikes.

There are many factors hindering the adoption of sustainable energy sources. One is complacency and inertia towards adopting new production techniques. Another is the high initial costs of change. A third is apprehension about whether renewable energy will be as reliable as fossil fuels. A fourth is concerns among firms that they might lose competitiveness relative to firms that do not transition to renewable energy sources.

Governments, firms, scholars, and other stakeholders should focus on addressing these problems. They should nurture a sense of urgency towards adopting eco-friendly techniques. They should consider special taxes such as levies on tourists to fund the required technological changes. They should learn lessons from failures of renewable energy sources in other countries. They should develop reliable methods to highlight to consumers the firms that are actually adopting greener production methods. They should initiate pilot projects and scale up those that prove successful. Universities, businesses, industry organizations, and think tanks should work together to study how to transition to sustainable energy sources and then disseminate their findings.

6. Conclusions

Oil plays a vital role in Japan and Korea's energy mix. Almost all of this oil is imported. Researchers have argued that oil price increases should act as a tax on firms relying on imported oil and that it should transfer wealth from oil importers to oil exporters (Fernald and Trehan [1] and Golub [2]). For these reasons, the IMF [46] argued that oil price increases would produce large decreases in stock prices for importing countries such as Japan and Korea.

To investigate these effects, this paper examines how oil prices changes affect sectoral stock returns. Since stock prices equal the expected present value of future earnings, this approach sheds light on how they affect sectoral profits and output. This paper also uses Hamilton's [3] method to distinguish between oil price changes driven by global aggregate demand and by oil supply.

Contrary to the predictions of Fernald and Trehan [1], Golub [2], and the IMF [46], the results indicate that stock returns in many sectors in Japan and Korea gain from oil price increases. For both countries, aggregate demand-driven oil price increases raise share prices for sectors that compete in world markets such as machinery, electronic components, consumer electronics, and shipbuilding. For Japan, supply-driven oil price increases raise share prices for the industrial and engineering sectors. This reflects the fact that Japanese firms provide crucial products that agents demand when oil prices increase.

Japan and other countries often use blanket subsidies to offset the burden of rising oil prices. These subsidies encourage fossil fuel consumption. The evidence reported here that many sectors gain from higher oil prices militates against universal subsidies. Limited benefits targeted to sectors that lose from higher oil prices or to poorer households would be wiser fiscally and more salutary environmentally.

The results indicate that many sectors in both countries suffer from oil price increases. These are largely sectors oriented towards the domestic economy such as food producers, railroads, hotels, restaurants, and delivery services.

Oil prices will remain volatile as tariffs, trade wars, monetary and fiscal policy changes, and other factors impact global aggregate demand, and as OPEC decisions, wars, geopolitical events, and other factors impact oil supply. Since many sectors are affected positively or negatively by oil price changes, oil price volatility will disrupt markets.

Individual sectors and firms should reduce their exposure to oil prices. This would not only make them more resilient to oil prices, but also promote sustainability. The

airline industry could do this by using sustainable aviation fuel, reorganizing flight plans, adjusting flap angles during takeoff, releasing the landing gear later, and employing fuel-efficient planes. The cosmetics sector could do this by replacing petrochemicals with environmentally friendly products such as oleochemicals. Food producers could do this by adopting smart farms. Hotels could do this by switching to renewable energy sources. Semiconductor manufacturers could do this by decreasing the share of high global-warming potential gases used in manufacturing, reducing the energy requirements of their equipment, and transporting goods to their customers in fuel-efficient ways. Governments should encourage firms in these and other sectors to move in these eco-friendly directions.

This paper has examined how oil prices affect sectoral stock returns. Future research should investigate how they impact sectoral profits, output, and investment. Impulse response functions could be used to trace out the impact of demand- and supply-driven oil price changes on sectoral variables over time.

Future research could also extend the results to many other countries. It could examine how the impact of oil price changes on stock returns differs between oil-exporting and oil-importing countries, between advanced and developing economies, and between countries with comparative advantages in advanced manufacturing, labor-intensive manufacturing, and commodities.

Oil prices will remain volatile and whipsaw the Japanese and Korean economies. To stay resilient, both countries should expedite their transitions from fossil fuels to sustainable energy sources. They are targeting carbon neutrality by 2050. However, because of the need to import oil and the damage to large swaths of their economies from oil price swings, they should expedite the process.

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Appendix A

Table A1. Regression diagnostics from estimating the exposure of Japanese sectors to oil price changes and the JPY/USD exchange rate.

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Airlines	0.234	0.055	1.00	0.790	−16.8 ***	−16.8 ***	−16.8 ***
Aluminum	0.444	0.071	2.58 *	1.66	−14.8 ***	−14.8 ***	−14.8 ***
Automobiles	0.700	0.036	1.78	1.06	−14.9 ***	−14.9 ***	−14.9 ***
Auto Parts	0.754	0.035	0.035	1.21	−14.7 ***	−14.7 ***	−14.7 ***

Table A1. *Cont.*

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Banks	0.667	0.042	1.34	1.20	−14.8 ***	−14.8 ***	−14.8 ***
Biotechnology	0.078	0.129	1.53	1.14	−16.2 ***	−16.2 ***	−16.2 ***
Cement	0.342	0.074	0.06	1.73	−16.5 ***	−16.5 ***	−16.6 ***
Chemicals	0.830	0.025	2.42 *	1.22	−14.7 ***	−14.7 ***	−14.7 ***
Construction	0.408	0.051	2.05	0.86	−16.9 ***	−16.9 ***	−16.9 ***
Consumer Electronics	0.552	0.058	0.19	1.75	−14.4 ***	−14.5 ***	−14.4 ***
Consumer Staples	0.857	0.020	0.16	2.06 *	−12.5 ***	−12.5 ***	−12.5 ***
Cosmetics	0.296	0.051	0.053	0.34	−15.3 ***	−15.4 ***	−15.0 ***
Delivery Services	0.379	0.051	1.21	0.20	−15.6 ***	−15.7 ***	−15.7 ***
Electronic and Electrical Equipment	0.809	0.028	0.60	0.54	−14.7 ***	−14.7 ***	−14.6 ***
Electronic Equipment: Controls	0.400	0.063	041	1.44	−8.6 ***	−8.6 ***	−8.6 ***
Electronic Equipment: Gauges	0.754	0.032	0.08	0.60	−13.1 ***	−13.2 ***	−13.0 ***
Electronic Equipment: Pollution	0.279	0.065	5.88 ***	2.83 **	−15.0 ***	−15.0 ***	−15.0 ***
Electronic Office Equipment	0.611	0.040	4.31 **	3.74 ***	−13.3 ***	−13.3 ***	−13.4 ***
Electricity	0.144	0.063	0.93	1.05	−16.2 ***	−16.1 ***	−16.2 ***
Electronic Component	0.778	0.033	0.67	0.33	−14.6 ***	−14.6 ***	−14.6 ***
Fishing and Farming	0.319	0.045	0.09	0.46	−14.4 ***	−14.4 ***	−14.4 ***
Fertilizers	0.237	0.086	0.11	2.06 *	−13.6 ***	−13.6 ***	−13.6 ***
Food Producers	0.414	0.030	0.40	1.49	−17.3 ***	−17.3 ***	−17.1 ***
Food Retail and Wholesale	0.382	0.043	1.41	0.96	−16.3 ***	−16.4 ***	−16.3 ***
Gas Distribution	0.211	0.038	0.10	0.72	−15.4 ***	−15.4 ***	−15.4 ***
General Industrials	0.702	0.040	0.90	3.91 ***	−13.7 ***	−13.6 ***	−13.7 ***

Table A1. *Cont.*

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Health Care	0.549	0.029	0.72	1.09	−14.3 ***	−14.2 ***	−14.3 ***
Home Furnishings	0.389	0.043	1.08	0.55	−15.9 ***	−15.9 ***	−15.9 ***
Home Construction	0.597	0.040	3.66 **	1.66	−15.5 ***	−15.5 ***	−15.6 ***
Hotels	0.391	0.055	0.06	0.81	−14.8 ***	−14.8 ***	−14.8 ***
Industrial Engineering	0.821	0.029	1.21	1.16	−14.4 ***	−14.4 ***	−14.4 ***
Industrial Suppliers	0.632	0.045	3.54 **	3.91 **	−14.4 ***	−14.4 ***	−14.3 ***
Industrial Materials	0.347	0.057	2.47 *	2.01	−16.0 ***	−16.0 ***	−16.0 ***
International Oil and Gas	0.460	0.057	0.50	2.37 *	−13.8 ***	−13.8 ***	−13.8 ***
Iron and Steel	0.664	0.047	0.25	0.57	−14.6 ***	−14.5 ***	−14.6 ***
Leisure Goods	0.703	0.036	0.21	1.79	−12.7 ***	−12.7 ***	−12.7 ***
Luxury Items	0.452	0.064	0.60	1.73	−13.5 ***	−13.5 ***	−13.6 ***
Machinery: Agriculture	0.509	0.063	9.08 ***	1.62	−15.3 ***	−15.3 ***	−15.2 ***
Machinery: Construction	0.607	0.058	0.38	1.64	−14.6 ***	−14.5 ***	−14.6 ***
Machinery: Industrial	0.759	0.033	0.88	1.35	−14.7 ***	−14.7 ***	−14.7 ***
Machinery: Specialized	0.661	0.045	0.19	5.70***	−13.8 ***	−13.8 ***	−13.8 ***
Machinery: Tools	0.633	0.052	2.03	2.32 *	−12.9 ***	−12.8 ***	−12.9 ***
Marine Transport	0.538	0.064	0.96	1.44	−15.6 ***	−15.6 ***	−15.6 ***
Medical Equipment	0.461	0.046	0.67	1.61	−15.5 ***	−15.3 ***	−15.5 ***
Nonferrous Metals	0.599	0.056	2.51 *	0.68	−15.3 ***	−15.3 ***	−15.3 ***
Oil Equipment and Services	0.446	0.089	1.27	2.15 *	−14.9 ***	−14.9 ***	−15.0 ***
Oil Refining and Marketing	0.319	0.064	1.34	1.76	−13.1 ***	−13.1 ***	−13.2 ***
Oil: Crude Production	0.492	0.055	3.57 **	1.49	−14.1 ***	−14.1 ***	−14.1 ***

Table A1. *Cont.*

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Pharmaceuticals	0.456	0.034	2.79 *	0.84	−15.2 ***	−15.3 ***	−15.1 ***
Railroads	0.460	0.031	0.43	0.25	−16.3 ***	−16.3 ***	−16.3 ***
Restaurants and Bars	0.413	0.032	1.29	0.44	−14.9 ***	−15.1 ***	−14.9 ***
Semiconductors	0.596	0.057	0.03	0.92	−13.3 ***	−13.3 ***	−13.4 ***
Technology Hardware	0.739	0.037	0.96	0.63	−13.0 ***	−13.1 ***	−13.0 ***
Tires	0.470	0.053	0.79	1.78	−16.8 ***	−16.7 ***	−16.7 ***
Transport Services	0.576	0.041	3.23 **	1.41	−15.5 ***	−15.4 ***	−15.4 ***
Travel and Leisure	0.542	0.031	0.32	1.54	−15.2 ***	−15.3 ***	−15.2 ***
Trucking	0.481	0.037	1.39	0.61	−15.7 ***	−15.7 ***	−15.7 ***

Notes: The table presents diagnostic statistics for the results reported in Table 2. Column (3) reports the standard error of regression. Column (4) reports the F-statistic from the Breusch–Godfrey serial correlation test of the null hypothesis of no serial correlation. Column (5) reports the F-statistic from the Breusch–Pagan–Godfrey heteroskedasticity test of the null hypothesis of homoscedasticity. Columns (6) through (8) report augmented Dickey–Fuller test statistics of the null hypothesis that returns on the sectors in column (1) which have a unit root. *** (**) [*] denote significance at the 1% (5%) [10%] levels.

Table A2. Regression diagnostics from estimating the exposure of South Korean sectors to oil price changes and the KRW/USD exchange rate.

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept Only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Airlines	0.378	0.097	2.46 *	1.81	−15.5 ***	−15.5 ***	−15.4 ***
Asset Managers	0.087	0.064	1.40 *	2.36 *	−11.0 ***	−11.2 ***	−10.9 ***
Auto Parts	0.423	0.068	0.33	0.49	−13.7 ***	−13.8 ***	−13.5 ***
Automobiles	0.408	0.072	1.07	2.93 **	−14.0 ***	−14.0 ***	−14.0 ***
Banks	0.642	0.051	1.13	6.80 ***	−14.2 ***	−14.3 ***	−14.2 ***
Basic Materials	0.646	0.043	0.21	1.05	−13.2 ***	−13.3 ***	−13.5 ***
Basic Resources	0.536	0.052	2.32	1.25	−13.9 ***	−14.0 ***	−13.8 ***
Biotechnology	0.039	0.160	2.42 *	1.22	−12.3 ***	−12.3 ***	−12.1 ***
Casinos/Gambling	0.136	0.076	2.45 *	1.19	−16.2 ***	−16.2 ***	−16.2 ***
Cement	0.265	0.128	2.59 *	1.47	−16.1 ***	−16.1 ***	−16.1 ***
Chemicals	0.486	0.069	1.97	0.70	−13.9 ***	−14.0 ***	−13.8 ***

Table A2. *Cont.*

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept Only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Commercial Vehicles and Parts	0.378	0.094	1.39	0.43	−16.7 ***	−16.7 ***	−16.4 ***
Computer Hardware	0.262	0.085	1.37	0.90	−12.8 ***	−12.9 ***	−12.8 ***
Computer Services	0.061	0.080	0.48	0.63	−11.1 ***	−11.3 ***	−10.9 ***
Consumer Digital Services	0.296	0.100	1.05	0.70	−14.9 ***	−14.9 ***	−14.6 ***
Construction and Materials	0.525	0.023	2.73 *	0.40	−14.9 ***	−15.2 ***	−14.9 ***
Construction	0.435	0.074	0.27 **	1.60 **	−15.0 ***	−15.4 ***	−15.0 ***
Consumer Discretionary	0.691	0.039	2.20	0.49	−13.3 ***	−13.3 ***	−13.1 ***
Consumer Electronics	0.49	0.070	0.45	0.57	−13.6 ***	−13.5 ***	−13.6 ***
Consumer Products and Services	0.519	0.040	3.46 **	0.26	−13.9 ***	−13.9 ***	−13.6 ***
Consumer Staples	0.672	0.040	2.73 *	0.30	−13.8 ***	−13.8 ***	−13.6 ***
Cosmetics	0.106	0.095	0.14	1.55	−15.1 ***	−15.4 ***	−14.7 ***
Diversified Industrials	0.526	0.069	2.27	0.60	−14.4 ***	−14.4 ***	−14.3 ***
Diversified Retail	0.365	0.066	0.13	1.23	−14.2 ***	−14.6 ***	−16.2 ***
Drug/Grocery Stores	0.114	0.091	1.04	0.76	−13.3 ***	−13.4 ***	−13.1 ***
Electronic Entertainment	0.091	0.121	0.07	2.09 *	−14.7 ***	−14.7 ***	−14.6 ***
Electricity	0.185	0.067	1.52	1.20	−15.4 ***	−15.4 ***	−15.4 ***
Electronic Components	0.424	0.074	0.28	0.76	−13.1 ***	−13.2 ***	−13.0 ***
Energy	0.443	0.069	1.37	0.55	−16.2 ***	−16.3 ***	−16.1 ***
Financial Data Providers	0.294	0.077	1.95	3.95 ***	−13.6 ***	−13.6 ***	−13.6 ***
Food Producers	0.269	0.061	1.12	4.13 ***	−15.8 ***	−15.6 ***	−15.7 ***
Health Care	0.063	0.111	2.67 *	0.10	−17.6 ***	−17.6 ***	−17.2 ***
Household Equip. Production	0.207	0.091	2.93 *	0.40	−12.6 ***	−12.8 ***	−12.4 ***
Industrial Engineering	0.470	0.082	0.57	0.39	−15.1 ***	−15.4 ***	−15.1 ***

Table A2. *Cont.*

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept Only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Industrial Goods and Services	0.740	0.041	0.68	0.52	−14.4 ***	−14.6 ***	−14.4 ***
Industrial Metals and Mines	0.535	0.052	2.19	0.27	−13.9 ***	−14.0 ***	−13.9 ***
Industrial Support Systems	0.301	0.071	1.64	4.33 ***	−17.0 ***	−17.2 ***	−17.0 ***
Industrial Transport	0.427	0.074	2.16	0.96	−16.0 ***	−16.1 ***	−16.0 ***
Insurance	0.439	0.046	2.19	0.67	−15.2 ***	−15.6 ***	−15.1 ***
Investment Banks and Brokers	0.662	0.059	0.10	1.12	−16.5 ***	−16.5 ***	−16.5 ***
Iron and Steel	0.495	0.057	1.78	1.41	−14.0 ***	−13.9 ***	−13.9 ***
Leisure Goods	0.434	0.067	2.12	0.13	−13.2 ***	−13.2 ***	−13.2 ***
Life Insurance	0.218	0.047	0.96	1.01	−12.0 ***	−12.0 ***	−11.9 ***
Machinery: Industrial	0.310	0.118	0.18	0.92	−15.7 ***	−15.8 ***	−15.6 ***
Marine Transport	0.418	0.085	0.03	0.83	−14.4 ***	−14.5 ***	−14.4 ***
Nonlife Insurance	0.402	0.060	2.15	0.81	−15.5 ***	−15.7 ***	−15.3 ***
Oil Refining and Marketing	0.295	0.081	0.72	1.45	−15.7 ***	−13.1 ***	−13.2 ***
Personal Goods	0.172	0.078	0.03	1.13	−14.6 ***	−14.9 ***	−14.1 ***
Personal Product	0.118	0.092	1.09	0.78	−13.3 ***	−13.5 ***	−13.1 ***
Pharmaceutical and Biotech	0.063	0.111	2.67 *	0.09	−17.6 ***	−17.6 ***	−17.2 ***
Pharmaceuticals	0.038	0.137	3.36 **	0.15	−8.6 ***	−8.6 ***	−8.6 ***
Precious Metals and Mines	0.299	0.097	2.12	2.27 *	−13.1 ***	−13.1 ***	−13.0 ***
Retailers	0.360	0.065	0.25	1.43	−14.3 ***	−14.8 ***	−14.3 ***
Software and Computer Services	0.299	0.096	0.08	0.99	−15.8 ***	−15.4 ***	−15.9 ***
Security Systems	0.109	0.071	6.10 ***	8.92 ***	−18.9 ***	−19.0 ***	−19.6 ***
Semiconductors	0.236	0.142	1.46	1.32	−3.8 ***	−4.1 ***	−3.8 ***
Technology Hardware	0.403	0.082	0.36	2.25 *	−13.6 ***	−13.7 ***	−13.6 ***
Telecommunication Equipment	0.198	0.078	3.12 **	1.08	−13.3 ***	−13.4 ***	−13.2 ***
Telecommunication Service Providers	0.196	0.055	2.82 *	0.95	−16.7 ***	−16.7 ***	−16.7 ***

Table A2. *Cont.*

(1)	(2)	(3)	(4)	(6)	(7)	(8)	(9)
Sector	**Adjusted R-Squared**	**S.E.R.**	**Breusch–Godfrey Serial Correlation LM Test (2lags)**	**Heteroskedasticity Test: Breusch–Pagan–Godfrey**	**ADF Test Statistic (Intercept Only)**	**ADF Test Statistic (Intercept and Trend)**	**ADF Test Statistic (No Intercept or Trend)**
Tires	0.252	0.083	0.91	0.76	−16.0 ***	−16.3 ***	−15.8 ***
Tobacco	0.025	0.061	1.52	0.83	−16.1 ***	−15.8 ***	−16.0 ***
Transport Services	0.081	0.071	0.64	0.35	−12.3 ***	−12.4 ***	−12.3 ***
Travel and Leisure	0.408	0.058	3.06 **	1.99 *	−14.8 ***	−14.9 ***	−14.8 ***
Trucking	0.098	0.105	1.96	1.52	−14.2 ***	−14.2 ***	−14.2 ***

Notes: The table presents diagnostic statistics for the results reported in Table 4. Column (3) reports the standard error of regression. Column (4) reports the F-statistic from the Breusch–Godfrey serial correlation test of the null hypothesis of no serial correlation. Column (5) reports the F-statistic from the Breusch–Pagan–Godfrey heteroskedasticity test of the null hypothesis of homoscedasticity. Columns (6) through (8) report augmented Dickey–Fuller test statistics of the null hypothesis that returns on the sectors in column (1) which have a unit root. *** (**) [*] denote significance at the 1% (5%) [10%] levels.

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