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Modelling economic policy issues

Does COVID-19 play any role in the asymmetric relationship between oil prices and exchange rates? Evidence from South Korea

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The primary contribution of the present research is to explicitly take into consideration the role that the current outbreak of coronavirus diseases proxied by the COVID-19 index plays when studying the asymmetric impact that oil prices have on the South Korean won (KRW)/US dollar (USD) exchange rate. We discover that the COVID-19 pandemic seems to have been a significant factor in affecting the asymmetric impact of oil prices on the KRW/USD rate in both the short and long run.

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1. Introduction

The COVID-19 pandemic has triggered the deepest global recession since the end of World War II. In this short empirical paper, our modest and incremental contribution to the literature is to allow for the role that COVID-19 may play when studying the nexus between oil prices and a country’s exchange rate.

Many authors have analyzed the impacts that oil prices have on exchange rates. Early studies commonly assume that changes in the price of crude oil symmetrically influence a country's exchange rate – that is, the effects of oil price hikes on exchange rates are regarded as the exact opposite of those of oil price declines – and analyze the subject using symmetrical linear regression methods. Among others, see Amano and Van Norden (1998), Chaudhuri and Daniel (1998), Huang and Guo (2007), Benassy-Quere et al. (2007), Chen and Chen (2007), Narayan et al. (2008), Nikbakht (2010), Ghosh (2011), Mohammadi and Jahan-Parvar (2012), Reboredo (2012), Wu et al. (2012). Lately, a small but expanding body of work has claimed that, since the foreign exchange market is likely to have different reactions towards ups and downs of oil prices in practice, previous analyses may be misspecified (see Iwayemi and Fowowe, 2011; McLeod and Haughton, 2018; Kisswani et al., 2019; Baek and Kim, 2020; Baek, 2021). When tackling the subject, therefore, the recent literature employs asymmetrical nonlinear regression methods. It is worth noting, however, that although it has been more than a year since the onset of the COVID-19 pandemic, little research has dealt with the asymmetry of exchange rates by

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See Baek (2021) for a complete literature review.

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incorporating a variable representing the current outbreak of coronavirus disease in a model. Evidently, there remains a strong need to learn more about the issue amidst the global COVID-19 pandemic.

Thus, our goal of the present research is to investigate whether COVID-19 influences the asymmetric relationship between oil prices and exchange rates, specifically the South Korean won (KRW)/US dollar (USD) exchange rate. The COVID-19 pandemic index recently constructed by Narayan et al. (2021) offers a great opportunity for us to shed light on such effects. The method we employ to accomplish this purpose is the nonlinear autoregressive distributed lag (NARDL) model, which is one of the most recent nonlinear regression methods and enables us to estimate cointegration and asymmetric nonlinearity simultaneously.

The next section illustrates our strategy adopted for our empirical modeling. Section 3 presents our key outcomes. Section 4 summarizes what we have learned from our empirical analyzes.

2. Methodology

In examining the asymmetry linkages between oil prices \((op_t)\) and the KRW/USD exchange rate \((er_t)\), we extend an empirical framework developed by Baek and Kim (2020) to include a variable representing COVID-19. Thus, our NARDL model looks like

\[
\Delta \log(er_t) = \alpha_0 + \sum_{k=1}^{p} \alpha_{1,t-k}\Delta \log(er_{t-k}) + \sum_{k=0}^{p} \alpha_{2,t-k}\Delta op_{t-k}^+ + \sum_{k=0}^{p} \alpha_{3,t-k}\Delta op_{t-k}^- \\
+ \sum_{k=0}^{p} \alpha_{4,t-k}\Delta \log(cov_{t-k}) + \gamma_0 \log(er_{t-1}) + \gamma_1 op_{t-1}^+ + \gamma_2 op_{t-1}^- + \gamma_3 \log(cov_{t-1}) + u_t
\]

(1)

where:

- \(er_t\) = the KRW/USD exchange rate,
- \(op_t^+\) = oil price increases gauged by \(\sum_{i=1}^{t} \max[\Delta \log(op_t, 0)]\),
- \(op_t^-\) = oil price decreases gauged by \(\sum_{i=1}^{t} \min[\Delta \log(op_t, 0)]\),
- \(cov_t\) = the COVID-19 index constructed by Narayan et al. (2021).

We summarize the steps for estimating Eq. (1) using the NARDL:

1. Obtain the long- and short-run impacts. The coefficients of \(\gamma_1, \gamma_2, \text{ and } \gamma_3\) divided by \(-\gamma_0\) exhibit the long-run impacts. The estimates attached to \(\Sigma\) denote the short-run impacts.
2. Form the Wald statistic to test for asymmetry (using the chi-square distribution). The null is symmetry in the long-run (short-run) - that is, \(H_0: \gamma_1 = \gamma_2 = \gamma_3\). Asymmetry is identified if the null is rejected.
3. Test for cointegration to avoid spurious regression. We can use the \(F\)-statistic to detect whether a set of \(\gamma_0, \gamma_1, \gamma_2, \text{ and } \gamma_3\) is different from zero and the \(t\)-statistic to determine whether \(\gamma_0\) is different from zero.\(^2\)

The data set comprises 343 daily observations from 6 January 2020 to 28 April 2021. The KRW/USD exchange rate \((er_t)\) comes from the Bank of Korea’s Economic Statistics System (ECOS). \(er_t\) measures KRW against USD, indicating that KRW appreciates as \(er_t\) declines. The U.S. Energy Information Administration (EIA) is the source of Brent Crude. Since the daily data set is used for analysis, there would be no need to turn \(er_t\) and \(op_t\) measured in nominal values into real values using consumer price Indexes. A daily index of COVID-19 constructed by Narayan et al. (2021) is used as a measure of the COVID-19 pandemic \((cov_t)\). The index analyzes 327 keywords from articles on COVID-19 in the 45 most popular newspapers worldwide and represents an overall measure of pandemic sentiments.

3. Empirical results

In this section, as an illustration of why incorporating the COVID-19 pandemic index in an exchange rate equation is useful, Eq. (1) is estimated with and without \(cov_t\).\(^3\) In the absence of \(cov_t\), we witness that the short-run coefficients on \(\Delta op_t^+\) and \(\Delta op_t^-\) are generally very significant (column (1) in Table 1). In the long run, however, none of these variables is individually significant. At this point, we must recall that finding an indication of whether oil prices asymmetrically influence the KRW/USD exchange rate would be of primary interest in the current article. It is revealed that the coefficients on \(op_t^+\) in both the short- and long-run seem to differ from the corresponding coefficients on \(op_t^-\) in terms of magnitude. Thus, the short- and long-run asymmetries appear to exist. To prove our assertion, however, the Wald statistic should be obtained. When we do this, the symmetry hypothesis in both the short- and long-run cannot be rejected at even the 10% level. Thus, we conclude that the KRW/USD rate does not behave differently to positive and negative changes in the price of oil prices in the short- and long-run.

\(^2\) Since we cannot use the usual critical values for the \(F\)- and \(t\)-statistics, Pesaran et al. (2001) tabulate the appropriate critical values for both tests.

\(^3\) A lag length of five is determined by AIC and shows no serial correlation for both models (Table 1).
We now turn to the outcomes of a model controlling for COVID-19 (column 2 in Table 1). We immediately detect that the coefficients on COVID-19 in the short- and long-run are highly significant. The significant estimates turn out to be all positive and conclude that a spike in COVID-19 cases tends to depreciate the KRW/USD exchange rate. One possibility is that, since the surge in new COVID-19 cases tends to have a detrimental effect on the global economy via the increased uncertainty, such an effect would likely push down South Korea’s exports and generate a trade deficit, thereby depreciating the KRW/USD rate. In fact, Fig. 1 illustrates that the identified empirical relationship between the COVID-19 pandemic index and the KRW/USD rate is visible. When then looking at the short-run coefficients on oil prices, they are generally very significant as in the absence of COVID-19 in the model. In addition, the long-run coefficients on oil prices now turn out to be significant with a positive sign, which means that a rise (drop) in oil prices depreciates (appreciates) the KRW/USD rate via an upsurge in production costs and a trade deficit. Further, as with the model in the absence of COVID-19, the fact that coefficient estimates on oil prices in the short- and long-run have different magnitudes from the corresponding estimates on oil prices leads us to suspect that there seem to be short- and long-run asymmetries. Again, the Wald statistics should be calculated to ensure the reliability of our observation. When we try this, the symmetry hypothesis in both the short- and long-run are now rejected at the 10% level. Further, the dynamic multiplier displays that an upsurge in oil prices seems to

### Table 1
Estimated coefficients of the Korean exchange rate models.

| Dependent variable: log($e_{t}$) | (1) | (2) | (3) |
|-----------------------------------|-----|-----|-----|
| **Panel A: Short-run results**    |     |     |     |
| $\Delta op_{t}$                   | 0.003 (1.992)** | 0.005 (2.678)** | 0.007 (2.585)** |
| $\Delta op_{t-1}$                 |     |     |     |
| $\Delta op_{t-2}$                 |     |     |     |
| $\Delta op_{t-3}$                 |     |     |     |
| $\Delta op_{t-4}$                 |     |     |     |
| $\Delta \log(coi_{t})$            |     |     |     |
| $\Delta coi_{t}$                  |     |     |     |
| $\Delta coi_{t-1}$                |     |     |     |
| $\Delta coi_{t-2}$                |     |     |     |
| $\Delta coi_{t-3}$                |     |     |     |
| $\Delta coi_{t-4}$                |     |     |     |
| $\Delta log(coi_{t})$             |     |     |     |
| $\Delta coi_{t}$                  |     |     |     |
| $\Delta coi_{t-1}$                |     |     |     |
| $\Delta coi_{t-2}$                |     |     |     |
| $\Delta coi_{t-3}$                |     |     |     |
| $\Delta coi_{t-4}$                |     |     |     |
| $\Delta coi_{t}$                  |     |     |     |
| $\Delta coi_{t-1}$                |     |     |     |
| $\Delta coi_{t-2}$                |     |     |     |
| $\Delta coi_{t-3}$                |     |     |     |
| $\Delta coi_{t-4}$                |     |     |     |
| **Panel B: Long-run results**     |     |     |     |
| $op_{t}$                          | 0.096 (1.537) | 0.112 (2.079)** | 0.109 (2.168)** |
| $op_{t-1}$                        | 0.064 (1.307) | 0.085 (1.894)* | 0.095 (1.652)* |
| $\log(coi_{t})$                   | 0.052 (2.146)** |     |     |
| $coi_{t-1}$                       |     | 0.107 (2.289)** |     |
| $coi_{t-2}$                       |     | 0.101 (2.726)** |     |
| $coi_{t-3}$                       |     |     |     |
| $coi_{t-4}$                       |     |     |     |
| **Panel C: Diagnostic statistics**|     |     |     |
| $F$-statistic                     | 5.201*  | 5.183** | 4.685** |
| t-statistic ($\gamma_{0}$)        | -0.035 (-3.962)** | -0.043 (-4.574)** | -0.068 (-4.871)** |
| LM statistic                      | 0.164  | 0.262  | 1.066 |
| Oil prices                        |         |         |         |
| Wald-S                            | 2.703  | 3.063*  | 28.519** |
| Wald-L                            | 0.934  | 3.332*  | 4.893** |
| COVID-19                          |         |         |         |
| Wald-S                            | 19.674** |     |     |
| Wald-L                            | 7.265* |     |     |

Notes: **(*) denotes significance at the 5 percent (10 percent) level. The numbers in parentheses are t-statistics. The $F$-test for the 5 percent (10 percent) critical value with $k = 2, 3,$ and 4 are $5.060 (5.850)$, $4.545 (5.070)$, and $4.060 (4.570)$, respectively. The t-statistics for the 5 percent (10 percent) critical value with $k = 2, 3,$ and 4 are $-3.630 (-3.950)$, $-3.840 (-4.160)$, and $-4.040 (-4.360)$, respectively. The critical value of the Wald statistic at the 5 percent (10 percent) is $3.840 (2.710)$.

4 Notably, it seems that there is a noticeable change in the relationship between the two variables at the beginning of the 4th quarter of 2020. Since the COVID-19 index does not account for keywords such as a vaccine, vaccinations, or U.S. elections, these factors may have played a role in causing this seemingly structural break.
be rather more pronounced than a plunge in oil prices over time (Fig. 2). Thus, these outcomes explain why incorporating a variable representing the current outbreak of coronavirus disease is crucial when estimating the asymmetric relationship between oil prices and the KRW/USD rate amidst the COVID-19 pandemic properly.\footnote{It would be very useful to extend the analysis beyond April 28, 2021, as the COVID-19 sentiments may have changed with global vaccinations and new variants of the COVID virus. Unfortunately, however, the daily index of COVID-19 is not currently available beyond April 28, 2021.}

There is an additional point worth highlighting: estimating Eq. (1) relies on the underlying assumption that $c_{\text{ov}_t}$ symmetrically affects the KRW/USD rate. As with oil prices, however, the foreign exchange market is also highly likely to have different reactions towards the ups and downs of COVID-19 cases. For completeness, therefore, we also formally test the asymmetry effects that COVID-19 may have on the KRW/USD rate (column (3) in Table 1). The coefficients of interest now are $c_{\text{ov}_t^+}$ and $c_{\text{ov}_t^-}$. In the short run, most of the coefficients on $\Delta c_{\text{ov}_t^+}$ and $\Delta c_{\text{ov}_t^-}$ are highly significant. By
and large, therefore, COVID-19 cases appear to play an important role in fluctuating the KRW/USD rate in the short run. When then turning to the long-run outcomes, both \( \text{cov}_1^+ \) and \( \text{cov}_1^- \) are highly significant with positive signs. This means that a surge (drop) in COVID-19 cases depreciate (appreciate) the KRW/USD rate. Further, the Wald statistics reveal that there is strong evidence of the short- and long-run asymmetries in COVID-19 cases. At this point, we should notice that the statistical significance of the estimated coefficients of \( \text{op}_2^- \) and \( \text{op}_2^+ \) in both the short- and long-run is quite similar between linear and nonlinear models of the COVID-19 pandemic index. Thus, this can be considered one piece of evidence confirming the robustness of our results obtained from the model controlling for \( \text{cov}_1 \).\(^5\)

Two other issues should be given attention in the context of the NARDL modeling. The first is to ensure that no series are \( I(2) \) across models because the NARDL can only be applied to either \( I(0) \) or \( I(1) \). When the Dickey–Fuller generalized least squares (GLS) is applied, there is strong (little) evidence against a unit root in levels (first differences), indicating evidence of \( an I(1) \) series; hence, a NARDL can safely be applied to our models (Table 2). The second is to check for possible cointegration. The calculated \( F \)-and \( t \)-statistics across models turn out to exceed the 10% upper critical value, indicating that cointegration holds for the three models (Panel C in Table 1); thus, the regression results are not spurious and tell us a meaningful relationship.

Before ending this section, for comparison, we also address the issue for five primary economies of South East Asia such as Indonesia, Malaysia, the Philippines, Singapore, and Thailand (Table 3). In the absence of \( \text{cov}_1 \), we notice that the calculated \( F \)- and \( t \)-statistics across countries are commonly below the 10% upper critical value, indicating no cointegration. When looking at the outcomes of a model controlling for \( \text{cov}_1 \), on the other hand, the values of the \( F \)- and \( t \)-statistics for Indonesia, Malaysia and Singapore are well above the 10% upper critical value, supporting cointegration. Allowing for \( \text{cov}_1 \) in a model increases the \( F \)- and \( t \)-statistics for cointegration markedly. Further, as with the models in Korea, the coefficients on \( \text{op}_2^- \) and \( \text{op}_2^+ \) reveal different magnitude in both the short- and long-run. When we calculate the Wald statistics, however, only the short-run symmetry hypothesis is rejected at the 10% level, so there is evidence of short-run asymmetry effects for Indonesia, Malaysia, and Singapore. Thus, the asymmetric relationship between oil prices and exchange rate for Southeast Asian economies could be viewed as a short-run phenomenon.

### 4. Concluding remarks

The present research explores the asymmetric impact that oil prices have on the KRW/USD exchange rate. Our primary contribution is to explicitly take into consideration the role that the current outbreak of coronavirus disease proxied by the COVID-19 index plays when addressing the issue. When estimating the model without the COVID-19 index, we discover no evidence confirming the asymmetric impact of oil prices on the KRW/USD rate in the short- and long-run. After adding control for the COVID-19 index, we uncover that oil prices asymmetrically influence the KRW/USD rate in both the short- and long-run. Thus, the COVID-19 pandemic appears to have been a significant factor in determining asymmetric oil price impact on the KRW/USD rate.

From an empirical perspective, it is conceived that when studying the asymmetric effects oil price fluctuations have on the KRW/USD rate, the role of the COVID-19 pandemic should be incorporated in a model; otherwise, empirical approaches may be misspecified, questioning the credibility of the outcomes. From a policy perspective, although our findings indicate that a spike in COVID-19 cases tends to depreciate the KRW/USD exchange rate, it is also likely to push down South Korea’s exports via the increased uncertainty of the global economy and its trade balance. At a time when COVID-19 cases are heading up, therefore, this implies that the Bank of Korea (BOK) would have to implement further depreciation of KRW to enhance South Korea’s global competitiveness.

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\(^5\) As another robustness check, an anonymous referee suggests including other determinants of the exchange rate in Eq. (1) to see if the current results hold. For example, the monetary model of exchange rate determination can be estimated with and without the COVID-19 pandemic index. However, the absence of complete daily data on the monetary variables makes it impossible to resolve this request.

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### Table 2

| Variable | Level | First difference | Decision |
|----------|-------|------------------|----------|
| \( \log(\text{err}_0) \) | -1.480 (2) | -8.262 (1)** | \( I(1) \) |
| \( \log(\text{op}_1) \) | -1.152 (0) | -19.276 (0)** | \( I(1) \) |
| \( \text{op}_2^+ \) | -0.380 (1) | -5.558 (4)** | \( I(1) \) |
| \( \text{op}_2^- \) | -0.075 (1) | -16.258 (0)** | \( I(1) \) |
| \( \log(\text{cov}_1) \) | -2.825 (6) | -4.082 (6)** | \( I(1) \) |
| \( \text{cov}_1^+ \) | -1.882 (5) | -11.730 (4)** | \( I(1) \) |
| \( \text{cov}_1^- \) | -2.032 (5) | -10.911 (4)** | \( I(1) \) |

Notes: ** (*) denotes rejection of the null at a significance level of 5 percent (10 percent). The critical value at the 5 percent (10 percent) is \(-2.902 \) (\(-2.590 \)). The Schwert Information Criterion (SIC) is employed to select lag order.
Table 3
Estimated coefficients of the exchange rate models for ASEAN-5 countries.

|                      | Indonesia          | Malaysia          | Philippines         |
|----------------------|--------------------|-------------------|---------------------|
|                      | (1) (2)            | (1) (2)           | (1) (2)             |
| Panel A: Short-run results |
| $\Delta p_1^t$      | $-0.028(2.739)^{**}$ | $-0.026(2.546)^{**}$ | $-0.011(2.001)^{**}$ | $-0.007(1.270)$ |
| $\Delta p_{-1}$     | 0.008(0.744)       | 0.008(0.742)      |                    |                    |
| $\Delta p_{-2}$     | 0.002(1.846)       | 0.003(0.254)      |                    |                    |
| $\Delta p_{-3}$     | $-0.025(2.502)^{**}$ | $-0.024(2.496)^{**}$ |                    |                    |
| $\Delta p_{-4}$     | $-0.011(1.612)^{*}$ | $-0.011(1.619)^{*}$ |                    |                    |
| $\Delta p_{-5}$     | $-0.014(1.805)^{*}$ | $-0.014(1.831)^{*}$ |                    |                    |
| $\Delta p_{-6}$     | $-0.012(1.591)$    | $-0.013(1.702)^{*}$ |                    |                    |
| $\Delta p_{-7}$     | 0.007(0.783)       | 0.008(0.955)      |                    |                    |
| $\Delta p_{-8}$     | $-0.023(2.976)^{**}$ | $-0.023(3.044)^{**}$ |                    |                    |
| $\Delta \log(c_{t-1})$ | 0.003(2.325)^{**} |                    |                    |                    |
| $\Delta \log(c_{t-2})$ |                    |                    |                    |                    |
| $\Delta \log(c_{t-3})$ |                    |                    |                    |                    |
| Panel B: Long-run results |
| $p_1^*$             | $-0.085(1.599)$    | $-0.049(0.883)$   |                    |                    |
| $p_{-1}$            | $-0.075(1.794)$    | $-0.036(0.780)$   |                    |                    |
| $\log(c_{t-1})$     | 0.056(2.040)^{**}  |                    |                    |                    |
| Constant            | 0.442(3.487)       | 0.472(4.224)      | 0.036(2.765)       | 0.053(4.091)       |
| Trend               | 0.001(2.418)       | 0.0001(2.647)     | $-0.001(1.011)$    | $-0.001(3.496)$    |
| Panel C: Diagnostic statistics |
| F-statistic         | 4.025              | 4.414             | 2.534              | 4.159              |
| $r$-statistic        | $-0.046(3.486)$    | $-0.051(4.222)^{**}$ | $-0.025(2.766)$    | $-0.044(4.099)^{**}$ |
| LM statistic         | 0.350              | 0.187             | 3.523              | 3.858              |
| Wald-S               | 5.546^*            |                    | 2.97^*             |                    |
| Wald-L               | 2.258              |                    | 0.19               |                    |

Panel A: Short-run results
- $\Delta p_1^t$ represents the changes in the exchange rate.
- $\Delta p_{-i}$ represents the changes in the exchange rate lagged by $i$ periods.
- $\Delta \log(c_{t-1})$ represents the changes in the log of currency supply lagged by one period.
- $\Delta \log(c_{t-2})$ represents the changes in the log of currency supply lagged by two periods.
- $\Delta \log(c_{t-3})$ represents the changes in the log of currency supply lagged by three periods.

Panel B: Long-run results
- $p_1^*$ represents the coefficient of the current period's exchange rate.
- $p_{-1}$ represents the coefficient of the previous period's exchange rate.
- $\log(c_{t-1})$ represents the log of currency supply lagged by one period.
- Constant represents the constant term of the model.
- Trend represents the trend term of the model.

Panel C: Diagnostic statistics
- F-statistic and $r$-statistic are used to test the joint significance of the model's coefficients.
- LM statistic is used to test the serial correlation in the residuals.
- Wald-S and Wald-L are used to test the overall significance of the model.

Notes: $^{**}$ (*) denotes significance at the 5 percent (10 percent) level. The numbers in parentheses are t-statistics. The F-test for the 5 percent (10 percent) critical value with $k = 2$ and $3$ are $5.060 (5.850)$ and $4.450 (5.070)$, respectively. The $r$-statistics for the 5 percent (10 percent) critical value with $k = 2$ and $3$ are $-3.630 (-3.950)$ and $-3.840 (-4.160)$, respectively. The critical value of the Wald statistic at the 5 percent (10 percent) is $3.840 (2.710)$.

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