Modeling the Asymmetric Relationship between the Covid-19 and the U.S Dollar Exchange Rate: an Empirical Analysis via the NARDL Approach

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Abstract

This research paper analyses the extent to which Covid-19 changes hold an asymmetric impact on the US dollar exchange rate for the period starting from the 01st March 2020 to the 28th of August 2020. In order to attain this objective, an asymmetric nonlinear co-integration approach (NARDL) is applied. As a matter of fact the results evidence three findings. First, we find a long-run co-integrating relationship between the US dollar exchange rate and the Covid-19 (number of cases and number of deaths). Second, in this relationship, the long-run asymmetry runs from the number of cases to the US dollar exchange rate, a finding that is statistically robust as the parameters of the NARDL models are stable with well-behaved errors. Third, we reveal that the number of deaths has no asymmetric impact on the US dollar exchange rate, which implies the fact that both a positive and a negative number of deaths, movements have the same impacts on the US dollar exchange rate in the short-run and long-run. Therefore, this study recommended that the American government must take nonlinear decisive actions to deal with the health and economic crises in the face of major uncertainty.

Key Words Exchange rate.Pandemic.Covid-19. NARDL

JEL Classification: F3. F4. F43

1. Introduction

One of the research issues to be solved is the modeling of exchange rate behavior. Because of the importance of exchange rates in the economy, no one can deny the need to understand the behavior of the foreign exchange market. It is necessary to study in detail the determinants of exchange rates and the behavior of the foreign exchange market. The currency method developed in the 1970s is an important tool for explaining exchange rate changes.

The estimation and prediction of exchange rates have brought considerable theoretical and experimental challenges. Exchange rate changes have a wide range of effects, affecting prices, wages, interest rates, production levels and employment opportunities. After the collapse of the Bretton Woods system, the currency value fluctuations of different economies have increased. After the transition from a fixed exchange rate to a flexible exchange rate in the early 1970s and thereafter, short-term volatility increased significantly.

High volatility and sudden exchange rate changes are one of the obstacles to the successful implementation of macroeconomic policies. Need to develop models with theoretical and empirical validity. Predicting the nominal exchange rate is a difficult task, especially in a flexible exchange rate system (Meese and Rogoff, 1983a).

The factors that affect the exchange rate can be economic, political, and psychological factors, as well as short-term or long-term factors. The behavior of exchange rates can be studied more appropriately through macro and micro variables. Policymakers want to know what measures can be taken to limit the fluctuations in currency values. In order to find the answers to these policy questions, economists began to conduct extensive conceptual and empirical research aimed at explaining exchange rate behavior since the early 1970s.

So far, researchers have achieved limited success in their research to understand exchange rate behavior. At the same time, policy directions have evolved and lessons have been learned, but through the experience of maintaining macroeconomic stability in the ever-changing global economy, new questions have been raised.

The behavior of exchange rates is a complex issue involving many aspects. The research based on the balance of payments method mainly relies on the elastic method or the absorption method. Research based on monetary methods uses purchasing power parity conditions, quantitative monetary theory (QTM), interest rate parity, money demand

functions, and cumulative positions in currency accounts to test exchange rate behavior. In the early 1980s, it was clear that empirical research did not confirm the support of a monetary approach to exchange rates. However, due to the development of econometric techniques, statistical tools, and model specifications, recent empirical studies have provided evidence to support the long-term effectiveness of monetary methods (Wilson, 2009).

Since the outbreak of the financial crisis in 2008, the evolution of the dollar has been a paradox in many respects. First, although there is a crisis in the United States, especially in the real estate sector (subprime mortgage crisis), the U.S. dollar has appreciated during the most severe financial turmoil. At first glance, this appreciation is even more surprising, because before the crisis, many observers pointed out that the U.S. dollar could depreciate sharply due to the high current account deficit recorded by the United States.

Subsequently, the special measures taken by the Fed in response to the crisis aroused concerns about the sharp depreciation of the U.S. dollar and international financial flows, especially the sudden flow of emerging countries. However, seven years after Lehman Brothers went bankrupt; the effective exchange rate of the U.S. dollar was stronger than since the early 2000s. These developments show that the link between monetary policy and exchange rates is particularly complex, and other factors may also affect the dollar.

At the beginning of 2020, the world is busy spreading the new virus COVID-19, which has become a global epidemic and has attracted great attention from the international community. Since its appearance in China on December 31, 2019, the new type of corona virus or COVID-19 has spread to almost every country in the world. The Wuhan Municipal Health Commission of China reported a series of pneumonia cases in Wuhan and Wuhan, Hubei, and identified the virus. The new corona virus was finally declared a pandemic by the World Health Organization (WHO) on March 11, 2020 (World Health Organization, April 27, 2020).

Because COVID-19 is highly contagious (R0 = 2-5, one patient can infect another 2-5), and in other parts of the world, this situation is increasing, so it quickly became a pandemic (Liu et al 2020).

A recent study in Spain showed that COVID-19 may become more contagious over time, which means that R0 may increase (Garcia-Iglesias and de Cos Juez, 2020). Its impact on health is severe enough to cause more than half of the world's population to be subject to some form of restriction, and its economic impact is rated as more severe than the 2008-09

global financial crisis and compared with the Great Depression of 1930. Global stock markets have experienced the worst decline in decades (Baker et al., 2020). Researchers all over the world are trying to record the new knowledge gained through preliminary observations and experience of the situation. There is a global effort to learn more about this virus, and to slow down and ultimately stop the spread of this threat.

What started as a crisis in our public health system has now developed into an economic crisis with global consequences. In fact, this pandemic has caused oil prices to fall, leading to significant reductions in shale oil production and layoffs. It also crushed U.S. business investment, which collapsed at a rate of 27% and reduced capital expenditures, which fell at a rate of 37.7%. In addition, the contagiousness of the virus spread rapidly around the world in the first quarter of 2020, and the supply chain was disrupted due to the closure of global companies. As many countries have adopted containment measures, the pandemic has also reduced demand. Oil prices are gradually falling, which is a reaction to the spread of Covid-19.

In this context, we draw attention to the new impact of the pandemic corona virus on the United States. Therefore, we help analyze the relationship between the US dollar exchange rate and Covid-19 by empirically assessing the potential nonlinear asymmetry (cases/deaths) between US exchange rate and Covid-19 in the long-term outlook. Specifically, we divide Covid-19 into positive and negative changes. The asymmetric impact of changes in Covid-19 on the exchange rate of the U.S. dollar depends on the signs and magnitude of the positive and negative changes in Covid-19. In other words, in an absolute sense, do the decrease in Covid-19 and the increase in Covid-19 have a similar impact on the dollar exchange rate?

In particular, if people want to understand the volatility of the U.S. dollar, especially during periods of high risk aversion, they must consider the international role of the U.S. dollar, especially its status as a safe haven. Indeed, the good performance of the US dollar reminds people that the crisis did not question the international role of the US dollar: even today, more than forty years after the end of the Bretton Woods system, the US dollar plays an unprecedented role in the international monetary system. Regardless of the standard adopted, in terms of the percentage of global foreign exchange reserves, and even in terms of international payments for the purchase of high-quality real estate or real estate, the U.S. dollar still ranks first in the share of transactions in the foreign exchange market and monetary assets.

In addition, the United States enjoys the "privilege" of borrowing in dominant international currencies, which is sometimes considered "excessive", which makes it easier for them to finance external deficits without worrying about their currency depreciation. Finally, the United States is still the main provider of global risk-free assets, which is why a large amount of international capital flows into the country during the crisis, and the U.S. dollar appreciates. However, as far as the provision of international liquidity is concerned, this position implies a special responsibility (excessive responsibility) to the rest of the world, especially in the form of swap lines between central banks.

The above theoretical suggestions show that exchange rate management policies have always played a fundamental role in developed countries, especially in the announcement of the structural adjustment and economic stability policies of certain countries. As a result, the concept of exchange rate has often become the main mystery in many studies in international economics.

As far as we know, this is the first study based on US data. We use the intraday data from March 1, 2020 to August 28, 2020, and use the nonlinear autoregressive distributed drift model (NARDL). Importantly, we include the control variables for the economic differences between the US and the EU, namely financial volatility (VIX), economic policy uncertainty (EPU) and crude oil price (WTI).

There are two main empirical conclusions. First, there is a long-term co-integration relationship between the U.S. dollar and the euro and Covid-19. Second, in this long-term relationship between variables, we found evidence of asymmetry caused by the exchange between the US dollar and all cases. On the contrary, changes in the total number of deaths have a long-term symmetrical impact on the dollar exchange rate. These results are reliable because the parameters of the NARDL model are stable, do not change over time and their errors perform well.

The rest of this document is structured as follows. Section 2 introduces the literature. In Section 3, we describe the data and methods. The results of the NARDL method are presented in Section 4. Conclusions and policy implications are introduced in Section 5.

2. Literature Survey

In this review, we are interested in empirical studies that have focused on the determinants of

the exchange rate and the link between COVID 19 and certain macroeconomic variables. The objective being to inspire us to study the link between the Covid-19 and the U.S Dollar Exchange Rate

2.1.Determinants of exchange rate

Most previous studies on exchange rate behavior focused on explaining and predicting exchange rate levels, not its volatility. Several structural models have been proposed to capture exchange rate models, such as currency exchange rate models and portfolio balance models. However, none of these models can outperform naive random walk models in predicting sample exchange rates (for example, see Meese and Rogoff, 1983b).

Simon (1997) found that the exchange rate and current account have a direct and positive correlation with inflation. He concluded that exchange rate and current account are both key factors that seriously affect small economies.

Edwards (2000) studied the dynamic links between exchange rate regimes, capital flows and currency crises in emerging economies. The study draws on the experience and lessons of the 1990s to deal with some of the most important policy disputes that emerged after the crises in Mexico, East Asia, Russia and Brazil. He concluded that under appropriate conditions and policies, floating exchange rates are effective and efficient.

Taylor (2001) discussed the failure of Argentina's liberalization policy. He said that Argentina has failed to maintain liberalization policies regarding capital flows and a strong currency. Argentina formulated an anti-inflation plan based on a frozen exchange rate in the early 1990s. This means that the country's internal money supply and the supply of credit to companies are directly linked to international reserves. Therefore, if the country receives capital inflows, the supply of money and credit will increase, leading to a sharp increase in domestic prices.

Harberger (2003) studied the impact of economic growth on the real exchange rate. He found that there is no systematic link between economic growth and the real exchange rate.

Hussein et al. (2004) found in their research that weaker and underdeveloped countries have almost no access to international capital, so the low inflation rate and higher persistence are related to the fixed exchange rate system of these countries. However, they found that there is no strong relationship between the economic performance of developing economies and the

exchange rate regime. They also found that in a flexible exchange rate system, without a high level of inflation, advanced economies may experience sustained and slightly higher growth rates.

Due and Sen (2006) studied the interaction between real exchange rates, capital flow levels, liquidity fluctuations, fiscal and monetary policy indicators, and India's current account surplus from the second quarter of 1993 to the first quarter of 2004. Estimates indicate that the variables are cointegrated, and each Granger will result in a real exchange rate.

Chin and Chee-hong (2013) attempted to use monthly data to assess the impact of trade openness on the Malaysian exchange rate. Their findings are consistent with the expected signs of all variables. It is also in line with the theoretical prediction; the increase in trade openness will depreciate the Malaysian currency, and vice versa. This finding confirmed the idea of the threshold level. The economy will open up at a certain level, and if it is higher than that, it will devalue the currency.

Bakari and Tiba (2020) studied the impact of Tunisian exports and domestic investment on the exchange rate from 1966 to 2017. By using a comparison method between the ECM model and the ARDL model, they found that domestic investment and exports have a negative impact on the exchange rate in the long run.

2.2.Covid-19 and economic variables

Based on the above information, recent empirical studies have focused on the relationship between Covid-19 and economic variables, and have come to different results.

Corsetti and Marin (2020) emphasized that, like other global crises, the Covid-19 pandemic has triggered massive foreign exchange flows. However, in the novel coronavirus incident, the dynamics of foreign exchange transactions have accelerated significantly.

Albulescu (2020a) studied the impact of Covid-19 data on WTI crude oil prices while controlling the impact of the US CBOE Volatility Index (VIX) and Economic Policy Uncertainty (EPU) Index. The ARDL estimation results used in this study indicate that through the increase in financial market volatility, Covid-19 indirectly affected the crude oil price pattern in early 2020. Nonetheless, the study found that the long-term impact of this number is negative, but insignificant in the number of new infections Covid-19 causes on crude oil prices every day.

Albulescu (2020b) also analyzed the impact of Covid-19 and changes in oil prices on the EPU index by applying the ARDL model. This study found that the global rate of new infections and deaths had no significant impact on EPU.

Ding et al. (2020) conducted a study on corporate immunity during the COVID-19 pandemic. In the first quarter of 2020, they used data from more than 6,000 companies in 56 countries. Their purpose is to determine the impact of the COVID-19 case on stock prices and company characteristics in this situation. The results of the study show that companies with stronger financial conditions before 2020, less pandemic risk, deep-rooted executives and higher social responsibility activities face stock price declines caused by the pandemic. In addition, the survey results also show that companies with larger company ownership perform well, while companies with higher hedge fund ownership perform the worst.

Alfaro et al. (2020) presented a real-time analysis of company-level inventory and total returns during the COVID-19 pandemic. They are trying to explain that unexpected changes in the trajectory of COVID-19 infection are predicting returns in the US stock market. Based on a sample of 4 070 companies listed in the U.S. and taken from data from Yahoo Finance and Bloomberg, parameter estimates indicate that if the estimated infection rate doubles the next day, total U.S. market revenue will decrease. vice versa. The results of the study show that the market losses associated with COVID-19 increase as leverage and capital intensity increase. In companies or industries that are highly conducive to the spread of disease, the losses are much more severe.

The study by Amore et al. (2020) analyzed household ownership during the COVID-19 pandemic. They tested how including the family in governance and ownership affects the company's financial performance. The samples for this study were selected from Italian companies during the spread of COVID-19. The research results show that companies with controlling shareholders perform better than other companies during the pandemic.

Corbet et al. (2020) studied the infectious effects of COVID-19 in their research. They believe that since the beginning of the COVID-19 pandemic, China's financial market has played a central role in both financial and natural contagion. In the six stages analyzed, the results of the study showed a large number of expected characteristics in "safe flight". During the huge financial crisis, the relationship between Bitcoin and the Chinese stock market finally developed.

Schoenfeld (2020) evaluated the risk factors in the context of financial markets and pandemics in his research. The study uses the COVID-19 pandemic as a natural experiment to determine how financial markets respond to a pandemic. The survey results showed that, compared with the risk factors prescribed by the SEC, managers underestimated the risks associated with the pandemic, and therefore, the value of the company in this area has fallen. The research results also show that the pandemic is systematically important for financial markets and their performance.

Ruiz et al. (2020) analyzed the financial and economic impact of the COVID-19 pandemic. An analytical model has been established in this research, which helps to understand the temporal and spatial distribution patterns of COVID-19 diseases and their impact and relevance on financial markets. This article introduces a novel multidimensional geometric method and the concept of stagnation in a given epidemic situation.

Ashraf et al. (2020) analyzed the impact of Islamic equity investment (IEI) during the COVID-19 pandemic in their study. S&P Down Jones reported that in the first quarter of 2020, IEI continued to outperform traditional competitors. This request was made due to IIE's strict handling and potential hedging benefits. These findings provide evidence that IEI provides hedging benefits during periods of market downturns, and the research shows that hedging benefits have additional costs.

3. Data and methodology

3.1.Data

This research examines the relationship between the US dollar against the EURO, Covid-19 and other fundamental variables using a daily dataset that runs from March 01, 2020 – August 28, 2020 (181 observations). The US historical data of exchange rate (USD/EURO) is obtained from the Exchange Rates UK. The daily data on the number of Covid-19 reported cases (Total Cases) and deaths (Total Deaths) which are extracted from the European Centre from Disease Prevention and Control (ECDC). The financial volatility (VIX) data is coming from the Chicago Board Options Exchange (CBOE). The US Economic Policy Uncertainty (EPU) daily data is derived from Baker et al. (2016) and daily updated for the US from Economic Policy Uncertainty. Whereas the oil prices (WTI) data are obtained from the US Energy Information Administration (EIA). All variables are in the natural logarithmic form.

We specify equation (1) in linear form to express the relationship between (USD/EURO) and its fundamental determinants in the United States (with the expected sign of the coefficients in brackets):

$$\mathbf{USD/EURO} = \mathbf{f}(\mathbf{Covid19}, \mathbf{VIX}, \mathbf{EPU}, \mathbf{WTI}), \qquad (\mathbf{1})$$

Expected signe	$(-)$	$(+)$	$(-)$	$(+/-)$

USD/EURO represents the number of euro required to buy US dollars. It is affected by government policies and the economics of demand and supply in currency markets for the pair.

Covid-19is measured as the number of cases and the number of deaths. It has affected negatively the world's economy. We note some studies which have been done on china studies (Al-Awadhi et al. 2020; McKibbin and Fernando 2020). The results confirmed the negative impact of the Covid-19 outbreak which may affect the exchange rate.

Financial Volatility (VIX) is a measure of the "implied volatility" of options trading on the S&P 500 index. It is widely known as the "fear" index, it attempts to calculate the likelihood of unpredictable changes and uncertainty in the stock option prices. We notice that a higher uncertainty makes investors adopt risk-averse investment strategies. More precisely, the investors choose to hold cash, because cash is the greater liquid investment and is absolutely assured by the government. As a consequence, both theoretical and empirical works have studied the relationship between VIX and currency exchange rates (Liu et al. 2012; Corte et al. 2016).

Economic Policy Uncertainty (EPU) reflects "the situation where economic agents lack the knowledge necessary to assess the current situation with sufficient confidence"[1]. Thus, uncertainty is unobservable which takes an important part in defining the economic conjuncture. Many studies examine the relationship between the exchange market and the economic policy; their results reveal that a rise in the economic policy uncertainty increases the severity of the exchange market pressure in the long run (Ifedolapo et al. 2019). Other studies support the long-run negative effect of the EPU on the exchange rate (Pástor and Veronesi 2013; Baker et al. 2016; Brogaard and Detzel 2015; Pástor and Veronesi 2012, Arouri et al. 2016; Abid 2019).

[1] Reference: "The impact of uncertainty in activity in the euro area". European Central Bank publication (2017).

Oil-Prices (WTI) played an important role in determining future real exchange rates in G7 (Kilian 1999; Chen and Chen 2007; Yang et al. 2017). Thus, the relationship between the oil-prices and exchange rate is one of the questions economists tried to explain. Krugman (1980) and Golub (1983) attempted to study this relationship in a theoretical framework; it is shown thata rise in oil prices may lead the exchange rate of an oil-exporting country to appreciate and oil-importing country to depreciate and vice-versa (Reboredo 2012). However, Caprio and Clark (1981) say that higher oil-prices cause the value of dollar to decline in the long-run. Other literatures confirm the negative association between crude the oil prices and the exchange rate (Ghosh 2011; Fowowe 2014; García et al. 2018; Lizardo and Mollick 2010). On the other hand, some works (Benassy-Quere et al. 2007; Hasanov 2010; Živkov et al. 2019) show a positive association between the oil-prices and the exchange rate, more precisely, the authors conclude that a considerable rise in oil prices leads the exchange rate to appreciate simultaneously. However, their long-term effect on the exchange rate is ambiguous.

The aim of this paper is to complement this literature by investigating the extent to which the exchange rate can be determined by these fundamental variables and especially the asymmetric effect of Covid-19 on the exchange rate, which is different and absent from the literature listed in the study.

Table 1 displays the descriptive statistics of 181 observations from the time series variables. All of them are negatively skewed. Besides, the variables show high kurtosis, excluding the USD/EURO, EPU and WTI. Moreover, the JB statistics are significant at the 5% level, implying that the returns for all variables do not follow the normal distribution. This may be a sign of the presence of non-linearity of the series.

[Insert Table 1 here]

Table 2 provides the correlation analysis. We find a significant correlation between the USD/EURO and all variables. More precisely, the results indicate that the independent variables (Total Cases, Total Deaths, WTI and EPU) show a negative monotonic relationship with USD/EURO (dependent variable). However, the strength of association is stronger between USD/EURO and WTI as rho (ρ) approaches -1. Expected, the VIX index show a positive monotonic relationship; in line with the often-mentioned flight-to-safety phenomenon which entails a US dollar appreciation in the periods of volatility and crises.

[Insert Table 2 here]

Figure 1 shows the dynamic movement of the studies variables during the Corona Virus disease outbreak period. The sampling period is starting from the 01 of March 2020 until the 28 of August 2020 with a total of 181 trading days. The initial value of currency exchange (USD/EURO) is 1 EURO which is valued at 0.9046 United States Dollar (USD) on the 1st of March 2020.The value of exchange rate keeps fluctuating and reaches a minimum value on the 18th of July 2020 (140th observation) with a value of 0.837 USD for each EURO. This is one of the impacts of the Covid-19 to the economic landscape in the United States.

[Insert Figure 1 here]

3.2. Methodology

In this paper, we applied the NARDL (Non-Linear Autoregressive Distributed Lag), which is advanced by Shin et al. (2014). This model is very useful given the way it models the stochastic link between variables of different order of integration. It also provides better efficiency to short-run and long-run coefficient estimated (Ariz et al. 2017).The NARDL technique is an application of the autoregressive distributed lag (ARDL) model proposed by Pesaran and Shin (1999) and Pesaran et al. (2001). So, the NARDL models the dependent variable as a function of its lagged variables and lagged variables of independent variables. In order to explore the asymmetric dynamic link between the exchange rate (USD/EURO) and Covid-19, we decompose the independent variable (Covid-19) into its partial sum of rising (+) and falling (-) values.

Hence, we write equation (1) as follows:

$$\mathbf{USD/EURO} = \alpha_0 + \alpha_1 \mathbf{Covid}_t^+ + \alpha_2 \mathbf{Covid}_t^- + \alpha_3 VIX_t + \alpha_4 EPU_t + \alpha_5 WTI_t + \varepsilon_t \quad (2)$$

Here, $\alpha_0$is the intercept, α_i (i=1,2,3,4,5) represent coefficients vector for the long-run and Covid$^+$, Covid$^-$ are positive and negative changes in Covid-19 respectively:

$$\mathbf{Covid}_t^+ = \sum_{i=1}^{t} \Delta Covid_t^+ = \sum_{i=1}^{t} \mathbf{max}(\Delta \mathbf{Covid}_i, 0) \quad (3)$$

$$\mathbf{Covid}_t^- = \sum_{i=1}^{t} \Delta Covid_t^- = \sum_{i=1}^{t} \mathbf{min}(\Delta \mathbf{Covid}_i, 0) \quad (4)$$

Consistent with Shin et al. (2014) and Pesaran et al. (2001), we can restate equation 2 in the ARDL framework as:

$$\Delta(\mathbf{USDEURO})_t = \gamma_0 + \gamma_1 USD/EURO_{t-1} + \gamma_2^+ Covid_{t-1}^+ + \gamma_3^- Covid_{t-1}^- + \gamma_5 EPU_{t-1} + \gamma_6 WTI_{t-1} + \sum_{i=1}^{r} \theta_{1i} \Delta(USDEURO)_{t-i} + \sum_{i=1}^{m} \theta_{2i}^+ \Delta Covid_{t-i}^+ \sum_{i=1}^{n} \theta_{3i}^- \Delta Covid_{t-i}^- + \sum_{i=1}^{p} \theta_{4i} \Delta VIX_{t-i} + \sum_{i=1}^{k} \theta_{5i} \Delta EPU_{t-i} + \sum_{i=1}^{t} \theta_{6i} \Delta WTI_{t-i} + \varepsilon_t \quad (5)$$

Where, r, m, n, p, k and t show the respective lag orders. From equation (5), the long-run impact of the positive and negative effects of Covid-19 on USD/EURO can be derived as follows:

$\beta_1 = -\frac{\gamma_2^+}{\gamma_1}$; $\beta_2 = -\frac{\gamma_3^+}{\gamma_1}$ respectively. In the same vein the short-run positive and negative changes in Covid-19 can be derived as: $\sum_{i=0}^{j} \theta_{2i}$, $\sum_{i=0}^{j} \theta_{3i}$, respectively.

4. Empirical results

Our empirical analysis involves two steps. In the first step, we examine if the variables have a unit root. To determine this, we carry out the Augmented Dickey Fuller (ADF) and Philip-Perron (PP) tests. In the second step, we apply the nonlinear autoregressive distributed lag approach to investigate the asymmetric association between the exchange rate and Covid-19. Specifically, we verify if the impact of a drop in the Covid-19 is analogous, in absolute terms, to the impact of a rise in the Covid-19 on exchange rate.

Obviously, if variables included in the model are I(0) or I(1), it will be suitable to address for the NARDL methodology of co-integration. So, it is necessary to apply stationarity tests to verify the absence of I(2) variable in the model. For this objective, we check the stationarity of the variables via the Augmented Dickey Fuller and Philip-Perron tests.

Table 3 reports the ADF and PP tests results. The outcomes of the ADF and PP tests indicate that all the impulses are stationary in first difference. Hence, it can be inferred that all the variables included in the model do not have higher integration of order two. The I(1) of the variables imply that it is appropriate to proceed with the asymmetric ARDL approach.

[Insert Table 3 here]

Table 4 showcases the outcomes of the BDS test. The BDS test rejects the null hypothesis of independent and identically distributed residuals across various dimensions. This outcome

strongly confirms nonlinearity in the series and entails the applicability of NARDL popularized by Shin et al. (2014).

[Insert Table 4 here]

4.1.Main results

In this section, we employ a number of cases as the proxy of the Covid-19. Table 5 reports the NARDL results, namely the F-statistics estimated from the NARDL bound testing and their associated upper and lower bound critical values. In this case, the F-statistic value of 4.45 is higher than the 5% level of significance upper bound critical value of 4.18. Consequently, we do not reject the hypothesis that there is a long-run equilibrium relationship running from USD/EURO to the other variables. Hence, it has been ascertained that variables move together in the long-run.

[Insert Table 5 here]

Given the results from the NARDL bounds testing for co-integration, we estimate the long-run relationships for USD/EURO and (Total Cases, VIX, EPU, WTI) as the independent variables. The short and long-run results have been presented in Table 6.

In the short-run: (i) The increase in the $TotalCases^{+}$ has significant negative impact on the US dollar against the EURO, implying that a 10% increase in $TotalCases^{+}$ depreciates the US dollar against the EURO by 0.11%. The effect of the negative change in TotalCases ($TotalCase^{-}$) has been noticed to be negative and statistically significant at a 5 % level. It means that the association of TotalCases with the USD/EURO in the short-run is symmetric; the outcome of the WALD test further (Table 7) confirmed the short-run symmetric effects of TotalCases+ and TotalCases− on USD/EURO. (ii) VIX Index, which is showing signs of volatility in global markets that has a significant positive link with the USD/EURO in the short-run suggesting that a 10 % high volatility of the stock market will appreciate the US dollar against the EURO by 0.03 %, in line with the often-mentioned flight-to-safety phenomenon which entails a US dollar appreciation in periods of volatility and crises (Wei et al. 2018). This can be explained by investors selling stocks and reinvesting in safer US Treasury and cash. (iii) The economic policy uncertainty (EPU) coefficient is statistically significant at a 10 % level and that of the expected sign (-), suggesting that the EPU has a negative impact on exchange rate movements (Abid 2019). More precisely, a 10% increase in

the EPU depreciates the US dollar against the EURO by 0.03 %.Thus, we support the literature suggesting that macro-economic factors significantly explain exchange rate movements at least in the long run. Hence, a growth in the domestic EPU conducts the local currency to depreciate and vice-versa: when the EPU is high, economic agents adjust their expectations about the future of economic policies (Denis and Kannan 2013; Creal and Wu 2017; Fernández-Villaverde et al. 2015; Chuliá et al. 2017). They adopt a "wait and see" attitude by reporting /cancelling their investment or consumption decisions which lead to a depreciation of the local currency (Cheng 2017). (iv) Although the association between WTI and the USD/EURO is significant and has a positive sign (Ding and Vo 2012; Wu et al. 2012). More precisely, a 10% increase in Oil-Prices appreciates the US dollar against the EURO by 0.06%.

The error correction term is well-behaved. It is negative, statistically significant at the 5 % level, and less than one in absolute terms, which ensures a long-run equilibrium convergence in the model. Specifically, the magnitude of the error correction term suggests that approximately 5.5 % of any deviation from the long-run equilibrium is correct within the first day.

The second question of interest is whether the significant effect of TotalCases on exchange rate also holds in the long-run. The results reveal that the coefficient of TotalCases+ indicates that a 10% increase of the TotalCases depreciates the US dollar against the EURO by 0.18 %. This depreciation is statistically significant at the 10% level. At the same time, the coefficient of TotalCases^{-} indicates that a 10% reduction in the TotalCases is associated with a depreciation of the US dollar against the EURO by 0.46 %.

These results suggest the size of the long-run positive and negative changes in TotalCases also confirm the long-run asymmetric association between TotalCases and the USD/EURO. A Wald test (Table 7) to assess the difference between the coefficients of Totalcases^{+} and TotalCases^{-} supports this. The test statistic is 3.119 and it is statistically significant at the 10 % level. Thus, we conclude there is a long-run asymmetry between the effects of TotalCases+ and TotalCases−on the USD/EURO over the sample period.

Among the other variables, their coefficients move together and have the same signs of that in the short-run. Expected, the coefficient of the WTI indicates a significant and negative relationship between exchange rates and Oil-Prices. More specifically, a 10% increase in the

price of oil leads to a depreciation of the US dollar against the EURO by 0.79 %.

According to Krugman's (1980) model, the short-run and the long-run impacts of the oil price rise will be converse such as a rise in oil price at first leads to dollar appreciation but then it turns into dollar depreciation. The impact of an oil price rise on the exchange rate is based on "the share of local currency in OPEC's[2] portfolio", "the share of country's goods in OPEC imports", and "the country's share in world oil imports" in this model of Krugman (1980). In the model oil imports are exogenously fixed so the effect of oil price increase will also be affected by the OPEC's spending preferences of the money generated from oil sales. For instance; if OPEC prefers dollar payment for German goods then the value of dollar will increase in the short-run however will decrease in the long-run (Krugman 1980).

Leading to the idea that exchange rate can change oil prices via its effect on oil supply, via oil demand and via financial markets. First, on the supply side of the oil market, a depreciation of the US dollar might lead oil producers to limit oil supply and raise oil prices to stabilize the purchasing power value of their export revenues in dollars (Wirjanto and Yousefi; 2003, 2005) for evidence on this channel. Second, a depreciation of the dollar might also increase the demand for oil, as oil imports become cheaper in local currency for countries besides the US (De Schryder and Peersman 2012). Moreover, several countries such as China peg their currency to the US dollar. Dependent on their oil intensity, depreciation can lead to an increase in oil demand driven by higher exports (Bénassy-Quéré and Penot 2007).

Interestingly, our estimation is an empirical illustration of the scapegoat theory since the coefficients of determination R^2 and of adjustment ($\overline{R}^2$) are high. Such evidence sheds lights on the higher explanatory power of our specification in the short and the long-run. In the same vein, NARDL was subjected to several diagnostic tests as presented in Table 6. Results from the test show that the null hypothesis cannot be rejected at the 5 % significance level, meaning that no heteroscedasticity in the model (Breusch-Pagan-Godfrey Test). For the serial correlation test, the null hypothesis is no serialcorrelation in the model (Lagrange-multiplier test), and residuals are normally distributed (Jarque-Bera test).

Parameter stability is assessed by examining the cumulative sum of recursive residuals (CUSUM) test. This is done by graphing the CUSUM together with their 5% critical lines. Fig. 2 reports the CUSUM. From this figure, the CUSUM is within the 5% significant critical

[2]Organization of the Petroluem Exporting Countries.

lines. Consequently, the test does not find evidence of parameter instability over the sample period. In other words, the relationship between the variables as characterized by the NARDL models is not time-varying.

[Insert Table 6 here]

[Insert Table 7 here]

[Insert Figure 2 here]

4.2. Robustness checks

The robustness results considering the number of deaths as the proxy of Covid-19 confirm our initial findings. However, the bounds test shows that the existence of a co-integration relationship is documented at 5% significance level. Table 8 reports the NARDL results, namely the F-statistics estimated from the NARDL bound testing and their associated upper and lower bound critical values. In this case, the F-statistic value of 4.71 is higher than the 5% level of significance upper bound critical value of 3.79. Consequently, we do not reject the hypothesis that there is a long-run equilibrium relationship running from USD/EURO to the other variables. Hence, it has been ascertained that variables move together in the long-run.

The long-run link between the TotalDeaths and the USD/EURO is significant in this case as well. Nevertheless, Table 9 shows that in the long run, TotalDeaths^{-} has a rather reduced negative impact on the US dollar against the EURO. As consequence, the association of TotalDeaths with the USD/EURO in the long-run is symmetric; the outcome of the WALD test further (Table 10) confirmed the long-run symmetric effects of TotalDeaths+ and TotalDeaths− on USD/EURO,whereas the other variables have similar effects on the US dollar against the EURO.

The short-run equation reveals also homogeneous findings. However, the Wald test statistic of 0.118 is statistically insignificant at conventional levels (Table 10); this implies that there is no short-run asymmetry between the TotalDeaths and the USD/EURO.

As expected, the coefficient of error correction term is 11%, negative and statistically significant at the 1% level. Given the ECT is higher that the ECT estimated when the TotalCases was the proxy of Covid-19, which means that the speed of adjustment of the exchange rate is faster in this case.

In order to avoid misleading statistical inferences, the study verified and validated the model through diagnostic and stability checks. NARDL model was subjected to several diagnostic tests as presented in Table 9; residual serial correlation was tested using Lagrange-multiplier test based on Null Hypothesis: no serial correlation at lag order h. Results from the test show that the null hypothesis cannot be rejected at the 5% significance level, meaning that no serial correlation exists at lag order h. Results from the Breusch-Pagan-Godfrey test show that the null hypothesis cannot be rejected at the 5 % significance level, meaning that there is no heteroscedasticity in the model. Residual normality was tested using *Jarque-Bera* test based on Null Hypothesis: residuals are normal. Results from the test show that the null hypothesis cannot be rejected at the 5% significance level, meaning that residuals are normally distributed.

From Fig.3, the CUSUM is within the 5% significant critical lines. Consequently, the test does not find evidence of parameter instability over the sample period. In other words, the relationship between the variables as characterized by the NARDL models is not time-varying.

[Insert Table 8 here]

[Insert Table 9 here]

[Insert Table 10 here]

[Insert Figure 3 here]

5. Conclusion and policy implications

This study investigated the asymmetric effects of Covid-19 dynamics on the US dollar exchange rate using daily time-series data for the period from the 01st of March 2020 to 28th of August 2020. The results of the Augmented Dickey Fuller and Philip-Perron unit root tests revealed that the variables are integrated of order one (I(1)), thus meeting the requirement for carrying out a bound co-integration test. The results showed the existence of co-integration. To examine the non-linear dependence, we applied the BDS nonlinearity test (1996). The BDS test rejects the null hypothesis of independent and identically distributed residuals across various dimensions. Our findings commensurate with the BDS test, the F_{pss} test of Pesaran et al. (2001) and Shin et al. (2014) confirms the asymmetric co-integration between the US

dollar against the EURO and Covid-19, employing the nonlinear ARDL (NARDL) model of Shin et al. (2014).

We conclude that the relationship between USD/EURO and the number of cases is asymmetric in the long-run. In addition, the positive changes of TotalCases exert a significant negative effect on USD/EURO, although we noticed that the long-run negative changes of TotalCases have a significant positive effect on USD/EURO. This means that the application of the linear modeling will not be suitable to highlight the hidden long-run asymmetric co-integration between TotalCases and the US dollar against the EURO. Concurrently, in the short-run, the relationship between TotalCases and USD/EURO turned out to be symmetric. Furthermore, similar to the short-run results, the long-run results depict that TotalDeaths (positive and negative) have negative impacts on USD/EURO. The results of the Wald test suggested that TotalDeaths dynamics (positive and negative) have no asymmetric impact on USD/EURO.

For the reason that currency exchange rate seems to be sensitive to coronavirus, it is imperative to highlight some policy implications. First, it is essential to use the NARDL model, which would provide more information to American policymakers. Second, in a crisis such as the Covid-19 pandemic, the US government and monetary authorities should be able to quickly amplify the messages and actions that "turn the curve". Speed trumps perfection. In fact, linear responses will not keep pace with an exponentially growing pandemic. Third, it is important to put in place both short-term measures to deal with the economic shock and long-term measures to rebuild and restart. These measures will be implemented at the local, national and global levels. Lastly, it will be important to provide a clear narrative aimed at highlighting the links between the spread of the virus, its causes and consequences, and a broader vision of a sustainable development and climate.

In this research work, we only focused on the US dollar against the EURO. Our study can be replicated for more exchange rates, especially the exchange rate of safe haven currencies such as the Swiss franc against the background of the novel Corona virus' worldwide spread.

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