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Equity Market Pricing and Central Bank Interventions: A Panel Data Approach

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Abstract: This paper analyzes the effects of central bank interventions via large-scale purchases of government debt securities on the pricing of stock market indices. This study examines the effects of changes in the size of the Federal Reserve's balance sheet in three intervention scenarios: during the 2008–2013 period, the 2020–2022 period, and in the years between by using the instrumental variables three-stage least squares (3SLS) method for a time series approach, and calculates the effects of these interventions on each index in a fund of funds setup using the panel data strategy. This study confirms that large-scale purchases of government debt securities in response to the Great Recession and COVID-19 crises influenced the pricing of equity markets via their effect on the pricing of treasury bonds, with different degrees of sensitivity of each index to the effects on yields. Although the findings apply to the U.S. market, the results indicate that the pricing of small capitalization indices such as the Russell 2000 are less sensitive to changes in treasury yields caused by central bank interventions than large capitalization indices such as the DJIA. This research contributes to the understanding of financial asset pricing, particularly by identifying price distortions within equity market portfolios.

Keywords: Fed's balance sheet; Great Recession; instrumental variables; quantitative easing; tapering; COVID-19

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1. Introduction

On 3 November 2021, the Federal Reserve (Fed) announced the reduction in its large-scale purchases of debt securities program of $10 billion in Treasuries and $5 billion in MBSs, from the monthly $120 billion that the Fed was buying at the time, expecting to end them by July 2022 (Cox 2021). This decision was the result of observing the recovery of economic activity and employment figures in the U.S. economy, as well as progress on the COVID-19 vaccinations, after the breakout of the virus in February of 2020 (Federal Reserve 2021a). At the time of this decision, the federal funds rate was at its lowest level of 0.25 percent and the 10-year treasuries were trading at yields near 1.5 percent throughout 2021, for which the continuation of the central bank's active intervention was no longer required. Moreover, the stock market indexes showed solid proof of recovery from the low levels of 2020 at the midst of the pandemic outbreak. While the Dow Jones Industrial Average (DJIA) and Nasdaq composites had completely cleared all losses from the pandemic, the S&P500 was quoting at its maximum historical levels. However, in December 2021, the Fed accelerated the "tapering" (the gradual removal of quantitative easing policies formerly implemented by a central bank) by reducing its purchases by $20 billion and $10 billion, respectively, as signs of rising inflation emerged (Federal Reserve 2021b).

Although the 2021 tapering had begun, market health indicators continued to improve, reminding us of the times after the last tapering was employed to support the economy during the Great Recession. However, this time would be different, as unexpected side effects developed such as the inflation outbreak. While lack of inflation was a concern to investors back in 2013–2015, the Fed was now facing rising inflation to levels not seen in the last several decades. Figure 1 shows the performance of the 10-year treasury yields as the main indicator of the effects in the credit market interest rates in direct connection to the securities purchases made by the central bank in the last fourteen years. The figure proves that the launch of the Fed's purchases in March 2020 (and the increase in its balance sheet) drove the yields lower than 1 percent while also lowering the federal funds rate to 0.25 percent. Moreover, the figure also shows how the U.S. Consumer Price Index (CPI) escalated through the COVID-19 Quantitative Easing (QE) program in comparison to the various QE programs implemented in connection to the previous credit crisis.

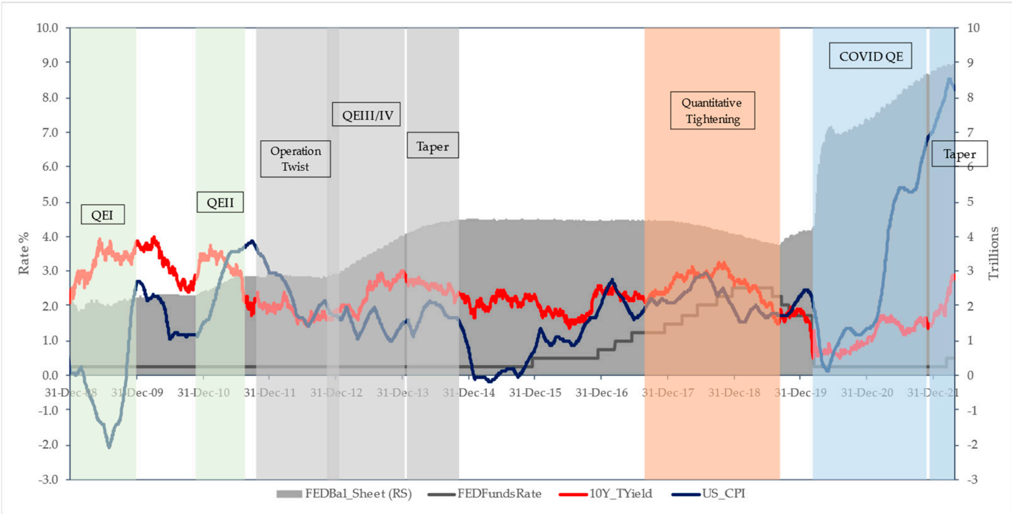

Figure 1. Fed's balance sheet, interest rates, and inflation (16 December 2008–29 April 2022).

As the credit market was stimulated, so was the stock market. The performances of the four major U.S. indices, the Dow Jones Industrial Average (DJIA), Nasdaq, S&P500 and Russell Small Cap 2000 (Russell) from December 2008 to April 2022 are shown in Figure 2.

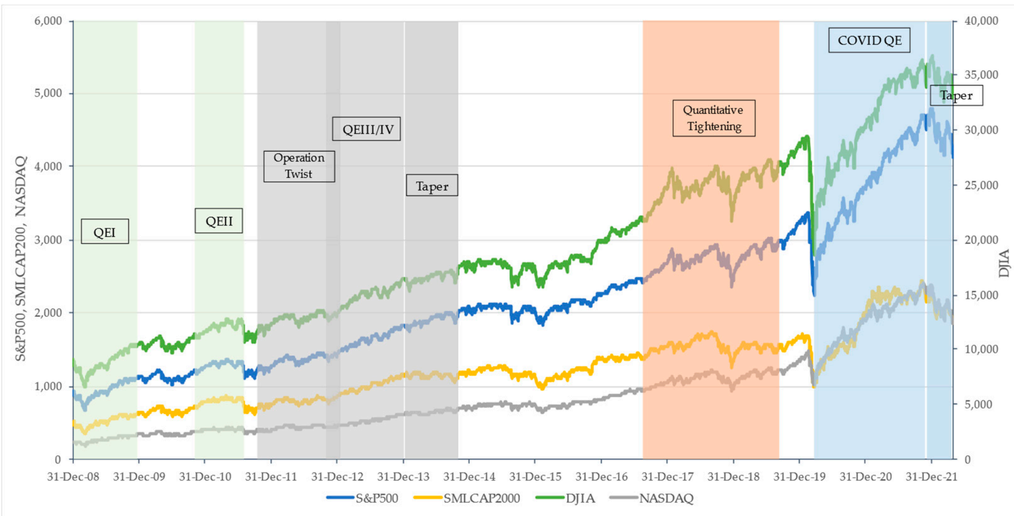

Figure 2. Performance of main U.S. indices (16 December 2008–29 April 2022).

Although the four indices display trends alike, they are not identical. In fact, though the DJIA and the S&P500 resemble each other, the Russell and Nasdaq differed in the past QEs. What is more interesting is that, although all four indices completely recovered all losses from the COVID-19 shock, the first two slightly diverged in mid-2021, and the other two matched during the 2020–2021 period.

Key moments in the indices' trajectories are worth noting. Take the DJIA and the S&P500 indices, for example; while the first quoted at its maximum historical value of 36,799.65, the latter did so at 4796.56 on 2 and 4 January 2022, returning some 25 and 42 percent before the COVID-19 correction when they traded at 29,551.42 and 3386.15 on 12 and 19 February 2020, respectively, and some 98 and 114 percent from 18,591.93 and 2237.4 at the bottom of the pandemic crisis, both on 23 March 2020, respectively. Even though the difference in the performance of each index relies on the way each index is constructed (that is, the number, type and size of firms that comprise each index), it is common to conclude that the stock market came out stronger from both crises.

In the context of this study, it has been identified that the Fed's intervention on the credit market via the purchase of government debt securities in the 2008–2013 and the 2020–2021 periods had an impact on the valuation of each index (Gagnon et al. 2011; Khemraj and Yu 2015). The aim of this study is, firstly, to identify whether there is an effect on the pricing of the stocks that are part of the main U.S. indices from the Fed's purchases of government securities. Secondly, if there is such an effect, a crucial goal will be to estimate the magnitudes of such effects on each index. As this study tests an identification strategy under two approaches, a third aim is to establish which of the approaches used is recommended to best estimate such effects.

In this paper, the interventions of the credit market of 2008–2013 and 2020–2021 in the U.S. are used as a quasi-natural experiment to explore whether government interventions in the credit markets policy have impacted the pricing of equity securities. This study uses the daily trading data of the DJIA, S&P500, Nasdaq and Russell indices in the U.S. equity market from 16 December 2008 until 29 April 2022 (performance through the Great Recession and the COVID-19 crises) as samples. Hence, the following research questions are addressed: Do central bank interventions (or dis-interventions) on government securities in the credit markets such as QE (or tapering) impact the pricing of equity securities? If that is the case, what is the relevance of such effects? Answers to these questions may have investment implications as they may point out a risk factor to account for when market interventions are implemented in times of financial distress. To answer these questions, this study uses the instrumental variables three-stage least squares (3SLS) method, contributing to the existing literature that mostly relies on event study methodologies that are applied to financial markets subsets (Wei and Han 2021), a specific country (Rao and Kumar 2023), or sectors (O'Donnell et al. 2024). This paper is divided into the following sections: this Introduction, a Literature Review, Methodology and Data, Results and Discussion, Implications and Conclusions.

2. Literature Review

Estimating the effects of central bank interventions on asset prices may become rather complex due to the endogeneity of policy implementations, and the fact that interest rates and asset prices are influenced by multiple other variables. Rigobon and Sack (2004) suggest that increases in short-term interest rates generated declines in stock prices for a dataset from 1994 to 2001. Their results indicate that for the four stock indices considered, a significant negative reaction to monetary policy holds. However, due to behavioral biases, the estimated effects on stock prices are rather small compared to the effects on treasury yields. Bernanke and Kuttner (2005) find that, on average, an unexpected 25 basis points cut in the Fed funds target rate may be associated with an average 1% rise in stock market indices.

Fama and French (2002) point out that the average stock return for the period 1951 to 2000 was much higher than expected; their evidence suggests that the high average return for that period was due to declining discount rates that produced large, unexpected capital gains. This leads us to believe that any actions by the central bank that help steadily reduce interest rate levels should translate into larger equity premiums (Cochrane 2005; Sharpe 1964).

Since the times of the great recession of 2007–2009, the target federal funds rate has been at its lowest levels. In an attempt to further ease its monetary policy, the Fed implemented an unconventional monetary policy (UMP) which included primarily a program of massive purchases of assets of medium and long maturities. Gagnon et al. (2011) present evidence that those purchases led to economically meaningful and long-lasting reductions in longer-term interest rates on a range of securities, including securities that were not included in the purchase programs. In turn, those interest rate reductions reflected lower risk premiums in the fixed income markets, including long-term premiums. Moreover, Khemraj and Yu (2015) find evidence that QE stimulated the level of aggregate investment via the interest rate channel by narrowing the corporate bond spread to benchmark. In short, they found that the Fed's purchases of MBSs had a high statistical significance effect on aggregate private investment.

Further works on government interventions have pursued research on the effects of the discontinuation of such interventions on asset prices. Albu et al. (2016) suggest that both the QE policy and the gradual reduction therein ("Tapering") had relevant effects in terms of the volatility of the indices they analyzed. Furthermore, Chari et al. (2017) analyze the impact of U.S. UMP on capital flows and asset prices in emerging markets. They find that U.S. monetary policy shocks represent revisions to the expected trajectory of short-term interest rates and the required risk compensation, with this risk compensation factor becoming especially important during UMP periods. They also suggest that the relative effects of U.S. monetary policy shocks are larger for emerging market asset returns in relation to physical capital flows, and are larger for emerging equity markets relative to the fixed-income markets. Surprisingly, they find that these effects are larger when the Fed implements a "tapering" or reduction in its asset purchase program.

Other academic literature disputes the effects of central bank balance sheet expansions on inflation. Moessner (2015) finds no strong evidence that announcements about expansions of the European Central Bank (ECB) balance sheet have led to higher inflation expectations. On the other hand, Boeckx et al. (2014) affirm that inflation in Europe could have been 1 percent lower in 2012 had the LTRO programs not been implemented by the ECB. However, the question of whether inflation transmits into equity index levels remains unanswered.

Other studies reveal crucial links between interest rates and exchange rates. For instance, Krugman and Obstfeld (2006) indicate that increases in a country's money supply cause its currency to weaken in the foreign exchange market, as the former decreases the interest paid on deposits of that currency. Although the intuition behind the relationship between yields and currency prices is straightforward, further research hints at the ties of both rates to oil prices. Ergo, Krugman (1980) suggests short- and long-run effects of oil price changes on currency prices, and that these effects may go in opposite directions. That is, oil price increases will initially lead to dollar appreciation and eventually depreciation. Furthermore, Amano and van Norden (1995) point out that oil prices best capture exogenous terms-of-trade shocks that are crucial in currency price determination in the long run, while Beckmann et al. (2020) confirm that links between exchange rates and oil prices are strong; however, these links are frequently observed over the long run.

Interestingly, Fratzscher et al. (2013) reveal that the U.S. dollar, oil prices, and equity market returns are strongly linked mostly due to the rising use of oil as a financial asset. Moreover, Mokni (2020) finds evidence of country time-varying reactions of stock returns to oil shocks. In general, oil demand shocks positively impact oil-exporting stock returns and negatively impact oil-importing countries. Withal, stock returns react more to demand-side oil shocks than supply-side shocks, with a positive effect on almost all stock returns in the first and negative and modest effects in the latter case.

Although further academic research has been devoted to the effects of the large-scale purchases of treasury securities by the Fed, these effects concentrate on the pricing of debt securities and interest rates. Crucial contributions have been made by D'Amico and King (2010), D'Amico et al. (2012), Doh (2010), and Hamilton and Wu (2012), among others. The literature linking these effects to equity markets pricing, however, is rather tangential to the present, especially given how recently the last crisis took place. Vukovic et al. (2019)

finds changing effects on the bond pricing dynamics pre- and post-economic crisis in the European market for the 2005–2017 period that may give hints of probable changing effects on the pricing of bond securities during the COVID-19 crisis as well. This research not only pursues the finding of such links and effects, but endeavors to test the empirical methods available and contribute to filling the research gap in these spheres.

3. Methodology and Data

The literature above suggests that the treasury yield rate is highly influenced, among other variables (Moench and Soofi-Siavash 2022), by the size of the central bank balance sheet, as the latter expands each time treasury securities are purchased by the Fed. Additionally, given the size of the U.S. treasuries market, changes in the treasury rate are a major driver of the value of its currency as well (Kim 2023), among other macroeconomic factors. In this study, we describe that the dynamics of a given equity index in the U.S. is influenced by the dynamics in the central bank balance sheet through its impact on treasury yields. Moreover, the dynamics of its currency value is influenced by that of treasury yields and the oil prices due to the large international exchange of this commodity (Amano and van Norden 1995; Beckmann et al. 2020; Fratzscher et al. 2013; Krugman 1980; Mokni 2020).

In particular, following Krugman and Obstfeld (2006), the relationship between treasury yields and the central bank's balance sheet may be described by a function with a negative slope in the money market, in which a rise in the Fed's balance sheet is associated with a drop in the treasury yields. Simultaneously, as foreign investors add to a portion of the demand for treasuries, the foreign capital flows of arbitrage pressure the currency price to maintain interest rate parity (Krugman and Obstfeld 2006). Hence, a function of expected foreign currency returns against yields with a negative slope in the foreign exchange market is also supported, in which drops in the treasury yields are associated with a rise in the local currency price. In short, four hypotheses will be tested in this paper. Firstly, the hypothesized model of central bank interventions effects on financial markets is applied as per the description in Figure 3, from which the following two hypotheses can be derived:

H1: *The excess liquidity provided by the size of the Fed's balance sheet directly impact the pricing in the debt market.*

H2: *The pricings in the debt and currency markets influence the pricing of equity securities.*

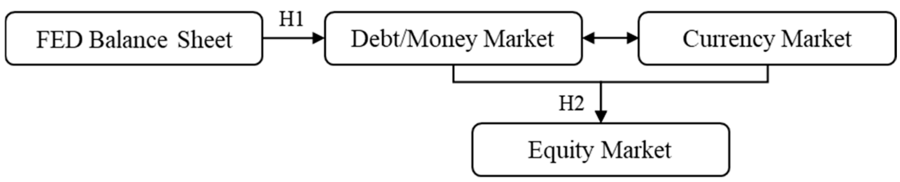

Figure 3. Hypothesized model of central bank intervention effects on financial markets.

From these first two hypotheses, this paper will demonstrate that a third and fourth are implied:

H3: *Equity indices, as measures of equity market performance, have different sensitivities to changes in yields caused by changes in the size of the central bank's balance sheet.*

H4: *Index sensitivities vary depending on different interventions. That is, index sensitivities change at different stimulations.*

For the sake of proving these hypotheses, the instrumental variables method is employed as the research identification strategy. Given their complexity and how highly interconnected financial markets are today, simultaneity of estimations in different markets at once is required. Hence, a 3SLS method (Zellner and Theil 1962; Fisher 1970; Hausman et al. 1987) is able to provide a suitable solution for dealing with simultaneity in establishing causalities, while capturing biases and endogeneity issues in the data, and link several market clearings at the same time at different moments. Furthermore, two approaches of this strategy are employed. The time series approach helps to estimate the impact of the balance sheet size on each index individually, while with the panel data approach, all four index sensitivities are analyzed within one large portfolio of equity assets.

3.1. Empirical Model

In order to establish the discussed causalities and linkages, the instrumental variables strategy is used in this research. This is because of the assumption that the indices prices are influenced in part by the treasury yield and currency levels, and the latter are explained by the balance sheet and oil price levels, respectively. Fitly, the 3SLS method solves the endogeneity puzzle between treasury yields and the central bank balance sheet levels, and between the currency, treasury yield and oil price values. The causalities, thus, are best described by the following by stages three simultaneous equations system:

$$\textit{Stage 1: } t\_yield_t = \pi_0 + \pi_1\, Fed\_BS_t + \Sigma\pi_i Y_{i,t} + v_t \tag{1}$$

$$\textit{Stage 2: } usd\_eur_t = \delta_0 + \delta_1\, t\_yield_t + \delta_2\, wti\_spt_t + \Sigma\delta_i Z_{i,t} + e_t \tag{2}$$

$$\textit{Stage 3: } index_{i,t} = \beta_0 + \beta_1\, t\_yield_t + \beta_2\, usd\_eur_t + \beta_3\, Fed\_FRte_t + \beta_4\, us\_cpi_t + u_t \tag{3}$$

where π_0, δ_0 and β_0 are intercepts, $Y_{i,t}$ and $Z_{i,t}$ are the vectors of covariates in (2) and (3) and v_t, e_t and u_t, are error terms.

In the first equation, t_yield_t is the treasury yields level (endogenous) variable, explained by the Fed's balance sheet level, Fed_BS_t (Cochrane 2005; Sharpe 1964), the control variable for the system. In the second equation, the currency price, usd_eur_t, is an endogenous variable explained by the treasury yields, t_yield_t, determined by the first equation, and by the oil prices, wti_spt_t, an exogenous variable whose value is determined in the international oil market. In the principal equation, $index_{i,t}$ is the value of each of the indices, influenced by the value of the federal funds rate, Fed_FRte_t (Bernanke and Kuttner 2005; Rigobon and Sack 2004), general price levels, us_cpi_t, treasury yields, t_yield_t (Fama and French 2002) and currency prices, usd_eur_t, the latter two being determined by the first and second equations. While computation of the 3SLS estimates by Narayanan (1969) and Hausman (1983) proves the goodness of this approach in these two aspects, Wooldridge (2002) gives attention to the identification issues for choosing the right estimator. That is, for just identified equations, the 2SLS and the 3SLS estimations coincide, in which case the latter does not offer added efficiency.

A key feature of the simultaneous equations approach proposed here is that, although every equation is specified to be linear, the relationships among the variables considered are presumed nonlinear. That is, there will typically be nonlinear identities connecting the variables in the different equations of the system (Fisher 1970). In order to calculate the estimations of the proposed instrumental variables system of simultaneous equations, we begin by employing the 3SLS for a time series strategy on each index and then use the 3SLS in a panel data setting.

3.2. Data

This research takes the daily data of the DJIA, S&P500, Nasdaq and Russell indices, the Fed's balance sheet size, the federal funds interest rate and the 10-year treasury bond yields as samples, as well as other relevant data such as currency (USD/EUR) and oil spot prices (WTI) and inflation (CPI), taken as relevant daily financial indicators. The data range from 16 December 2008 to 29 April 2022, that is, the whole period that included both interventions and dis-interventions. All data have been obtained from the EIKON Refinitive (2022) terminals. Table 1 summarizes all data variables' statistics. The data described in Table 1 will be used without any transformations for the estimations of this paper. The end results of the models will refer to the estimated values of portfolios under the times series approach, and of the value of an aggregate portfolio (fund of funds) under the panel data approach, rather than their expected returns, at each financial crisis.

Table 1. Summary descriptive statistics for all variables (16 December 2008–29 April 2022).

Variable	Obs.	Mean	Std. Dev.	Min	Max	Variance	Skewness	Kurtosis
SP500	3366	2210.98	981.02	676.53	4796.56	96,2396.9	0.776312	2.919836
DJIA	3366	19,267.45	7585.67	6547.05	36,799.65	57,500,000	0.535292	2.316637
Nasdaq	3366	5869.56	3670.72	1268.64	16,057.44	13,500,000	1.118963	3.39836
Russell	3366	1220.94	472.38	343.26	2442.74	223,147.1	0.512697	2.711547
Fed_BS	3366	4.2554	1.7627	1.8434	8.9650	3.106988	1.120021	3.684149
L1_BS	3365	4.2540	1.7611	1.8434	8.9650	3.101389	1.120168	3.687226
L5_BS	3361	4.2484	1.7547	1.8434	8.9650	3.078825	1.120617	3.699171
Fed_FRte	3366	0.6326	0.6877	0.250	2.500	0.472965	1.64255	4.223993
t_yield	3366	2.2673	0.7317	0.499	3.994	0.535385	−0.06953	2.715562
usd_eur	3366	0.81961	0.07531	0.6605	0.9627	0.005672	−0.15913	1.747966
wti_spt	3366	68.8356	23.1513	7.79	126.47	535.981	−0.08693	2.232741
us_cpi	3366	1.9182	1.6700	−2.10	8.56	2.788834	1.361179	6.635508

Note(s): This table presents the dataset key statistics. Symmetric distributions for coefficient of skewness have value zero; negative coefficients skewed left and positive skewed right. Smaller kurtosis coefficients for flatter distributions (fat tails), assuming normal distributions have a coefficient of kurtosis of 3. Source: own estimations.

4. Results and Discussion

4.1. Correlations Analysis

From the results displayed in Table 2, it is possible to verify our expectations about a high negative correlation between the levels of the Fed's balance sheet and the treasury yields, as well as a high positive correlation of the balance sheet with the value of the foreign exchange rate and inflation. This goes in line with the fact that the higher demand from the central bank for treasuries lowers their yield, while weakening its currency and increasing the value of the CPI. Notice that in the fifth column, there is a high correlation between the balance sheet instrument Fed_BS_t, and the t_yield_t (−0.6140), usd_eur_t (0.5391) and us_cpi_t (0.5439). Moreover, the results confirm the significant negative correlations between the yields and the currency prices and the latter with the oil prices, of −0.4978 and −0.6676, respectively.

Another key finding in this table is the high positive correlations of the balance sheet with the four indices, ranging from 0.8830 in the case of the DJIA to 0.9342 for the Nasdaq, as displayed in the fourth row. Also, notice that since the open-market purchases are reported weekly, lags of the balance sheet level series have been calculated for one day and one-week delays ($L1\_BS_t$ and $L5\_BS_t$), showing similar correlation results with the index. Moreover, the high positive correlations of the indices with the currency value and the CPI (ranging from 0.5551 to 0.6318 and from 0.5450 to 0.5742, respectively), imply that a weakening of the currency as well as increases in the price of the products sold may drive the index up.

Finally, although there is a lower negative correlation (ranging from −0.2483 to −0.3043) between the indices and the oil prices, all the above-mentioned results suggest that, for the data used in this study, these variables are relevant as instruments for our estimations. Tables A1 and A2 of Appendix A show the correlation results for the first and second interventions, respectively.

4.2. Regressions Results

The regression results, estimated by the 3SLS approach for the four indices, are shown in Table 3. In this model, the variable Fed_BS_t has been used as the instrument in the first equation for the endogeneity of the treasury yield variable, t_yield_t. In turn, the treasury yield variable, t_yield_t, has been used as instrument in the second equation for the endogeneity of the currency variable, usd_eur_t.

Table 2. Correlations matrix (2 April 2007–1 February 2023).

	SP500	***DJIA***	***Nasdaq***	***Russell***	***Fed_BS***	***L1_BS***	***L5_BS***	***Fed_FRte***	***t_yield***	***usd_eur***	***wti_spt***	***us_cpi***
SP500	1											
DJIA	0.9925 *	1										
	0.0000											
Nasdaq	0.9893 *	0.9731 *	1									
	0.0000	0.0000										
Russell	0.9771 *	0.9803 *	0.9546 *	1								
	0.0000	0.0000	0.0000									
Fed_BS	0.9255 *	0.8830 *	0.9342 *	0.8857 *	1							
	0.0000	0.0000	0.0000	0.0000								
L1_BS	0.9257 *	0.8832 *	0.9343 *	0.8860 *	0.9999 *	1						
	0.0000	0.0000	0.0000	0.0000	0.0000							
L5_BS	0.9262 *	0.8838 *	0.9345	0.8875	0.9996 *	0.9997 *	1					
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000						
Fed_FRte	0.3128 *	0.4120 *	0.2373 *	0.3602 *	−0.0184	−0.0178	−0.0156	1				
	0.0000	0.0000	0.0000	0.0000	0.2866	0.3014	0.3672					
t_yield	−0.5405 *	−0.5189 *	−0.5578 *	−0.4742 *	−0.6140 *	−0.6134 *	−0.6111 *	0.0951 *	1			
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
usd_eur	0.6167 *	0.6318 *	0.5551 *	0.6078 *	0.5391 *	0.5390 *	0.5388 *	0.4339 *	−0.4978 *	1		
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			
wti_spt	−0.2946 *	−0.3043 *	−0.2948 *	−0.2483 *	−0.2748 *	−0.2750 *	−0.2760 *	−0.2653 *	0.4104 *	−0.6676 *	1	
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		
us_cpi	0.5742 *	0.5522 *	0.5703 *	0.5450 *	0.5439 *	0.5440 *	0.5446 *	0.0587 *	−0.1449 *	0.1221 *	0.3675 *	1
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	

Note(s): (*) denotes coefficients significant at 10% level. Source: author’s calculations.

Based on the coefficients in Table 3, it is possible to conclude that the Fed's intervention by expanding its balance sheet through the purchase of treasury securities causes the treasury yields to drop while weakening its currency, which supports the high negative correlation between the currency price and the treasury yields shown in the ninth column of Table 2 in concordance with Krugman and Obstfeld (2006). As for the principal equation, the results show that the indices increases are associated with raises in the federal funds rate, Fed_FRte_t, as shown by its positive coefficient, and drops in the indices are associated with cuts in this rate. These results, however, contradict the findings of Rigobon and Sack (2004) due to a different period of the dataset and the inclusion of different types of monetary policies. Moreover, the coefficients of the oil prices, *wit_spt*, and price index, *us_cpi*, indicate that increases in the oil prices and in the price levels in the economy drive the indices to drop and rise, respectively, with the former via the weakening of the currency.

In Table 3, the numbers in brackets indicate the index model. Each index model includes two columns. The second column of each index model is the same regression model, though it includes a one-week lag in the Fed's balance sheet in the first equation. Hence, each column pair shows the composition of the effects of the balance sheet growth on the treasury yields without and with a weekly lag. That is, although we have established that an increase in the Fed's balance sheet explains the drop in the yields, this change is about 23.37 basis points (bps) for each trillion added to the Fed's balance sheet, as shown in the first column middle section of the S&P500 index. This, however, is a result of netting a sharp drop of about 140.81 bps (in the second column) in the yields as the purchases are executed in the current week (Fed_BS_t); subsequently, though, the yields rise throughout the week as the liquidity is absorbed by the market in about 117.90 bps ($L5\_BS_t$), for a net drop of about 22.91 bps per trillion. From these findings, Equation (1) has been re-specified to derive each parallel results as follows:

$$Stage\ 1'\text{: } t\_yield_t = \pi_0 + \pi_1\ Fed\_BS_t + \pi_2\ L5\_BS_t + \Sigma\pi_i Y_{i,t} + v_t \quad (4)$$

Finally, the R-squared values for each of the three equation sets are displayed at the bottom of each equation coefficients. Since the simultaneous equations approach is used in this research, the aim is not to maximize the R-squared values of any of the simultaneous equations (Fisher 1970). However, the results register plausible enough R-squares in each equation, as well as high chi-square values. Although the estimates from the 3SLS are assumed to be robust, they can be verified by the results obtained via the two-step generalized method of moments (GMM) as well as the seemingly unrelated regressions (SUR) estimators for all indices without and with one week lag balance sheet size in Table A3 of Appendix B. To test for the joint significance of the simultaneous equations, the (Breusch and Pagan 1980) test has been performed on each index set of equations. The results of the Breusch–Pagan test of independence confirm that all three equations' correlation coefficients are highly jointly significant, as shown in Table A4 of Appendix C.

4.3. Intervention Regressions Results

The following step runs the same methods on the data solely on the periods under the interventions of the central bank to estimate any changes in the coefficients of the equations. In turn, running the specified 3SLS model for the period from 16 December 2008 to 31 December 2013 for the first intervention, and for the period from 18 March 2020 to 29 March 2022 for the second intervention, yielded the sets of coefficients for all four indices in Table 4. In this table, two twelve-equation systems for each intervention are displayed on panels A and B, for the first and second interventions, respectively.

Table 3. Regression results by index (16 December 2008–29 April 2022). Three-stage least squares regressions by index.

	(1)		(2)		(3)		(4)	
Variable	SP500	SP500_L5	DJIA	DJIA_L5	Nasdaq	Nasdaq_L5	Russell	Russell_L5
Fed_FRte	384.9307 ***	382.3947 ***	4137.8340 ***	4119.3300 ***	1183.6030 ***	1174.2210 ***	208.4120 ***	206.6854 ***
us_cpi	333.8543 ***	332.7607 ***	2469.4850 ***	2462.0310 ***	1292.0510 ***	1289.9160 ***	146.9944 ***	146.2313 ***
_cons	1327.1010 ***	1331.8390 ***	11,913.1100 ***	11,947.2600 ***	2642.4890 ***	2655.5140 ***	807.1451 ***	810.3717 ***
R-squared	0.4077	0.4068	0.4494	0.4486	0.3657	0.3649	0.4044	0.4034
χ	2411.66	2385.72	2903.65	2873.31	2230.06	2210.86	2187.3	2161.54
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_yield								
Fed_BS	−0.233722 ***	−1.408131 ***	−0.228948 ***	−1.372496 ***	−0.233966 ***	−1.360477 ***	−0.253249 ***	−1.543998 ***
L5_BS	-	1.178981 ***	-	1.147626 ***	-	1.130360 ***	-	1.298019
_cons	3.261833 ***	3.25493 ***	3.241519 ***	3.236392 ***	3.262874 ***	3.258566 ***	3.344931 ***	3.327776 ***
R-squared	0.3744	0.3897	0.3731	0.3883	0.3745	0.3895	0.377	0.3929
χ	1778.33	1862.02	1714.78	1800.21	1783.27	1871.68	2060.26	2123.75
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
usd_eur								
t_yield	−0.044983 ***	−0.042221 ***	−0.046512 ***	−0.043667 ***	−0.051962 ***	−0.049034 ***	−0.038969 ***	−0.036551 ***
wti_spt	−0.001836 ***	−0.001847 ***	−0.001832 ***	−0.001844 ***	−0.001836 ***	−0.001849 ***	−0.001878 ***	−0.001882 ***
_cons	1.047974 ***	1.042690 ***	1.051195 ***	1.045825 ***	1.063766 ***	1.058340 ***	1.037202 ***	1.032244 ***
R-squared	0.4767	0.4907	0.4716	0.4865	0.4490	0.4669	0.4918	0.5026
χ	4490.07	4345.55	4565.02	4419.63	4910.79	4763.24	4309.16	4164.75
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Endogenous variables:	SP500 DJIA Nasdaq Russell *t_yield usd_eur*							
Exogenous variables:	*Fed_FRte us_cpi L5_BS Fed_BS wti_spt*							

Note(s): This table displays the coefficients of the variables in the models as well as the statistical significances of each proposed model for all four indices. The models considered are the instrumental variables three-stage least squares (IV3SLS) for time series *with* and *without* one-week lag in the central bank balance sheet size tested for the entire data period (16 December 2008–29 April 2022). Both models use the size of the Fed's balance sheet as the control variable. *** indicate coefficients are significant at the 1% level. Source: own estimations.

Table 4. Regression results by index per interventions. Three-stage least squares regressions by index per intervention.

Panel A: Regressions Results First Intervention (2008–2013)								
Index	SP500	SP500_L5	DJIA	DJIA_L5	Nasdaq	Nasdaq_L5	Russell	Russell_L5
Variable	(1)		(2)		(3)		(4)	
Fed_FRte	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)	(omitted)
us_cpi	71.7047 ***	70.8900 ***	707.6381 ***	700.8915 ***	185.9111 ***	183.6030 ***	52.0364 ***	51.4864 ***
_cons	1159.469 ***	1161.948 ***	10,754.628 ***	10,774.796 ***	2373.388 ***	2380.588 ***	671.684 ***	673.402 ***
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_yield	(5)		(6)		(7)		(8)	
Fed_BS	−0.7962 ***	2.2288 ***	−0.7390 ***	2.3320 ***	−0.7995 ***	2.2430 ***	−0.8747 ***	2.0488 ***
L5_BS	-	−3.0620 ***	-	−3.1103 ***	-	−3.0796 ***	-	−2.9574 ***
_cons	4.8069 ***	4.8887 ***	4.6529 ***	4.7403 ***	4.8159 ***	4.8980 ***	5.0185 ***	5.0925 ***
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
usd_eur	(9)		(10)		(11)		(12)	
t_yield	−0.0308 ***	−0.0339 ***	−0.0311 ***	−0.0342 ***	−0.0304 ***	−0.0334 ***	−0.0303 ***	−0.0332 ***
wti_spt	−0.0005 ***	−0.0006 ***	−0.0005 ***	−0.0006 ***	−0.0005 ***	−0.0006 ***	−0.0005 ***	−0.0006 ***
_cons	0.8665 ***	0.8826 ***	0.8673 ***	0.8833 ***	0.8665 ***	0.8825 ***	0.8663 ***	0.8823 ***
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Panel B: Regressions Results 2nd Intervention (2020–2022)								
Index	SP500	SP500_L5	DJIA	DJIA_L5	Nasdaq	Nasdaq_L5	Russell	Russell_L5
Variable	(13)		(14)		(15)		(16)	
Fed_FRte	−899.4386 *	−934.4934 *	−8372.9004 *	−9421.7857 *	−5603.9925 **	−5440.0177 ***	−1481.5871 ***	−1570.1119 ***
us_cpi	209.6201 ***	198.2083 ***	1343.0482 ***	1263.4306 ***	682.0166 ***	631.6812 ***	94.3413 ***	89.6114 ***
_cons	3379.689 ***	3440.396 ***	28,658.166 ***	29,297.266 ***	11,841.987 ***	12,023.146 ***	1979.489 ***	2026.039 ***
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
t_yield	(17)		(18)		(19)		(20)	
Fed_BS	0.4025 ***	1.4701 ***	0.3935 ***	1.5285 ***	0.3993 ***	1.5056 ***	0.3774 ***	1.6158 ***
L5_BS	-	−0.9766 ***	-	−1.0390 ***	-	−1.0100 ***	-	−1.1297 ***
_cons	−1.8795 ***	−2.6344 ***	−1.8098 ***	−2.6064 ***	−1.8549 ***	−2.6521 ***	−1.6859 ***	−2.5842 ***
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
usd_eur	(21)		(22)		(23)		(24)	
t_yield	0.2952 ***	0.1108 *	0.2637 ***	0.0964 *	0.3541 ***	0.1165 **	0.3205 ***	0.1128 ***
wti_spt	−0.0038 ***	−0.0011	−0.0032 ***	−0.0008	−0.0048 ***	−0.0012	−0.0041 ***	−0.0011
_cons	0.7107 ***	0.7838 ***	0.7175 ***	0.7862 ***	0.6925 ***	0.7836 ***	0.6966 ***	0.7802 ***
p-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Endogenous variables:	SP500 DJIA Nasdaq Russell *t_yield usd_eur*							
Exogenous variables:	*Fed_FRte us_cpi L5_BS Fed_BS wti_spt*							

Note(s): This table displays the coefficients of the variables in the models as well as the statistical significances of each model for all four indices during the two interventions. The instrumental variables three-stage least squares (IV3SLS) for time series models with and without one-week lag (L5) in the central bank balance sheet size tested for the great recession (2008–2013) and the COVID-19 (2020–2022) intervention periods. All approaches use the size of the Fed's balance sheet as the control variable. ***, **, * indicate coefficients are significant at the 1%, 5%, 10% level. Source: own estimations.

Firstly, the coefficients under the first intervention suggest that the Fed's intervention via the expansion of its balance sheet through the purchase of treasury securities led the treasury yields to drop, and this drop was followed by a weakening of the currency, in line with the results obtained for the entire 2008–2022 period. However, the opposite happened to the yields during the second intervention, turning the yield-to-balance sheet coefficient positive in the first equation of the system. That is, although the balance sheet size increased abruptly in the spring of 2020, the treasury yields did not continue to drop as they were already at their historically lowest levels, and instead moderately raising yet to levels below those before the start of the first intervention. Moreover, its one week lagging adaptability was inverted. For instance, the yields indeed dropped in the week prior to each purchase, yet rose higher in the week of the purchase for all four indices. Notice that the currency-to-yields coefficient has also switched in the second equation of the second intervention, strengthening the currency while the yields rose.

As for the principal equation, the results show that each index no longer increased by the federal funds rate, *Fed_FRte*; instead, this rate has been omitted by our model in the first intervention, as it stayed constant at the lowest level possible throughout that intervention. Furthermore, the index falls at the end of the second intervention as the Fed had to raise its rate to tackle the inflation outbreak in early 2021. This is shown by the negative coefficients on the top part of Panel B on Table 4. These last results indeed are in line with those of Rigobon and Sack (2004).

Finally, the coefficients of the price index, *us_cpi*, and the constant terms both expanded threefold for each index. These results indicate that the inflation component on the index remained the same on both interventions, and that the value of the index tripled in the second intervention from the first one, as did the size of the Fed's balance sheet.

4.4. The Portfolio Approach

Let us now proceed to analyze the effects of the central bank interventions from an asset allocation perspective. That is, consider a hypothetical investor who contemplates investing in the four main U.S. indices as attainable investment portfolios. The investment selection must now consider two important assumptions, however. First, although some of the four indices share stocks in common, not all do. For instance, while the Apple Inc. stock holds 2.92, 13.36 and 6.67 percentage weights in the DJIA, S&P500 and Nasdaq indices, this stock is not included in the Russell index valuation. Second, the weights of the stocks shared in common vary by index, and the risk exposure of any given stock shared in common also varies. That is, in the Apple stock case, given the weights mentioned above, the market risk exposure for the investor is about five and two times higher should she be invested in the S&P500 and Nasdaq portfolios instead of in the DJIA, respectively. Other cases with different weights among the four indices also manifest. The upshot is that all four portfolios are different from the asset allocation perspective, holding different sensitivity degrees to any market stimulations.

Based on these assumptions, a crucial question arises: what is the effect of central bank interventions on each of the four portfolios within the whole U.S. asset allocation? To answer this question, it can be assumed that the hypothetical investor distributes her asset allocation in equal parts among the four U.S. indices, forming a fund of funds, and estimates the effects of the interventions per fund within the whole fund.

Panel Data Regression Results

The panel data strategy allows for decomposing the effects of the instruments on each of the indices. Table 5 exhibits the 3SLS regression results for all four indices in a panel data setting. Before analyzing the effects of the balance sheet expansions on the indices, it is worth clarifying that under the panel data strategy, all indices values are merged into one central index, which is the average value of the indices. The panel data strategy computes its estimations beginning from the selected base index within the index set, and upon that, calculates the added factors for the other indices. Hence, the values in the top portion of

Table 5 correspond to the average value of the four indices as though it were only one index (a fund of funds). Thus, the coefficients of the variables in the principal equation such as *Fed_FRte* and *us_cpi* illustrate the effect of those variables on that fund of funds.

Table 5. Regression results panel data by interventions. Three-stage least squares panel data regressions by index per intervention.

Intervention	**(2008–2022)**		**(2008–2013)**		**(2020–2022)**	
Variable	**PD3SLS**	**PD3SLS_L5**	**PD3SLS**	**PD3SLS_L5**	**PD3SLS**	**PD3SLS_L5**
Index						
Fed_FRte	1475.3616 ***	1472.4005 ***	2469.4850	2462.0310	1292.0510	1289.9160
us_cpi	1079.7697 ***	1078.8033 ***	11,913.1100	11,947.2600	2642.4890	2655.5140
_cons	4137.7912 ***	4147.3559 ***	0.4494	0.4486	0.3657	0.3649
t_yield						
Fed_BS	−0.27328 ***	−1.29542 ***	−0.68698 ***	2.34144 ***	0.38780 ***	1.11081 ***
5L_BS	-	1.02347 ***	-	−3.05222 ***	-	−0.68834 ***
idcode						
1923	−0.06365 ***	−0.06212 ***	0.01690	0.01667	−0.00552	−0.00249
1971	−0.05000 ***	−0.04878 **	0.01468	0.01448	−0.00372	−0.00168
1984	−0.06735 ***	−0.06573 ***	0.01773	0.01749	−0.00592	−0.00267
_cons	3.47543 ***	3.47138 ***	4.50041 ***	4.55814 ***	−1.76234 ***	−2.04237 ***
usd_eur						
t_yield	−0.04424 ***	−0.04365 ***	−0.03336 ***	−0.03548 ***	0.54657 ***	0.30718 ***
wti_spt	−0.00188 ***	−0.00188 ***	−0.00041 ***	−0.00049 ***	−0.00797 ***	−0.00436 ***
idcode						
1923	−0.00130	−0.00124	0.00085	0.00081	−0.00379	−0.00415
1971	−0.00102	−0.00097	0.00074	0.00070	−0.00255	−0.00279
1984	−0.00137	−0.00131	0.00089	0.00085	−0.00406	−0.00444
_cons	1.05060 ***	1.04929 ***	0.86797 ***	0.88047 ***	0.63617 ***	0.72941 ***
note: Fed_FRte omitted because of collinearity				legend: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$		
idcodes: 1896 = DJIA, 1923 = SP500, 1971 = Nasdaq, 1984 = Russell						
Endogenous variables:		1896 1923 1971 1984 *t_yield usd_eur*				
Exogenous variables:		*Fed_FRte us_cpi L5_BS Fed_BS wti_spt*				

Note(s): This table displays the coefficients of the variables as well as the cumulative factor levels of each of the four indices within one panel data model by intervention. The models considered are the instrumental variables three-stage least squares (IV3SLS) for panel data with and without one-week lag in the central bank balance sheet size tested for the first intervention (2008–2013), second intervention (2020–2022) and the entire data period (2008–2022). Both models use the size of the Fed's balance sheet as a control variable. idcode: 1896 = DJIA used as baseline. ***, ** indicate coefficients are significant at the 1%, 5% level. Source: own estimations.

The middle portion of Table 5 shows how the yields are influenced by the size of the Fed balance sheet on each of the indices that diverge from the base index estimator, called the base level, which in this model is the DJIA index. Since the statistical software classifies the indices by numeric codes, we have assigned the inception year of each index as their identification codes, that is, 1896, 1923, 1971 and 1984 for the DJIA, S&P500, Nasdaq and Russell 2000, respectively. Pointing to the S&P500 (coded 1923), the −0.06365 shown in the first column is the additional effect factor on the value of the S&P500 compared to the base index (the DJIA) from the effect of the Fed balance sheet expansion on the treasury yields in the 2008–2022 period data. The 0.01690 shown in the third column is the additional effect on the value of the S&P500 to the DJIA during the first intervention, while the −0.00552 in the fifth column is the additional effect in the second intervention.

The bottom portion of Table 5 shows the effects by index on the second equation of the model, that is, the foreign exchange market. Although the instrumental variables coefficients in both the first and second equations of the model are similar to those of Tables 3 and 4, the value of each index is influenced by the different effects outlined in Table 5. Moreover, while the effects of the S&P500 and the Russell 2000 indices are very similar, the Nasdaq index offers the smallest effects, closer to the DJIA.

4.5. Identification of Instrumental Variables Tests

The results of the IV identification tests for the panel data models are outlined in Table 6. The Anderson Lagrangian Multiplier test was performed to estimate if fewer instrumental variables than endogenous ones were being used in the models, showing that this statistic was large enough to strongly reject the null hypothesis that the models could be underidentified. In line with these results, the Sargan (1964) statistics confirmed that there are sufficient relevant instruments in the models, as all of these statistics were quite large for all periods under consideration.

Table 6. Instrumental variables identification tests by interventions panel data index.

Underidentification test (Anderson canon. corr. LM statistic): Ho: underidentification of instrumental variables					Sargan statistic (overidentification test of all instruments): Ho: underidentification of instrumental variables			
Intervention Period: (2008–2013)								
Panel2SLS	2100.473	Chi-sq(6) *p*-value	=	0.0000	4852.170	Chi-sq(5) *p*-value	=	0.0000
Panel2SLS_L5	1236.610	Chi-sq(7) *p*-value	=	0.0000	2825.749	Chi-sq(6) *p*-value	=	0.0000
Intervention Period: (2020–2022)								
Panel2SLS	908.122	Chi-sq(6) *p*-value	=	0.0000	2010.235	Chi-sq(5) *p*-value	=	0.0000
Panel2SLS_L5	521.401	Chi-sq(7) *p*-value	=	0.0000	1176.060	Chi-sq(6) *p*-value	=	0.0000
Intervention Period: (2008–2022)								
Panel2SLS	6347.892	Chi-sq(6) *p*-value	=	0.0000	11,000.000	Chi-sq(5) *p*-value	=	0.0000
Panel2SLS_L5	3727.789	Chi-sq(7) *p*-value	=	0.0000	6307.683	Chi-sq(6) *p*-value	=	0.0000

Note(s): This table shows high Chi^2 values in the instrumental variables underidentification test. These reject the null hypothesis of less relevant instruments in the models than endogenous variables. The zero *p*-values suggest no underidentification of instruments. In the overidentification test, large Chi2 values and zero *p*-values detect overidentification of instruments. That is, there is one endogenous variable *t_yield* but more than one valid instrument in addition to *Fed_BS*, which are (2): *usd_eur* and *wti_spt* in the simple models and (3): plus *L5_BS* in the lagged models. Source: own estimations.

4.6. Relevance of Instrumental Variables Tests

To determine whether the instruments used in the models are indeed relevant, two tests were performed. Table 7 shows the results of the Stock–Yogo (Stock and Yogo 2005) and the Montiel–Pflueger (Olea and Pflueger 2013; Pflueger and Wang 2015) robust weak instrument tests. The instruments used in the models are to be considered relevant as long as none of these statistics surpass the Cragg–Donald Wald (C-D-W) F statistic (Cragg and Donald 1993) outlined at the top of the table. The large C-D-W F values signal relevance of the instruments, while low values mean weak instruments. Both (the Stock–Yogo and the Montiel–Pflueger) critical values were considerably low compared to the C-D-W F statistics for all six panel data models in all intervention periods, proving considerable relevance of the instruments used.

4.7. Results Discussion

Based on the results exhibited in Table 3, a positive relationship between the value of the four main U.S. indices and the size of the Fed balance sheet is statistically significant for the entire 2008–2022 period, via its effects on investors' opportunity cost levels, that is, the treasury yields values. To be more precise, as the treasury yields are maintained at low levels, as a consequence of the interventions, investment flows into equity securities rise, pressuring their price levels measured by the indices. However, from the results of Table 4, it is possible to identify that as the sources of both financial crises were different, the normal flows of liquidity learned from the first intervention may be altered. For instance, in the 2020–2021 intervention, massive flows of liquidity from the global investors went directly to the purchase of U.S. treasuries, pushing their yields to extremely low levels never seen before though with the help of the Fed's involvement. Hence, the second intervention proved to be rather ineffective in its goal of lowering the yields further.

Table 7. Weak instrumental variables tests per intervention of panel data index.

Weak Identification Test (Cragg–Donald Wald F Statistic):						
					Panel2SLS	**Panel2SLS_L5**
2008–2013					596.264	302.789
2020–2022					270.322	130.619
2008–2022					2000.412	1013.536
Stock–Yogo weak ID test critical values:						
	5% maximal IV relative		19.28	5% maximal IV relative		19.86
	10% maximal IV relative		11.12	10% maximal IV relative		11.29
	20% maximal IV relative		6.76	20% maximal IV relative		6.73
	30% maximal IV relative		5.15	30% maximal IV relative		5.07
	10% maximal IV size		29.18	10% maximal IV size		31.5
	15% maximal IV size		16.23	15% maximal IV size		17.38
	20% maximal IV size		11.72	20% maximal IV size		12.48
	25% maximal IV size		9.38	25% maximal IV size		9.93
Montiel–Pflueger robust weak instrument test						
	Critical Values:	TSLS	LIML	Critical Values:	TSLS	LIML
	% of Worst Case Bias			% of Worst Case Bias		
	tau = 5%	19.595	7.209	tau = 5%	20.297	6.346
	tau = 10%	11.520	4.874	tau = 10%	11.804	4.352
	tau = 20%	7.209	3.595	tau = 20%	7.294	3.264
	tau = 30%	5.673	3.134	tau = 30%	5.695	2.874

Note(s): This table shows lower S-Y weak ID test critical values than the C-D Wald F statistics in all intervention periods. The Montiel–Pflueger robust test for weak instruments also showed that neither of the TSLS and LIML critical values for threshold values $\tau \in$ (5%, 10%, 20%, 30%) exceeded the F statistics in all intervention periods. Thus, the null hypothesis that the instruments used in the models are weak should be rejected. Had any of the S-Y and Montiel–Pflueger TSLS and LIML critical values been larger than the C-D Wald F values, there would be at least one weak instrument in the models. Source: own estimations.

Special attention is given to the currency-to-yields coefficient switching in the second equation of the second intervention, showing the strengthening of the currency as a key effect of the flight-to-quality flows while the yields caught an upward trend. Additionally, the results show that in the second intervention, the indices no longer increased alongside with the federal funds rate; instead, the indices fell at the end of the second intervention as the Fed had to raise its rate to halt the inflation outbreak of early 2022. Furthermore, the large growth in the coefficients of the inflation and the constant terms of each index equation, although the inflation proportion on the indices remains constant on both interventions, suggest that long-run growth accumulated during the 2014–2019 dis-intervention period, as the value of the index tripled in the second intervention from the first one. This conclusion can be drawn as the size of the Fed's balance sheet also tripled as of the end of the second intervention.

The results of the 3SLS for time series strategy allow for an understanding of the effects of one instrument on the value of each of the indices under analysis individually. However, although the panel data strategy confirms the effects calculated under the time series strategy for the first and second equations of the individual models, this strategy allows for an identification of the effects of the same instrument on the value of each of the indices within a whole market portfolio, notwithstanding the asset allocations of each of the indices. The results outlined in Table 5 establish that regardless of the intervention period, the DJIA portfolio is the most sensitive to changes in the yield rate as a consequence of changes of the same magnitude in the Fed's balance sheet. Then, the Nasdaq, S&P500 and Russell 2000 portfolios are less sensitive, respectively, in terms of the amount of basis points required by investors to make a change in the value of the respective index.

5. Implications

The results in this research have important investment and policy implications. First, as the Fed's balance sheet expands, the effect it has on treasury yields has impacts on the valuation of the selected U.S. indices. Although each week the Fed's balance sheet expands, causing a drop in the yield, after that drop there is a smooth adjustment in the yields. While this dynamic takes place in the treasuries market, the equity indices continue with a long-term trend and continue to rise. That is, while the traders in the fixed income market make their investment decisions on a short-term basis (Vasicek 1977), the investors in the stock market do so on a long-term basis (Fama 1965).

The results shown in Table 3 suggest that for the 2008–2020 period, given a change in the balance sheet and in the treasury yields, these simultaneous changes are associated with changes in the valuation of each index at different rates. For instance, given a change of one billion dollars in the Fed's balance sheet, investors in the DJIA index would value this index more than the Russell 2000, because the change in the opportunity cost to invest in the riskier investments are −0.2289 and −0.2532. In other words, investors in the DJIA portfolio are less patient than those in the Russell 2000, as those in the second portfolio would react to the treasury yields to drop 25.32 bps while only 22.89 bps in the first portfolio. Hence, the Russell 2000 has the lowest sensitivity to changes in the size of the balance sheet among the selected indices, while the DJIA is the most sensitive.

Figure 4 shows the results of Equation (1) of Table 3 graphically, in which the steeper slope belongs to the Russell 2000 function. That is, for any given change in the size of the central bank balance sheet, a higher effect on the treasury yields is required to transmit into the valuation of this index. The results from Table 5 confirm these findings, as the fixed effect for the Russell 2000 is also the largest, while that of the DJIA is the smallest of all, as it serves as the base index for the calculation of the fixed effects of the other indices.

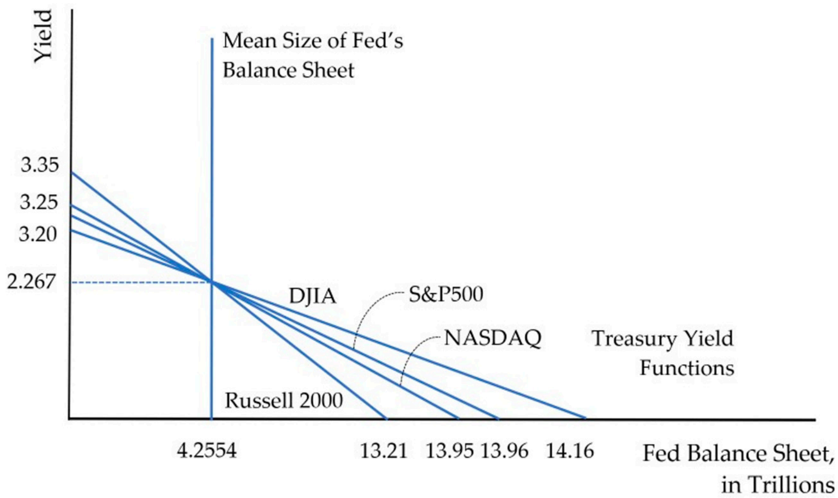

Figure 4. Index effects as function of balance sheet size (2008–2022). Source: own estimations.

The estimators in Table 4 also suggest that for both intervention periods, given a change in the balance sheet and in the treasury yields, the simultaneous changes are associated with changes in the valuation of each index at different rates. That is, given a change of one billion dollars in the Fed's balance sheet, investors in the DJIA index would also value this index more than the Russell 2000. In other words, investors in the DJIA portfolio are also less patient during both interventions than those in the Russell 2000. However, the direction of the effects are mixed. For instance, while the signs of the balance sheet-to-yield estimators in the first equation are negative, in line with those for the whole 2008–2022 period, the signs turn positive during the second intervention. This switching of the first equation estimators are described in Figures 5 and 6. Figure 5 shows that for an increase of one billion dollars in the Fed's balance sheet, it takes a smaller drop in the treasury yields to make the same relative change in the DJIA than in the Russell 2000. Hence, the DJIA has the highest sensitivity to changes in the size of the balance sheet among the selected indices, while the Russell 2000 is least sensitive.

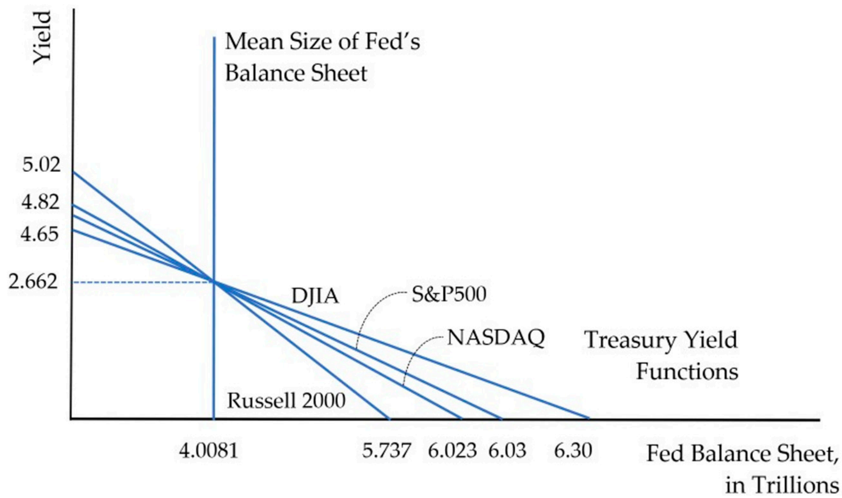

Figure 5. Index effects as function of balance sheet size (2008–2013). Source: own estimations.

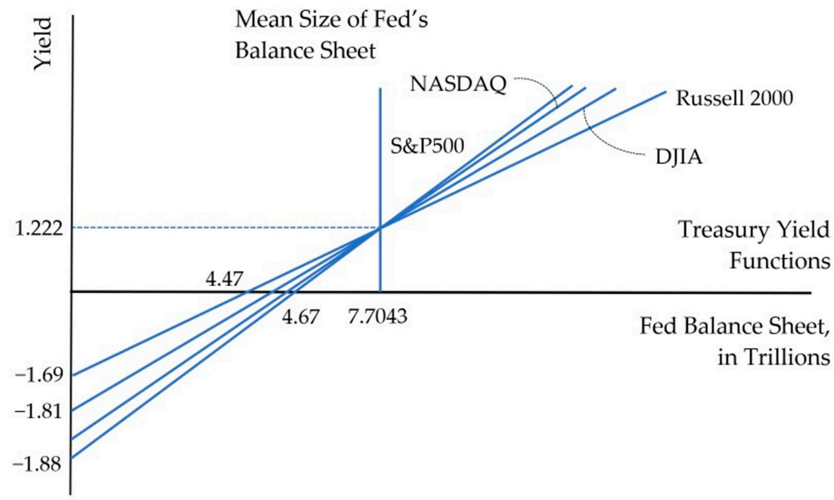

Figure 6. Index effects as function of balance sheet size (2008–2013). Source: own estimations.

Figure 6 shows similar results in terms of relative effects among the analyzed indices. Although the signs of the coefficients are switched, the relative sensitivities to the Fed's balance sheet among the indices remain. Again, we see how the steeper slope belongs to the Russell 2000 function, while the least steep of the slopes belongs to the DJIA. This phenomenon is possibly attributed to the fact that during the second intervention the treasury yields dropped as low as near the zero lower bound, so that further expansions of the Fed's balance sheet would turn ineffective and the yields would bounce back up regardless of how much cash was injected into the economy.

The *within* asset allocation estimations of Table 5 also imply the smaller sensitivities of the S&P500, Nasdaq and Russell 2000 portfolios to the size of the central bank balance sheet than that of the DJIA portfolio for the 2008–2022 period. Although with different proportions, these effects remain on both central bank interventions, confirming the lowest sensitivity of the Russell 2000 portfolio obtained in the time series strategy and displayed in Figure 4. In short, the stocks of the small capitalization companies mostly present in the Russell 2000 portfolio were the least influenced by the two interventions.

6. Conclusions

This research used the credit crisis of 2007 and the COVID-19 pandemic crisis as quasi-natural experiments to explore whether the UMP interventions in the credit markets such as large-scale treasury securities purchases by the Fed impacted the pricing in some equity markets.

Although this research has proved that pricing in the debt market is directly affected by the size of the Fed's balance sheet, it also validates that pricings in the debt and currency markets, which may be affected by Fed interventions, influences the pricing of equity securities as well, at least under simultaneous equations time series and panel data analyses performed on the four most prominent equity markets' benchmarks. From these findings, it is also possible to identify that equity indices, as measures of equity market performance, have different sensitivities to changes in yields caused by changes in the size of the central bank's balance sheet. For instance, the additional effect on the Nasdaq to the DJIA index was −0.0500, while on the S&P500 and the Russell 2000 the effects were −0.06365 and −0.06735, respectively, for the entire dataset (16 December 2008, to 29 April 2022). The results prove that although the direction of the effects on index sensitivities vary upon the different interventions, the order of those sensitivities remain during the stimulations. That is, during the great recession intervention, the additional effect on the Nasdaq to the DJIA index was 0.01468, while on the S&P500 and the Russell 2000 the effects were 0.01690 and 0.01773, respectively; these added effects were −0.00372, −0.00552 and −0.00592, respectively, during the COVID-19 intervention. In short, the results imply a lower sensitivity of the Nasdaq, S&P500 and Russell 2000 indices valuations to the size of the central bank balance sheet than that of the DJIA portfolio regardless of the intervention period studied.

Moreover, the sources of each financial crisis differ; hence, different interventions may be implemented. The 2007 crisis originated within the U.S., making it an internal crisis. However, the 2020 crisis originated globally, catching the U.S. at a moment of financial soundness; toward which unprecedented flows of liquidity migrated and helped keep the U.S. treasury yields at their lowest historical levels, for which the already known QE mechanism may have been unnecessary for maintaining low yields.

Empirically, this study used two identification strategies, the 3SLS for time series and for panel data, to calculate the effects of the interventions on the equity indices' pricing. Based on the results of both strategies, it is fair to suggest that while the 3SLS for time series approach allowed us to measure the effects of the interventions on each index individually, the panel data approach was useful to estimate the marginal effects of each index within a large portfolio composed by the selected indices. However, some limitations of this approach should be considered. The panel data approach may be more accurate if the indices do not share stocks in common, which would reduce problems such as endogeneity and collinearity among the indices; the accuracy of this approach may also be limited by the fact that it assumes equal portfolio allocations. Further research may suggest using the panel data strategy in measuring the effects of the instruments on a global portfolio analysis by selecting indices of different countries where no stocks are shared in common.

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Data Availability Statement: The data that support the findings of this study are available from the Federal Reserve Bank of St. Louis (FRED) datasets website https://fred.stlouisfed.org (accessed on 28 November 2022).

Conflicts of Interest: The author declares no conflicts of interest.

Appendix A

Table A1. Correlation results (2008–2013).

	SP500	***DJIA***	***Nasdaq***	***Russell***	***Fed_BS***	***L1_BS***	***L5_BS***	***Fed_FRte***	***t_yield***	***usd_eur***	***wti_spt***	***us_cpi***
SP500	1											
DJIA	0.9956 *	1										
Nasdaq	0.0000	0.9900 *	1									
	0.9950 *	0.0000										
	0.0000											
Russell	0.9914 *	0.9844 *	0.9896 *	1								
	0.0000	0.0000	0.0000	0.9322 *	1							
Fed_BS	0.9391 *	0.9391 *	0.9427 *									
	0.0000	0.0000	0.0000	0.0000	0.9996 *	1						
L1_BS	0.9386 *	0.9388 *	0.9425 *	0.9316 *								
	0.0000	0.0000	0.0000	0.0000	0.0000							
L5_BS	0.9368 *	0.9374 *	0.9418 *	0.9293 *	0.9982 *	0.9986 *	1					
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000						
Fed_FRte	-	-	-	-	-	-	-	1				
	-	-	-	-	-	-	-					
t_yield	−0.4187 *	−0.4707 *	−0.4211 *	−0.3546 *	−0.4962 *	−0.4979 *	−0.5067 *	-	1			
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-				
usd_eur	0.1716 *	0.1940 *	0.1821 *	0.1411 *	0.1938 *	0.1946 *	0.1976 *	-	−0.5324 *	1		
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-	0.0000			
wti_spt	0.8186 *	0.8385 *	0.8342 *	0.8335 *	0.7295 *	0.7291 *	0.7290 *	-	−0.2902 *	0.0066	1	
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-	0.0000	0.8146		
us_cpi	0.3866 *	0.4392 *	0.4068 *	0.4032 *	0.4016 *	0.4016 *	0.4017 *	-	−0.3064 *	0.0608	0.6168 *	1
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-	0.0000	0.0304	0.0000	

Note(s): (*) denotes coefficients significant at 10% level. Source: author's calculations.

Table A2. Correlation results (2020–2022).

	SP500	***DJIA***	***Nasdaq***	***Russell***	***Fed_BS***	***L1_BS***	***L5_BS***	***Fed_FRte***	***t_yield***	***usd_eur***	***wti_spt***	***us_cpi***
SP500	1											
DJIA	0.9909 *	1										
Nasdaq	0.0000	0.9762 *	1									
	0.9783 *	0.0000										
	0.0000											
Russell	0.9176 *	0.9454 *	0.9530 *	1								
	0.0000	0.0000	0.0000	0.7923 *	1							
Fed_BS	0.9395 *	0.9169 *	0.8818 *									
	0.0000	0.0000	0.0000	0.0000	0.9985 *	1						
L1_BS	0.9387 *	0.9156 *	0.8808 *	0.7897 *								
	0.0000	0.0000	0.0000	0.0000	0.0000							
L5_BS	0.9329 *	0.9074 *	0.8758	0.7799 *	0.9942 *	0.9952 *	1					
	0.0000	0.0000	*0.0000	0.0000	0.0000	0.0000						
Fed_FRte	0.137	0.1129	0.0779	0.0518	0.1998 *	0.2005 *	0.2003 *	1				
	0.0019	0.0105	0.0778	0.2416	0.0000	0.0000	0.0000					
t_yield	0.8249 *	0.8272 *	0.7448 *	0.7776 *	0.8121 *	0.8190 *	0.8280 *	0.3310 *	1			
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000				
usd_eur	−0.2720 *	−0.3581 *	−0.4108 *	−0.5149 *	−0.0833	−0.0792	−0.0457	0.2030 *	−0.048	1		
	0.0000	0.0000	0.0000	0.0000	0.0594	0.0736	0.3043	0.0000	0.2774			
wti_spt	0.9011 *	0.8884 *	0.8441 *	0.8231 *	0.8783 *	0.8786 *	0.8812 *	0.2782 *	0.9232 *	−0.1361	1	
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020		
us_cpi	0.8725 *	0.8317 *	0.7680 *	0.6746 *	0.8822 *	0.8838 *	0.8902 *	0.2509 *	0.8595 *	0.1269	0.9073 *	1
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0040	0.0000	

Note(s): (*) denotes coefficients significant at 10% level. Source: Author's calculations.

Appendix B

Table A3. Three-stage least squares, seemingly unrelated and two-step GMM regressions estimation results by index (16 December 2008–29 April 2022).

Model	3SLS	3SLS_L5	SUR	SUR_L5	Robust	Robust_L5
Index			S&P500			
Fed_FRte	384.93074	382.39472	341.87481	343.29474	404.62291	397.81695
us_cpi	333.8543	332.7608	320.0322	319.9994	337.4309	335.8427
_cons	1327.1010	1331.8388	1380.8500	1381.1001	1307.7838	1316.1561
t_yield						
Fed_BS	−0.2337	−1.4081	−0.2225	−1.7064	−0.2202	−1.7530
L5_BS		1.1790		1.4893		1.5363
_cons	3.2618	3.2549	3.2141	3.2070	3.2042	3.2056
usd_eur						
t_yield	−0.0450	−0.0422	−0.0391	−0.0375	−0.0472	−0.0435
wti_spt	−0.0018	−0.0018	−0.0017	−0.0017	−0.0018	−0.0018
_cons	1.0480	1.0427	1.0234	1.0217	1.0519	1.0449
Index			Nasdaq			
Fed_FRte	1183.6028	1174.2210	1026.3398	1031.1730	1164.4119	1145.8599
us_cpi	1292.0513	1289.9159	1243.1496	1244.3260	1275.7923	1272.5377
_cons	2642.4893	2655.5136	2835.7710	2833.6290	2685.8162	2706.8413
t_yield						
Fed_BS	−0.2340	−1.3605	−0.2260	−1.6988	−0.2122	−2.0778
L5_BS		1.1304		1.4781		1.8716
_cons	3.2629	3.2586	3.2289	3.2219	3.1702	3.1642
usd_eur						
t_yield	−0.0520	−0.0490	−0.0411	−0.0395	−0.0555	−0.0513
wti_spt	−0.0018	−0.0018	−0.0017	−0.0018	−0.0018	−0.0018
_cons	1.0638	1.0583	1.0324	1.0308	1.0699	1.0623
Index			DJIA			
Fed_FRte	4137.8341	4119.3297	3813.1064	3823.4318	4350.7396	4308.5433
us_cpi	2469.4851	2462.0312	2362.0200	2362.6059	2502.5455	2494.4704
_cons	11,913.1050	11,947.2620	12,324.6550	12,325.5320	11,715.0120	11,765.1700
t_yield						
Fed_BS	−0.2289	−1.3725	−0.2182	−1.6731	−0.2067	−2.1008
L5_BS		1.1476		1.4598		1.9005
_cons	3.2415	3.2364	3.1956	3.1901	3.1468	3.1391
usd_eur						
t_yield	−0.0465	−0.0437	−0.0393	−0.0377	−0.0502	−0.0461
wti_spt	−0.0018	−0.0018	−0.0017	−0.0017	−0.0018	−0.0018
_cons	1.0512	1.0458	1.0248	1.0231	1.0576	1.0500
Index			Russell			
Fed_FRte	208.4120	206.6854	186.2845	186.9564	212.6758	209.6973
us_cpi	146.9944	146.2313	140.5160	140.3782	148.0706	147.0385
_cons	807.1451	810.3717	833.5691	834.1026	802.3836	806.9149
t_yield						
Fed_BS	−0.2532	−1.5440	−0.2403	−1.8271	−0.2490	−1.6239
L5_BS		1.2980		1.5945		1.3810
_cons	3.3449	3.3278	3.2897	3.2735	3.3270	3.3154
usd_eur						
t_yield	−0.0390	−0.0366	−0.0374	−0.0359	−0.0397	−0.0369
wti_spt	−0.0019	−0.0019	−0.0017	−0.0017	−0.0019	−0.0019
_cons	1.0372	1.0322	1.0200	1.0182	1.0384	1.0328
Endogenous variables:	1896 1923 1971 1984 *t_yield usd_eur*					
Exogenous variables:	*Fed_FRte us_cpi L5_BS Fed_BS wti_spt*					

Note(s): This table shows how similar the estimators of the 3SLS are to other model estimators, as well as the robustness test for the 3SLS for panel data setting using the two-step GMM estimations. Source: own estimations.

Appendix C

Table A4. Test of independence of errors by index (16 December 2008–29 April 2022).

Panel A: Correlation Matrix of Residuals (*without* Balance Sheet Weekly Lag):				Panel B: Correlation Matrix of Residuals (*with* Balance Sheet Weekly Lag):			
	SP500	t_yield	usd_eur		SP500	t_yield	usd_eur
SP500	1			SP500	1		
t_yield	−0.1666	1		*t_yield*	−0.1631	1	
usd_eur	0.1094	0.2443	1	*usd_eur*	0.1042	0.2207	1
Breusch–Pagan test of independence: chi2(3) = 334.467,			Pr = 0.0000	Breusch–Pagan test of independence: chi2(3) = 289.651,			Pr = 0.0000
Correlation matrix of residuals:	DJIA	t_yield	usd_eur	Correlation matrix of residuals:	DJIA	t_yield	usd_eur
DJIA	1			DJIA	1		
t_yield	−0.1859	1		*t_yield*	−0.1813	1	
usd_eur	0.0984	0.2443	1	*usd_eur*	0.0931	0.2207	1
Breusch–Pagan test of independence: chi2(3) = 349.718,			Pr = 0.0000	Breusch–Pagan test of independence: chi2(3) = 303.367,			Pr = 0.0000
Correlation matrix of residuals:	Nasdaq	t_yield	usd_eur	Correlation matrix of residuals:	Nasdaq	t_yield	usd_eur
Nasdaq	1			Nasdaq	1		
t_yield	−0.1702	1		*t_yield*	−0.1649	1	
usd_eur	0.029	0.2443	1	*usd_eur*	0.0238	0.2207	1
Breusch–Pagan test of independence: chi2(3) = 301.150,			Pr = 0.0000	Breusch–Pagan test of independence: chi2(3) = 257.073,			Pr = 0.0000
Correlation matrix of residuals:	Russell 2000	t_yield	usd_eur	Correlation matrix of residuals:	Russell 2000	t_yield	usd_eur
Russell 2000	1			Russell 2000	1		
t_yield	−0.0943	1		*t_yield*	−0.0981	1	
usd_eur	0.162	0.2443	1	*usd_eur*	0.1568	0.2207	1
Breusch–Pagan test of independence: chi2(3) = 319.167,			Pr = 0.0000	Breusch–Pagan test of independence: chi2(3) = 278.725,			Pr = 0.0000

Note(s): This table displays the correlation matrix of errors across the three equations and the Breusch–Pagan test of independence of the errors for each of the indices. High χ^2 indicate that the three correlation coefficients are jointly significant. Source: own estimations.

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