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Wilson Donzwa *, **Rangan Gupta** **, **Mark E. Wohar** ***

* Department of Economics, University of Pretoria, Pretoria, South Africa

Email: donzwawilson@gmail.com

** Department of Economics, University of Pretoria, Pretoria, South Africa; IPAG Business School, Paris, France

Email: rangan.gupta@up.ac.za

*** College of Business Administration, University of Nebraska at Omaha, Omaha, USA; School of Business and Economics, Loughborough University, Leicestershire, UK.

E-mail (corresponding author): mwohar@unomaha.edu

Volatility Spillovers between Interest Rates and Equity Markets of Developed Economies

Abstract: This study employs the recently developed Lagrange multiplier-based causality-in-variance test by Hafner and Herwartz (2006), to determine the volatility spillovers between interest rates and stock returns for the US, the euro area, the UK, and Japan. The investigation pays careful attention to volatility transmissions between stock returns and interest rates before and after these economies reached the Zero Lower Bound (ZLB), which is permitted via the use of Shadow Short Rates (SSR), used as a proxy for monetary policy decisions. The results based on daily data imply that while bidirectional causality is observed, the volatility spillover from interest rates to stock markets are more prominent for the full-sample, as well as the sub-samples covering the pre- and during-ZLB periods.

Keywords: Interest Rates, Stock Markets, Volatility Spillover

JEL-classification: C32, C58, E43, G1

1. Introduction

In the aftermath of the "Great Recession", many central banks in developed markets reduced short-term nominal interest rates to near-zero levels indefinitely. For example, in 2008 the Federal Reserve targeted its policy rate between zero and 25 basis points until late 2015, consequently, setting the U.S nominal short rate at its Zero Lower Bound

(ZLB). Ultimately, the ZLB diminishes the ability of a central bank to respond to adverse shocks or foster growth in the economy by reducing the nominal short rate (Bilal, 2017).

Consequently, many central banks have employed unconventional policy tools such as large-scale asset purchases (commonly known as quantitative easing) and forward guidance to try to affect long-term interest rates and influence the economy (Jakl, 2016; Meinusch and Tillmann, 2016; Angelovska–Bezhoska, 2018). A question that naturally follows is: how do asset prices behave when traditional monetary policy tools are no longer effective in realizing their goals? This paper aims to uncover a possible answer by examining the nature of volatility transmissions between stock returns and interest rates before and after an economy reaches a ZLB, by considering four developed economies of the US, the euro area, the UK, and Japan. In the process, we are more interested in analysing the relationship between the uncertainties associated with monetary policy and the stock market.

The intricacies of volatility spillovers between interest rates and stock returns have largely been unexplored because researchers have favoured studying the impact of government policy uncertainty on various macroeconomic variables including stock returns (Chuliá et al., 2017), or primarily studying the impact of monetary policy on stock returns, rather than its volatility (Nasir, et al., 2016). However, Pástor and Veronesi (2012) develop a simple asset pricing model which reveals that policy uncertainty may trigger a rise in the volatility of the stochastic discount factor. As a result, risk premia go up and stock returns become more volatile and more highly correlated across firms. In addition, their model also predicts that policy uncertainty disturbs investors' beliefs which in turn seep into the stock market in the form of increased volatility.

At the same time, stock market uncertainty may also impact interest rate volatility, resulting in a compromise of the effectiveness of monetary policy. Xu (2007) found that interest rate volatility and stock market uncertainty in the U.S. are positively correlated on account of substantial shifts in people's asset holdings when they are uncertain about the Fed's decisions on interest rate changes. The 'toddler's tantrum' behaviour of investors may also explain this positive link as recently suggested by Valera et al., (2017), who also found that stock market uncertainty increases interest rate volatility in a panel of ten Asian countries. The argument is that in the wake of the Zero Lower Bound (ZLB), low interest rate policies may be destabilizing by shifting the behaviour of investors towards riskier strategies (Rajan, 2006). If investor behaviour follows a 'toddler's tantrum', then they would expect that the central bank will provide additional monetary stimulus during increased financial market turmoil, thereby leading to an increased interest rate uncertainty. In other words, policy uncertainty can lead to equity market volatility and vice versa, with this relationship being positively related to each other. Therefore, assessing the monetary policy response based on interest rate volatility when stock market uncertainty is high, and also whether higher monetary policy uncertainty can lead to more volatile equity markets, is an issue of paramount importance.

Against this backdrop, the specific objective of this paper is to analyse the causality-in-variance between the equity markets and interest rates in the economies of the US, the euro area, the UK and Japan at daily frequency, by explicitly accounting for the effect of the financial crisis on reduced interest rates. To accommodate for the fact that these four economies hit the ZLB in the wake of the recent financial crisis, we use Shadow Short Rates (SSR), as proxy for monetary policy. SSR is the nominal interest rate that would prevail in the absence of its effective lower bound, with it being derived by modelling the term structure of the yield curve, and hence tends to vary (by turning negative) even when the actual policy rates are virtually fixed due to the ZLB. To the best of our knowledge, this is the first paper to analyse volatility spillovers between monetary policy and equity markets in four developed economies by explicitly accounting for the ZLB situation. The rest of the paper is organized as follows: the econometric methodology is outlined in section 2, followed by the discussion of data and results in Section 3, with Section 4 concluding the paper.

2. Methodology

This study employs the Lagrange multiplier-based causality-in-variance test, which was recently developed by Hafner and Herwartz (2006), to determine the volatility spillovers between interest rates and stock markets. Earlier, causality-in-variance tests, based on the cross-correlation functions (CCF) of the standardized residuals obtained from the estimates of the univariate general autoregressive conditional heteroscedasticity (GARCH), were developed by Cheung and Ng (1996) and Hong (2001). However, the corresponding CCF-based Portmanteau test is likely to suffer from significant oversizing in small samples when the volatility processes are leptokurtic (Hafner and Herwartz, 2006: 140). In addition, the results from the CCF-based testing approach are sensitive to the orders of leads and lags, which in turn question the robustness of the findings.

The volatility spillover test of Hafner and Herwartz (2006), based on the Lagrange multiplier (LM) principle, overcomes the above-mentioned shortfalls and is very practical for empirical analysis. Furthermore, the Monte Carlo experiment carried out in Hafner and Herwartz indicates that the gain from carrying the LM-based test increases with the sample size. In what follows, we briefly explain the details of the Hafner and Herwartz causality-in-variance test.

In the Hafner and Herwartz (2006) approach, testing for the in-variance causality is based on estimating univariate GARCH models. To test the null hypothesis of the non-causality in variance between returns (which in our case is stock returns and interest rates) i and j, the following model is put forth as:

$$\varepsilon_{it} = \xi_{it}\sqrt{\sigma_{it}^2(1+z_j'\pi)}, \qquad z_{jt} = \left(\varepsilon_{jt-1}^2, \sigma_{jt-1}^2\right)' \tag{1}$$

where ξ_{it} and σ_{it}^2 are respectively the standardized residuals and the conditional variance (volatility) for return *i*; ε_{jt-1}^2 and σ_{jt-1}^2 are respectively the squared disturbance term and the conditional variance for return *j*. In this specification, the null hypothesis of the non-causality in variance specified by $H_0 : \pi = 0$ is tested against the alternative hypothesis of causality in variance denoted by $H_1 : \pi \neq 0$. The score of the Gaussian log-likelihood function of ε_{it} is given by $x_{it}\left(\xi_{it}^2 - 1\right)/2$ where x_{it} are the derivatives of the likelihood function with respect to the parameters in the GARCH model. Hafner and Herwartz propose the following LM test in order to determine the volatility transmission between the series:

$$\lambda_{LM} = \frac{1}{4T}\left(\sum_{t=1}^{T}(\xi_{it}^2 - 1)z'_{jt}\right)V(\theta_i)^{-1}\left(\sum_{t=1}^{T}(\xi_{it}^2 - 1)z_{jt}\right) \tag{3}$$

where

$$V(\theta_i) = \frac{\kappa}{4T}\left(\sum_{t=1}^{T} z_{jt}z'_{jt} - \sum_{t=1}^{T} z_{jt}x'_{it}\left(\sum_{t=1}^{T} x_{it}x'_{it}\right)^{-1}\sum_{t=1}^{T} x_{it}z'_{jt}\right), \quad \kappa = \frac{1}{T}\sum_{t=1}^{T}(\xi_{it}^2 - 1)^2$$

The asymptotic distribution of the test statistic in Equation (3) depends on the number of misspecification indicators in zjt. Since there are two misspecification indicators in λ_{LM}, the test has an asymptotic chi-square distribution with two degrees of freedom.

3. Data and Results

Our data set includes daily observations for the interest rate and stock prices for the US (S&P500), the euro area (Euro Stoxx 50), the UK (FTSE 100), and Japan (Nikkei 225). Based on data availability, the samples covered are 25 November 1985 to 31 March 2017 (7832 observations), 2 January 1995 to 31 March 2017 (5805 observations), 4 January 1995 to 31 March 2017 (5479 observations), and 2 January 1995 to 31 March 2017 (5671 observations) for the US, the UK, Japan, and the euro area, respectively. All the stock indices were obtained from Yahoo Finance and converted to log returns by taking the first-differences of the natural logarithms of the data. The summary statistics of the data have been presented in Table A1 in the Appendix of the paper.

With policy rates in the Zero Lower Bound (ZLB) range for a prolonged period of time post the financial crisis included in our analysis, practitioners have been put into a very awkward position of not being able to observe the actual stance of monetary policy. This has posed a great challenge to empirical researchers dealing with monetary policy to find alternative quantitative measures that are able to describe monetary policy at the ZLB. One such measure is the Shadow Short Rate (SSR). The SSR is the nominal interest rate that would prevail in the absence of its effective lower bound, with it derived by modelling the term structure of the yield curve (Wu and Xia, 2016).[1]

The main advantage of the SSR is that it is not constrained by the ZLB and thus allows us to combine the data from the ZLB period with the data from the non-ZLB era, along with the fact that this data is available at the daily frequency to match the stock prices. With the SSR not constrained by the ZLB, we can compare the volatility spillovers for not only the entire sample, but also pre- and during-ZLB periods for each of the four economies. The SSR used in this paper is developed by Krippner (2013), based on models of term-structure, at a daily frequency for the four economies of our concern, and is available for download from the web-

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[1] The SSR is, however, not the only means to summarise the monetary policy stance at the ZLB. Existing alternative approaches have certain disadvantages. For example, one approach disregards short rates and only considers interest rates of longer maturities that have remained sufficiently above zero. However, interest rates of longer maturities do not offer a clear interpretation as they may carry other information aside from the stance of monetary policy itself, like changes in the natural rate of interest, inflation expectations, and risk and liquidity premia" as explained by Damjanović and Masten (2016). Other literature also employs the use of the quantity of money to describe monetary policy stance at the ZLB (Damjanović and Masten, 2016). The fault in this approach is the ambiguous relation of the quantity of money to macroeconomic variables.

site of the Reserve Bank of New Zealand.[2] The yield curve-based framework developed by Krippner essentially removes the effect that the option to invest in physical currency (at an interest rate of zero) has on yield curves, resulting in a hypothetical "shadow yield curve" that would exist if physical currency were not available. The process allows one to answer the question: "what policy rate would generate the observed yield curve if the policy rate could be taken negative?" The "shadow policy rate" generated in this manner, therefore, provides a measure of the monetary policy stance after the actual policy rate reaches zero.

The results for the volatility spillover tests are reported in Table 1. The Table not only reports the full-sample results, but also for the pre- and during-ZLB periods,[3] with the latter coinciding with the point in time from where the SSR first turned negative in the aftermath of the recent financial crisis. The dates of the sub-samples have been noted in Table 1. As can be seen for the US, volatility spillovers are observed both ways for the full-sample and the pre-ZLB period. For the during-ZLB era, stock market volatility is found to cause interest rate volatility, but the effect other way round is weak, with significance only observed at the 10 percent level. When we look at the euro area, the results are similar to that of the US, especially for the full-sample and the pre-ZLB period. For the ZLB-period, causality is weak in general, with no evidence of spillover observed from stock market to the interest rate, and interest rate volatility spills over to the equity market only at the 10 percent level of significance. For the UK, when we consider the full-sample, interest rate volatility causes stock market volatility, but not the other way round, with this observation also holding for the ZLB era. For the non-ZLB period however, causality is observed both ways. Finally for Japan, bi-directional causality is observed for the full-sample, but interest rate volatility is found to predict stock market volatility when we look at the sub-samples. In general, while there is heterogeneity in terms of the results across the four economies, the evidence of volatility spillovers from the interest rates to stock market is stronger than the other way round. This result is understandable, since it is expected that monetary policy decisions are likely to take time to be implemented in response to stock market volatility, while any uncertainty in monetary policy decisions is likely to feed in quickly into the stock market. Finally, we note that

[2] The data can be downloaded from the following link: https://www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy/comparison-of-international-monetary-policy-measures.

[3] On 16 December 2015, the FOMC raised the target range for the federal funds rate from 25 to 50 basis points, hence the lift-off from the zero lower bound. Hence, ideally speaking for the US, the "during-ZLB" period also incorporates the post-ZLB period as well.

whenever causality exists during the ZLB, the strength in general is weaker relative to the pre-ZLB period.[4]

Table 1: Variance-Causality Test Results between Stock Market Volatility (SMV) and Interest Rate Volatility (IRV)

	USA					
	Full Sample		Pre-ZLB		During-ZLB	
	25-11-1985 to 31-03-2017		25-11-1985 to 19-11-2008		20-11-2008 to 31-03-2017	
	LM STAT	p-VALUE	LM STAT	p-VALUE	LM STAT	p-VALUE
SMV to IRV	25.9366	0.0000	25.9142	0.0000	14.7122	0.0006
IRV to SMV	38.5914	0.0000	39.1869	0.0000	5.4828	0.0645
	EA					
	Full Sample		Pre-ZLB		During-ZLB	
	02-01-1995 to 31-03-2017		02-01-1995 to 05-01-2012		06-01-2012 to 31-03-2017	
	LM STAT	p-VALUE	LM STAT	p-VALUE	LM STAT	p-VALUE
SMV to IRV	29.1158	0.0000	28.8378	0.0000	2.7079	0.2582
IRV to SMV	43.4398	0.0000	40.7159	0.0000	5.7965	0.0551
	UK					
	Full Sample		Pre-ZLB		During-ZLB	
	02-01-1995 to 31-03-2017		02-01-1995 to 04-02-2010		05-02-2010 to 31-03-2017	
	LM STAT	p-VALUE	LM STAT	p-VALUE	LM STAT	p-VALUE
SMV to IRV	1.6956	0.4284	7.3464	0.02540	2.5686	0.2769
IRV to SMV	43.8833	0.0000	26.7054	0.0000	18.6022	0.0001
	Japan					
	Full Sample		Pre-ZLB		During-ZLB	
	04-01-1995 to 31-03-2017		04-01-1995 to 30-12-2008		05-01-2009 to 31-3 2017	
	LM STAT	p-VALUE	LM STAT	p-VALUE	LM STAT	p-VALUE
SMV to IRV	6.3131	0.0426	0.9434	0.6239	2.1951	0.3337
IRV to SMV	22 .3701	0.0000	9.8460	0.0073	14.5944	0.0007

Note: The LM STAT tests the null hypothesis that IRV (SMV) does not Granger cause SMV (IRV); SMV (IRV) stands for stock market volatility (interest rate volatility), and ZLB refers to the Zero Lower Bound, with the starting point of the "During-ZLB" period corresponding to the point in time when the Shadow Short Rate (SSR) turned negative.

[4] In this regard, using time-varying grey correlation degree as developed by Deng (1982), we observed a weakening of relationship between the volatility processes of stock returns and the SSR following the crisis. These results have been presented in Figures A1 through A4 in the Appendix of the paper.

4. Conclusion

This paper attempts to add more flesh to an already thin body of literature on volatility spillovers between equity markets and interest rates, by making use of the novel Lagrange multiplier-based causality-in-variance test developed by Hafner and Herwartz (2006). For our purpose, we look at the four economies of the US, the euro area, the UK, and Japan. The paper considers volatility transmissions between stock returns and interest rates before and after these economies reached the Zero Lower Bound (ZLB) which, in turn, is allowed via the Shadow Short Rates (SSR) used as a proxy for monetary policy decisions. Understandably, this distinction also allows us to consider the pre- and post-financial crisis period. The results based on daily data, imply that while bi-directional causality is observed, the volatility spillover from interest rates to stock markets are more prominent for the full-sample, as well as the sub-samples covering the pre- and during-ZLB periods.

References

1. Angelovska-Bezhoska, A., Mitreska, A., and Bojcheva-Terzijan, S. (2018). The Impact of the ECB's Quantitative Easing Policy on Capital Flows in the CESEE Region. *Journal of Central Banking Theory and Practice, 7(2), 25-48.*
2. Bilal, M. (2017). Zeroing In: Asset Pricing Near the Zero Lower Bound. 2017 Meeting Papers 377, Society for Economic Dynamics.
3. Cheung, Y., & Ng, L. (1996). A causality in variance test and its application to financial market prices. *Journal of Econometrics 72(1-2), 33-48.*
4. Chuliá, H., Gupta, R., Uribe, J., and Wohar, M.E. (2017). Impact of US uncertainties on emerging and mature markets: Evidence from a quantile-vector autoregressive approach. *Journal of International Financial Markets, Institutions and Money 48, 178-191.*
5. Damjanović, M., and Masten, I. (2016). Shadow short rate and monetary policy in the Euro area. *Empirica* 43(2), 279.
6. Deng, J.L., 1982. Control problems of grey system. *System and Control Letters* 1, 288-294.
7. Hafner, C., and Herwartz, H. (2006). A Lagrange multiplier test for causality in variance. *Economics Letters*, 93, 137-141.
8. Hong, Y. (2001). A test for volatility spillover with application to exchange rates. *Journal of Econometrics* 103(1-2), 183-224.
9. Jakl, J. (2016). Impact of Quantative Easing on Purchased Asset Yields, its Persistency and Overlap. *Journal of Central Banking Theory and Practice*, 6(2), 77-99.
10. Krippner, L. (2013). A Tractable Framework for Zero Lower Bound Gaussian Term Structure Models. *Discussion Paper, Reserve Bank of New Zealand, 2013/02*.
11. Meinusch, A., and Tillmann, P. (2016). The Macroeconomic Impact of Unconventional Monetary Policy Shocks. *Journal of Macroeconomics*, special issue on "What Monetary Policy Can and Cannot Do", 47, 58-67.
12. Nasir, M. A., Soliman, A., Yago, M., and Wu, J. (2016). Macroeconomic Policies Interactions & the Symmetry of Financial Marke t Responses. *Journal of Central Banking Theory and Practice*, 5(1), 53-69.
13. Pástor, L., and Veronesi, P. (2012). Uncertainty about government policy and stock prices. *Journal of Finance* 67, 1219--1264.
14. Rajan, R. G. (2006). Has Finance Made the World Riskier? *European Financial Management* 12, 499-533.
15. Wu, J-C., and Xia, F-D. (2016). Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound. *Journal of Money, Credit, and Banking*, 48(2-3), 253-291.

16. Valera, H.A.G., Holmes, M.J, and Gazi, H. (2017). Stock market uncertainty and interest rate: A Panel GARCH Approach. *Applied Economics Letters*, 24(11), 732-735.
17. Xu, J. (2007). Interest rate uncertainty and stock market volatility. (Unpublished master thesis), *Singapore Management University, Singapore.*

APPENDIX:

Table A1: Summary Statistics

	Variable							
Statistic	US SSR	S&P500 Returns	euro area SSR	Euro Stoxx 50 Returns	UK SSR	FTSE 100 Returns	Japan SSR	Nikkei 225 Returns
Mean	0.2358	0.0313	0.1137	0.0176	0.2311	0.0150	-0.1142	-0.0012
Median	0.3029	0.0582	0.1824	0.0502	0.3526	0.0134	-0.1025	0.0200
Maximum	0.7984	10.9572	0.4605	10.4377	0.6404	9.3843	0.1889	13.2346
Minimum	-0.4677	-22.8997	-0.6413	-9.0110	-0.5816	-9.2656	-0.5403	-12.1110
Std. Dev.	0.2899	1.1516	0.2345	1.4352	0.2967	1.1439	0.1393	1.5267
Skewness	-0.5083	-1.2571	-1.2203	-0.1023	-0.7806	-0.1608	-0.6574	-0.2867
Kurtosis	2.3837	30.8497	3.9445	7.5756	2.6491	9.1032	2.7944	8.3895
Jarque-Bera	461.2605	255168.1000	1618.2190	4957.0080	619.3270	9034.7150	404.2671	6706.0990
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	7832	7832	5671	5671	5805	5805	5479	5479

Note: SSR is the shadow short rate; Std. Dev. symbolizes the Standard Deviation; p-value corresponds to the test of normality based on the Jarque-Bera test.

Figure A1: Time-Point Grey Correlation Degree for the US

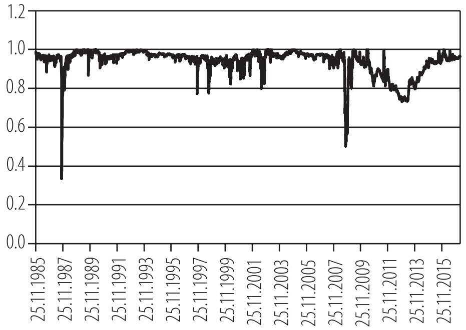

Figure A2: Time-Point Grey Correlation Degree for the euro area

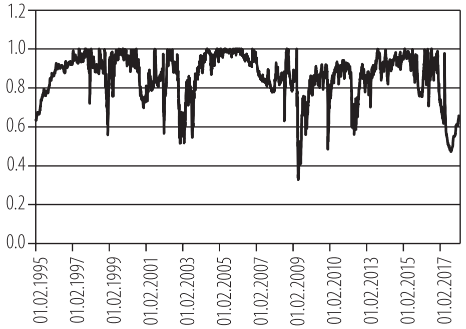

Figure A3: Time-Point Grey Correlation Degree for the UK

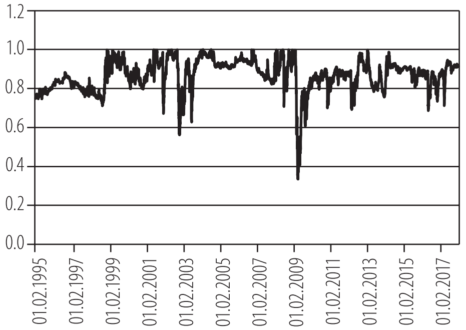

Figure A4: Time-Point Grey Correlation Degree for the Japan