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Forecasting Exchange Rate Realized Volatility: An Amalgamation Approach

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Introduction

- The implications of realized volatility (RV) in the fields of risk management, asset allocation and asset pricing has attracted academic interest during recent decades
- Schwert (1989) argued that there is little connection between RV and economic variables
- Academic literature has made significant progress both in terms of methodologies and variable selection
- The RV forecasting literature has provided evidence in favour of macroeconomic/financial variables
  - see among others Paye, 2012; Christiansen *et al.*, 2012; Conrad and Loch, 2015; Wang *et al.*, 2018
- Most recent contributions focus on stock market volatility
  - such as Paye (2012), Christiansen *et al.* (2012), Conrad and Loch (2015), Mittnik *et al.* (2015) and Nonejad (2017)
- Most studies focus on linear modelling, while Mittnik *et al.* (2015) provide evidence in favour of nonlinear modelling

Objectives

- Our objectives/contributions are to...
  - Investigate the predictive ability of several macroeconomic and financial predictors
  - Identify the sources of the forecasting ability
  - Complement linear methods with machine learning and wavelet (frequency domain) techniques
  - Investigate timing effects in the forecasting performance
  - Provide evidence that macroeconomic and financial variables contain useful information for future RV

Theoretical background

- The relationship is mainly established on the uncertainty regarding the existing state of the economy and/or the expected stock returns which generate volatility in the ex-post return

- The economic drivers of volatility can be summarized as
  1. The business cycle
  2. Liquidity effects
  3. Market sentiment/uncertainty about fundamentals
  4. Country characteristics

Theoretical background

- Risk premia change asymmetrically when the economic state changes
  - specifically, when the economy enters a negative state then risk premia increase and this generates volatility, Mele (2007)
- Shortage of liquidity in the market creates forces in the market that increase trading volumes, Schwert, (1989)
  - Leveraged asset holders face pressure to short sell, in order to maintain liquidity, Brunnermeier and Pedersen, 2009
- The uninformed traders are considered to be sentiment traders, since their investment decisions are based on trends and other tools rather than models supported by theory.
  - Thus, they create deviations in the market prices from the fundamental value
- David and Veronesi (2013) provide evidence that inflation and earnings uncertainty may enhance stock market volatility, since investors are not sure what the upcoming state of the economy is

Data – Candidate Predictors

- We use 7 widely traded currencies against the US dollar.
  - NZD, NOK, YEN, GBP, CAD, AUD and CHF.

- We calculate RV based on the standard framework, such as

$$RV_t = log\sqrt{\sum_{i=1}^{n} r_i^2}, \quad \text{t=1,2,..,T}$$

- Our sample covers the period extending from February 1986 to December 2019 (T = 407 observations)

- The observations of the first seven years are used as our in-sample period, and the remaining $P = 324$ monthly observations form the out-of-sample period,
  - i.e. from January 1993 to December 2019.

Data – Candidate Predictors

- The implications of US macroeconomics on the exchange rates is not new in the literature. Our candidate predictors are mostly related to the US economy
- We use 33 macroeconomic and financial predictors
- We consider predictors associated with **equity market** developments
  - Behmani-Oskooee (2015) provide a comprehensive literature review pointing out the relationship between stock markets and exchange rates
- Second, we employ **interest rates, spreads and bond market factors**
  - Interest rates-related variables enjoy a strong theoretical connection linking them with exchange rates
- The third group of variables depict general **macroeconomic conditions** in the US market
- The last set of variables are considered to approximate **liquidity, risk and economic activity** related factors

Methodology

- The information set to generate the forecast at time $t + 1$ utilizes solely information available up to time t. The information set is updated recursively

- The benchmark:

$$RV_t = a_j + \sum_{i=1}^{p} b_{j,i} RV_{t-i} + u_t$$

- Simple linear bivariate model forecasts:

$$RV_t = a_j + \sum_{i=1}^{p} b_{j,i} RV_{t-i} + \beta_1 X_{t-1} + u_t$$

Methodology

- The forecasts are evaluated based on the R^2_{OS} and the Clark and West (2007) test

- To aggregate information from all available predictors we use a number of commonly applied methods:
  - KS, Lasso, NN, SVR, PCA, ICA, PLS, POOL, MEDIAN, TRIM3, TRIM10

Methodology

- The problem of variable selection and the problem of model selection persists for the investor, since each method has different properties

- To solve the problem we employ the Amalgamation forecasts as introduced by Rapach and Strauss (2012)

$$\hat{f}_{t+1}^{(AMALG)} = \frac{1}{N}\sum_{n=1}^{N=9}\hat{\mathbf{f}}_{t+1}\left(n_1\right)$$

Empirical Findings: Individual Predictors

- The AR(p) benchmark significantly outperforms the simple AR(1) process in every case
- Predictors that provided good in-sample estimates generate statistically significant forecasts and positive R^2_{OOS} values
- The overall results show that
  - GBP and CHF – a significant amount of predictors outperforms the benchmark
  - YEN volatility proves to be the most challenging – only 4 predictors outperform the benchmark
  - Remaining four currencies – around a third of the predictors prove valuable
- At a group level,
  - Predictors associated with Interest rates, Spreads and Bonds and Equity market, are performing better
  - Macroeconomic conditions - demonstrate a mixed performance
  - Predictors that stand out
    - MSCI, LTY and CCONF,
    - Followed by DP, MKT, DFY and IPM

Table 1: Out-of-Sample Forecasts, Aggregate Information

	NZD	NOK	YEN	GBP	CAD	AUD	CHF
KS	>-100	>-100	>-100	>-100	>-100	>-100	>-100
LASSO	**2.39*** **	**2.91*** **	-1.45	**7.78*** **	**7.81*** **	**3.88*** **	**10.06*** **
NN	**3.72*** **	**1.23*** **	**-0.12*** **	**8.65*** **	**8.30*** **	**6.36*** **	**13.00*** **
SVR	-0.01	-0.55	0.57**	0.98***	0.94**	-0.64	1.89***
PCA	**4.76*** **	**4.51*** **	**0.72*** **	**9.42*** **	**13.67*** **	**6.97*** **	**8.57*** **
ICA	-2.17***	-33.97**	-1.75**	-17.12**	-4.89***	**1.30** **	-12.25**
PLS	-2.77***	-9.29***	-6.63***	**5.86*** **	-0.99***	**0.47*** **	**6.88*** **
POOL	**1.55*** **	**1.88*** **	**0.93*** **	**2.55*** **	**2.39*** **	**1.81*** **	**2.27*** **
MEDIAN	**0.56*** **	**0.55** **	**0.32** **	**0.88*** **	**0.84*** **	**0.82*** **	**0.77*** **
TRIM3	**1.37*** **	**2.14*** **	**1.08*** **	**2.43*** **	**2.34*** **	**1.84*** **	**2.45*** **
TRIM10	**1.54*** **	**2.91*** **	**1.19** **	**3.56*** **	**3.14*** **	**2.05*** **	**3.03*** **
AMLG	**5.70*** **	**5.59*** **	**2.91*** **	**7.79*** **	**7.75*** **	**7.22*** **	**9.98*** **
AMLG1	**6.18*** **	**5.38*** **	**3.35*** **	**7.82*** **	**7.87*** **	**7.83*** **	**10.28*** **
AMLG2	**6.33*** **	**5.26*** **	**3.30*** **	**7.63*** **	**7.86*** **	**7.92*** **	**9.86*** **
AMLG3	**7.24*** **	**4.61*** **	**3.14*** **	**8.36*** **	**9.30*** **	**9.44*** **	**11.40*** **
PI	**2.53*** **	**1.27** **	0.02	**2.94*** **	**4.25*** **	**2.50*** **	**2.64*** **

Shed further light…

- Wavelet analysis is a powerful tool to decompose time-series data into orthogonal components with different frequencies

- Following Risse (2019), Faria and Verona (2018) and Caraiani (2017), we employ wavelet decomposition analysis with the use of maximal overlap discrete wavelet transform (MODWT) and Haar wavelet filter with reflecting boundary conditions

- We also apply 6 levels of Multiresolution Analysis (MRA)
  - Hence, we break the initial series into 6 wavelet details, plus the smooth component
  - The new series capture gradually more and more abrupt changes, while the smooth detail works more as a long trend/memory series, such as:

$$RV_t = RV_t^{L1} + RV_t^{L2} + RV_t^{L3} + RV_t^{L4} + RV_t^{L5} + RV_t^{L6} + RV_t^{L7}$$

Shed further light…

- The short signal is calculated as

$$RV_t^{SS} = RV_t^{L1} + RV_t^{L2}$$

- the medium as

$$RV_t^{MS} = RV_t^{L3} + RV_t^{L4} + RV_t^{L5}$$

- the long signal as

$$RV_t^{LS} = RV_t^{L6} + RV_t^{L7}$$

Results for the short signal...
Out-of-Sample Forecasts, Short Frequency

	NZD	NOK	YEN	GBP	CAD	AUD	CHF
Panel A: Aggregating Information							
LASSO	-0.12	-3.14	-0.01	0.46	-1.30	-2.16	-1.23
NN	-1.33	-2.77	-3.10	**0.75***	**1.05***	-0.94	-0.55
SVR	-0.06	-0.05	**0.29***	0.10	-0.46	-0.30	0.22
PCA	**0.53***	-3.8	-1.46	**1.58****	**1.30***	-1.57	-0.10
ICA	-22.08*	-79.78	-26.18	-14.62*	-5.07	-12.14	-14.93
PLS	-69.45	-131.77	-66.29	-39.88*	-70.15	-55.78	-42.65*
POOL	0.13	0.18	**0.51***	**0.64****	**0.64****	**0.41***	**0.55***
MEDIAN	0.08	0.00	**0.13***	**0.25****	**0.29****	0.13	0.04
TRIM3	0.13	0.23	**0.68****	**0.64****	**0.81****	**0.43***	**0.64***
TRIM10	0.22	**0.42***	**0.88***	**1.00****	**1.05***	0.52	0.78
Panel B: Amalgamation Forecasts							
AMLG	-1.31	-4.19	-0.40	**0.98****	0.05	-0.57	**0.89***
AMLG1	-2.12	-6.21	-1.19	**0.68****	-0.25	-0.90	**0.72***
AMLG2	-3.49	-10.31	-2.29	**0.08****	-1.12	-1.73	**0.29***
AMLG3	-8.43	-24.08	-7.72	-2.62**	-3.79	-5.13	-2.51*

Results for the medium signal...

Out-of-Sample Forecasts, Medium Frequency

	NZD	NOK	YEN	GBP	CAD	AUD	CHF
Panel A: Aggregating Information							
LASSO	**5.21*** **	**7.97*** **	**3.31*** **	**7.09*** **	**0.64***	**8.72*** **	**10.45*** **
NN	**16.46*** **	**14.83*** **	**10.76*** **	**19.09*** **	**6.79*** **	**19.70*** **	**19.46*** **
SVR	**0.83*** **	**0.84*** **	-0.08	-0.59	-0.21	**0.48** **	-0.73
PCA	**14.44*** **	**10.86*** **	**7.42*** **	**15.54*** **	**9.09*** **	**15.17*** **	**17.40*** **
ICA	-5.47***	-9.66***	-6.22***	-16.68*	**3.45*** **	**1.25*** **	-7.73***
PLS	-9.02***	-11.97***	-6.49***	-16.89***	-8.90***	**1.19*** **	-7.86***
POOL	**2.12*** **	**2.36*** **	**1.48*** **	**2.77*** **	**1.69*** **	**2.53*** **	**3.12*** **
MEDIAN	**1.06*** **	**0.70*** **	**0.63*** **	**1.07*** **	**0.93*** **	**1.21*** **	**1.34*** **
TRIM3	**2.04*** **	**2.29*** **	**1.47*** **	**2.61*** **	**1.74*** **	**2.45*** **	**3.24*** **
TRIM10	**2.05*** **	**2.32*** **	**1.24*** **	**2.89*** **	**1.91*** **	**2.26*** **	**3.49*** **
Panel B: Amalgamation Forecasts							
AMLG	**9.50*** **	**9.41*** **	**6.69*** **	**10.64*** **	**6.74*** **	**13.03*** **	**11.85*** **
AMLG1	**10.46*** **	**9.84*** **	**7.34*** **	**11.34*** **	**7.73*** **	**14.27*** **	**12.42*** **
AMLG2	**9.74*** **	**8.46*** **	**6.50*** **	**9.53*** **	**7.71*** **	**13.66*** **	**11.17*** **
AMLG3	**11.06*** **	**8.99*** **	**6.99*** **	**9.96*** **	**9.48*** **	**16.60*** **	**12.61*** **

Results for the long signal...
Out-of-Sample Forecasts, Long Frequency

	NZD	NOK	YEN	GBP	CAD	AUD	CHF
Panel A: Aggregating Information							
LASSO	**2.78*** **	**35.60*** **	**15.71*** **	**33.74*** **	**17.24*** **	**9.67*** **	**43.56*** **
NN	-10.52***	**40.31*** **	**55.69*** **	**37.01*** **	**48.61*** **	**23.54*** **	**61.13*** **
SVR	**2.15*** **	-3.57	-2.4	-1.61	0.19	-1.03	-7.11
PCA	**2.86*** **	**20.66*** **	**20.96*** **	**22.52*** **	**31.40*** **	**18.02*** **	**28.73*** **
ICA	-22.80*	**1.14*** **	-2.13***	-4.73***	-0.31***	-52.91	**13.72*** **
PLS	-39.56***	**34.41*** **	**30.31*** **	**37.98*** **	**40.62*** **	**2.96*** **	**59.97*** **
POOL	**2.38*** **	**5.55*** **	**4.45*** **	**7.79*** **	**4.17*** **	**4.13*** **	**5.35*** **
MEDIAN	0.04	**0.48*** **	**0.54*** **	**1.26*** **	0.02	**0.20** **	**0.68*** **
TRIM3	**1.89*** **	**6.32*** **	**3.52*** **	**5.93*** **	**3.92*** **	**3.34*** **	**5.22*** **
TRIM10	**2.89*** **	**7.24*** **	**6.19*** **	**9.16*** **	**4.89*** **	**4.92*** **	**7.83*** **
Panel B: Amalgamation Forecasts							
AMLG	**6.47*** **	**25.11*** **	**25.90*** **	**29.62*** **	**23.90*** **	**16.12*** **	**32.78*** **
AMLG1	**6.20*** **	**24.38*** **	**28.45*** **	**30.06*** **	**26.08*** **	**16.91*** **	**33.40*** **
AMLG2	**4.72*** **	**20.49*** **	**22.66*** **	**26.42*** **	**22.44*** **	**12.70*** **	**28.02*** **
AMLG3	**3.05*** **	**26.95*** **	**29.40*** **	**33.82*** **	**30.13*** **	**13.95*** **	**39.16*** **

Frequency aggregated forecasts...

Table 5: Out-of-Sample Forecasts, Frequency Aggregated Forecasts

	NZD	NOK	YEN	GBP	CAD	AUD	CHF
Panel A: Aggregating Information							
LASSO	**0.93****	**3.07*****	**2.18*****	**5.83*****	**2.55*****	**4.80*****	**7.76*****
NN	**4.28*****	-2.83**	**1.71*****	**7.46*****	**9.32*****	**8.22*****	**11.40*****
SVR	-0.39	-2.41	**0.71***	**1.90****	**0.49***	**0.83***	**0.74***
PCA	**5.96*****	**2.37*****	**1.90*****	**10.06*****	**12.81*****	**7.83*****	**9.00*****
ICA	-3.16***	-34.93**	-5.00***	-16.82**	**0.03*****	**0.29*****	**-15.48****
PLS	-36.41***	-72.56**	-27.40***	-30.07***	-21.49***	-13.52***	-26.70***
POOL	**1.28*****	**-0.25**	**0.93****	**3.78*****	**2.59*****	**3.33*****	**2.14*****
MEDIAN	0.39	-1.73	0.32	**2.35*****	**1.04****	**2.24*****	**0.48***
TRIM3	**1.10****	-0.03	**1.09****	**3.67*****	**2.62*****	**3.34*****	**2.32*****
TRIM10	**1.25*****	**0.65***	**1.16****	**4.60*****	**3.36*****	**3.48*****	**2.80*****
Panel B: Amalgamation Forecasts							
AMLG	**5.20*****	**1.96****	**4.56*****	**7.62*****	**7.93*****	**9.89*****	**8.99*****
AMLG1	**5.63*****	**0.84****	**4.77*****	**7.41*****	**8.62*****	**10.65*****	**9.11*****
AMLG2	**5.07*****	-0.87**	**4.38*****	**6.04*****	**8.23*****	**10.77*****	**8.04*****
AMLG3	**4.28*****	-6.87***	**3.22*****	**3.85*****	**9.36*****	**12.02*****	**6.80*****

Frequency aggregated forecasts...after decomposing both y and x

Table 6: Out-of-Sample Forecasts, Frequency Aggregated Forecasts

	NZD	NOK	YEN	GBP	CAD	AUD	CHF
Panel A: Aggregating Information							
LASSO	**3.23*** **	-4.23***	**4.88*** **	**8.77*** **	**9.44*** **	**8.03*** **	**8.71*** **
NN	-8.71***	-14.00***	-7.87***	**1.08*** **	-0.70***	-2.84***	-0.06***
SVR	**3.83*** **	-2.81***	**1.36*** **	-2.91***	**9.49*** **	**-0.54*** **	**5.24*** **
PCA	**3.02*** **	-0.72***	-1.01***	**6.37*** **	**12.54*** **	**2.03*** **	**9.25*** **
ICA	-3.19**	-9.27**	-5.61**	**0.23*** **	-7.05**	-1.40***	-6.14***
PLS	-28.85***	-30.31***	-21.27***	-6.39***	-11.93***	-16.87***	-5.43***
POOL	**3.91*** **	**2.20** **	**1.83** **	**6.72*** **	**7.38*** **	**5.99*** **	**3.21*** **
MEDIAN	**2.03*** **	**1.36* **	**1.24** **	**4.76*** **	**5.06*** **	**4.04*** **	**0.80** **
TRIM3	**4.02*** **	**2.38** **	**2.08*** **	**6.88*** **	**7.45*** **	**6.34*** **	**3.46*** **
TRIM10	**4.08*** **	**2.98** **	**1.90*** **	**7.33*** **	**7.98*** **	**6.88*** **	**3.26*** **
Panel B: Amalgamation Forecasts							
AMLG	**8.82*** **	**6.83*** **	**5.76*** **	**13.77*** **	**17.06*** **	**13.17*** **	**11.52*** **
AMLG1	**8.99*** **	**6.90*** **	**5.45*** **	**13.40*** **	**17.09*** **	**13.03*** **	**11.35*** **
AMLG2	**9.06*** **	**6.91*** **	**5.68*** **	**13.16*** **	**17.25*** **	**12.60*** **	**11.17*** **
AMLG3	**7.85*** **	**5.61*** **	**4.35*** **	**14.63*** **	**17.86*** **	**13.70*** **	**11.00*** **

Timing Effect

Table 7: Timing Effects; Original Series

	NZD		NOK		YEN		GBP		CAD		AUD		CHF	
Pane A: Business Cycle														
	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.
AMLG	**3.07*** **	**19.84** **	**1.37** **	**24.73** **	**2.82*** **	**3.89***	**4.23*** **	**28.23** **	**6.96*** **	**12.09** **	**4.72*** **	**15.39** **	**8.59*** **	**24.92** **
AMLG1	**3.11*** **	**22.63** **	**1.17** **	**24.47** **	**3.35*** **	**3.32***	**3.91*** **	**30.25** **	**7.12*** **	**11.95** **	**5.05*** **	**16.92***	**8.84*** **	**25.65** **
AMLG2	**2.99*** **	**24.21** **	**0.93** **	**24.88** **	**3.32*** **	**3.02**	**3.75*** **	**29.89** **	**7.17*** **	**11.67** **	**5.11*** **	**17.12***	**8.32*** **	**26.39** **
AMLG3	**2.62*** **	**32.02** **	-1.13**	**30.63** **	**3.59*** **	-1.70*	**3.00*** **	**39.09** **	**8.55*** **	**13.45** **	**5.83*** **	**21.25***	**9.45*** **	**32.36** **
Panel B: Sentiment Periods														
	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT
AMLG	**10.29*** **	**1.29***	**8.18*** **	**1.70***	**2.10** **	**3.65*** **	**9.19*** **	**6.07*** **	**10.36*** **	**5.14*** **	**9.64*** **	**3.20*** **	**17.23*** **	**3.97*** **
AMLG1	**11.51*** **	1.05	**7.81*** **	**1.72** **	**2.02** **	**4.58*** **	**9.43*** **	**5.85*** **	**11.03*** **	**4.70*** **	**10.48*** **	**3.44*** **	**17.85*** **	**3.98*** **
AMLG2	**11.78*** **	1.08	**7.58*** **	**1.79** **	**2.46** **	**4.07*** **	**9.18*** **	**5.73*** **	**11.05*** **	**4.68*** **	**10.65*** **	**3.41*** **	**17.34*** **	**3.64*** **
AMLG3	**14.20*** **	0.54	**6.78*** **	**1.34** **	**1.05** **	**5.07*** **	**9.65*** **	**6.78*** **	**13.10*** **	**5.51*** **	**12.90*** **	**3.71*** **	**20.15*** **	**4.13*** **
Panel C: Liquidity Periods														
	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ
AMLG	**3.64** **	**6.89*** **	-0.9	**10.76*** **	**2.26** **	**2.73*** **	**5.60*** **	**9.53*** **	**7.02*** **	**8.21*** **	**8.16** **	**6.29** **	**9.02*** **	**10.81*** **
AMLG1	**3.40** **	**7.85*** **	-1.33	**10.72*** **	**2.64** **	**3.18*** **	**5.09*** **	**9.97*** **	**7.18*** **	**8.28*** **	**8.71** **	**6.94** **	**9.44*** **	**10.94*** **
AMLG2	**3.59** **	**7.97*** **	-1.41	**10.58*** **	**2.66** **	**2.99*** **	**4.62*** **	**9.99*** **	**7.57*** **	**7.95*** **	**8.87** **	**6.99** **	**9.39*** **	**10.06*** **
AMLG3	**2.58** **	**10.15*** **	-6.09	**13.22*** **	**2.45** **	**2.56*** **	**3.33** **	**12.27*** **	**8.47*** **	**9.80*** **	**10.71** **	**8.24** **	**10.37*** **	**12.29*** **
Panel D: Sub-sample Periods														
	2006	2019	2006	2019	2006	2019	2006	2019	2006	2019	2006	2019	2006	2019
AMLG	**1.59** **	**10.22*** **	-2.01	**12.32*** **	**1.98** **	**3.79*** **	**5.61*** **	**10.16*** **	**6.46*** **	**9.10*** **	**4.15*** **	**9.51*** **	**5.49*** **	**12.70*** **
AMLG1	**1.41***	**11.41*** **	-1.82	**11.76*** **	**2.49** **	**4.16*** **	**5.35*** **	**10.52*** **	**6.40*** **	**9.40*** **	**4.52*** **	**10.31** **	**5.41*** **	**13.21*** **
AMLG2	**1.16***	**12.00*** **	-1.66	**11.39*** **	**2.17** **	**4.37*** **	**5.42*** **	**10.05*** **	**6.22*** **	**9.57*** **	**4.67*** **	**10.36** **	**5.22*** **	**12.65*** **
AMLG3	**0.35***	**14.79*** **	-4.21	**12.43*** **	**1.79** **	**4.42*** **	**6.16*** **	**10.76*** **	**7.16*** **	**11.54*** **	**5.44*** **	**12.43** **	**5.47*** **	**14.98*** **

Timing Effect, cont'd

Table 8: Timing Effects; Decomposed both RV and X

	NZD		NOK		YEN		GBP		CAD		AUD		CHF	
Pane A: Business Cycle														
	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.	Exp.	Rec.
AMLG	**6.11*** **	**23.36** **	**1.89*** **	**29.24** **	**5.66*** **	**6.74** **	**10.82*** **	**30.68** **	**15.73*** **	**24.38** **	**9.76*** **	**24.32** **	**11.42*** **	12.64
AMLG1	**6.30*** **	**23.39** **	**2.35*** **	**27.50** **	**5.35*** **	**6.51** **	**10.83*** **	**28.12** **	**16.19*** **	**22.02** **	**10.23*** **	**22.21** **	**11.40*** **	10.8
AMLG2	**6.59*** **	**22.28** **	**2.53*** **	**26.77** **	**5.50*** **	**7.61** **	**10.80*** **	**26.69** **	**16.73*** **	**20.13** **	**9.99*** **	**21.15** **	**11.16*** **	11.36
AMLG3	**4.62*** **	**25.23** **	**0.55*** **	**28.58** **	**4.28*** **	**5.11** **	**11.37*** **	**33.32** **	**17.43*** **	**20.23** **	**11.05*** **	**22.37***	**10.56*** **	**15.72***
Panel B: Sntiment Periods														
	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT	HSENT	LSENT
AMLG	**12.76*** **	**5.03*** **	**11.31*** **	**0.12** **	**0.37** **	**10.73*** **	**14.57*** **	**12.78*** **	**15.83*** **	**18.30*** **	**14.90*** **	**10.32*** **	**16.65*** **	**7.26*** **
AMLG1	**13.34*** **	**4.80*** **	**11.55*** **	-0.08**	-0.73*	**11.16*** **	**14.34*** **	**12.24*** **	**15.40*** **	**18.78*** **	**14.46*** **	**10.67*** **	**16.54*** **	**7.04*** **
AMLG2	**13.46*** **	**4.82*** **	**11.78*** **	-0.42**	-0.17**	**11.09*** **	**14.29*** **	**11.77*** **	**15.88*** **	**18.63*** **	**14.06*** **	**10.18*** **	**16.25*** **	**6.96*** **
AMLG3	**13.00*** **	**2.90** **	**10.07*** **	-1.09**	-4.12*	**12.18*** **	**16.20*** **	**12.70*** **	**15.43*** **	**20.29*** **	**14.59*** **	**12.22*** **	**16.87*** **	**6.12*** **
Panel C: Liquidity Periods														
	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ	HLIQ	LLIQ
AMLG	**5.70** **	**10.81*** **	**0.87** **	**11.54*** **	**6.98*** **	**3.74*** **	**13.53*** **	**14.22*** **	**17.01*** **	**17.30*** **	**13.51*** **	**12.76*** **	**9.81*** **	**13.24*** **
AMLG1	**5.42** **	**11.25*** **	**1.57** **	**11.08*** **	**6.87*** **	**3.24*** **	**13.29*** **	**13.76*** **	**17.34*** **	**17.08*** **	**13.71*** **	**12.36*** **	**9.68*** **	**12.99*** **
AMLG2	**5.56** **	**11.31*** **	**1.62** **	**11.06*** **	**7.29*** **	**3.33*** **	**13.18*** **	**13.42*** **	**17.42*** **	**17.36*** **	**13.34*** **	**11.92*** **	**9.62*** **	**12.71*** **
AMLG3	**1.52** **	**12.02*** **	-0.08**	**10.09*** **	**6.60*** **	**1.32*** **	**13.35*** **	**15.93*** **	**17.95*** **	**18.06*** **	**14.69*** **	**12.87*** **	**8.69*** **	**13.51*** **
Panel D: Sub-sample Periods														
	2006	2019	2006	2019	2006	2019	2006	2019	2006	2019	2006	2019	2006	2019
AMLG	**2.60** **	**15.64*** **	-3.34*	**15.86*** **	**5.42*** **	**6.08*** **	**14.73*** **	**12.72*** **	**19.66*** **	**14.36*** **	**10.37*** **	**15.27*** **	**8.36*** **	**13.43*** **
AMLG1	**2.56** **	**16.04*** **	-2.97*	**15.64*** **	**5.23*** **	**5.66*** **	**15.03*** **	**11.62*** **	**20.12*** **	**13.93*** **	**10.63*** **	**14.83*** **	**8.63*** **	**12.99*** **
AMLG2	**3.07*** **	**15.63*** **	-2.04*	**14.85*** **	**5.21*** **	**6.12*** **	**14.90*** **	**11.26*** **	**20.36*** **	**14.01*** **	**10.27*** **	**14.34*** **	**8.30*** **	**12.91*** **
AMLG3	-0.28**	**16.79*** **	-5.69**	**15.63*** **	**3.65*** **	**5.01*** **	**15.87*** **	**13.28*** **	**20.09*** **	**15.54*** **	**11.09*** **	**15.65*** **	**7.30*** **	**13.23*** **

Conclusions

- There is evidence that macroeconomic/ financial variables can forecast RV
- Wavelet decomposition methodology can provide further insight for future RV
- Aggregating information contained in different predictors and different models can benefit the forecasting experiment
- The results are consistent with the leading theories on timing effects.
- Further research should be done on more elaborate ensemble techniques