

International Capital and Dynamic Changes in Tesla Stock Price: Evidence from Fed's Interest Rate Policy

Qiudan Jin

Department of economics, Chung-Ang University, Seoul, 156-756, South Korea

uhyio@stu.cuz.edu.cn

Abstract. Since the establishment of Tesla, it has attracted attention from outside the industry and is outstanding in new energy models, which can be reflected in the volatility of Tesla's stock price. This paper evaluates the main scenarios of Tesla stock prices and the Federal Reserve exchange rate in a global regional environment. This paper established ARMA-GARCH model and VAR model to analyze the correlation, impact, and changes in the value and volatility of these stock prices between the Fed rate hike and Tesla. This paper finds that the Fed's rate hike had a surprising impact on Tesla's stock price, which exploded overnight. From a theoretical point of view, Impact of Fed interest rate hikes on Tesla is going in a negative direction. But looking at the stock market, it can be found that the Fed's rate hike has little impact on Tesla's share price and yield, and it cannot be confirmed with certainty that it has an impact on its net effect. The significance of this study lies in whether investors and the government are overly affected by the environment of Fed rate hikes, but only looking at the impact of Fed rate hikes on Tesla studied in this article, it is minimal.

Keywords: Tesla; Fed; Interest Rate.

1. Introduction

Tesla is a U.S. electric vehicle and energy company founded on July 1, 2003, by Martin Eberhard and Mark Tarpenning [1]. Tesla hopes to accelerate the global transition to sustainable energy by working to provide every average consumer with a range of all-electric vehicles. General Motors abandoned production in 2002 after producing more than 2,000 vehicles because of a low input-output ratio. Later, Al Kocconi, Engineers involved in the EV-1 project set up an electric vehicle company, ACPropulsion, T-Zero, a one-man lead-acid battery car, was built in California. When AC's thrusters ran into trouble, a Silicon Valley engineer named Martin Eberhard invested \$150,000. In exchange, he wants Kocconi to try to power T-Zero with lithium-ion batteries from thousands of laptops.

The T-Zero has a range of more than 480 kilometers after switching to lithium batteries. Eberhard persuaded AC Propulsion to build such a car for him, but Kocconi had no intentions to start a car company.

By contrast, in 2022, Tesla's audience has also shifted from sports car favored by high earners and celebrities to high-performance models available to the public. In 2003, the T-Zero was replaced by a lithium battery with a range of 480kilometers. It took Tesla about five years to polish the sports car before it hit the market.

It was developed by Sla itself and has never had a battery failure. It also ensures that Tesla can always equip its electric cars with the most advanced batteries. On October 21, 2018, Tesla removed the long-standing "Full Self-Driving" option from its official reservation page.

On December 9, 2021, Tesla CEO Elon Musk sold another nearly \$940 million worth of Tesla stock, one step closer to his goal of selling 10% of his stake. On February 8, 2022, Tesla received another U.S. subpoena, according to Gasgoo. Securities and Exchange Commission).lon Musk has tweeted that he is considering taking Tesla private [2].

On January 27, 2022, after the stock market closed on Wednesday, local time in the United States, Tesla announced its fourth quarter 2021 financial report. According to the financial report, according to the GAAP.

Calculation, Tesla's fourth-quarter revenue was US\$17.72 billion, 65% year-on-year increase; Net income was \$2.3 billion, up 760% from a year ago, and earnings per share were \$2.05, an increase of

754% year-on-year. Electric vehicle deliveries reached 308,650 units, a year-on-year increase of 71%. But the stock fell slightly in after-hours trading as Tesla warned of intensifying supply chain problems. Tesla achieved revenue of \$17.719 billion, 65% year-over-year; net income was \$2.32 billion, up 760% year-over-year. On April 21, 2022, Tesla released its financial results for the first quarter of 2022, with total revenue of \$18.756 billion, an 81% year-over-year increase; net profit of \$3.318 billion, an increase of 658% year-over-year; adjusted earnings per share of \$3.22. Tesla's second-quarter revenue was \$16.934 billion, slightly higher than market expectations of \$16.88 billion, 42% year-on-year increase; net profit was \$2.259 billion, compared with market expectations of \$1.984 billion, 98% year-on-year increase; adjusted earnings per share (EPS) was \$2.27, up 57% year over year.

Fed meeting Evans said he was satisfied with one rate hike each in 2021 and 2022. At the company news level, Tesla's stock price rose nearly 4%, setting a new record closing record, and its total market value increased by \$70 billion [3].

Based on the Tesla background, it can better help to study the impact and relationship between Tesla and the Fed's interest rate hike. Insurance brokers once said: The impact of exchange rate fluctuations on the national economy and finance is divided into two aspects: 1. It affects whether prices rise or fall. In some cases, it will affect the productive sectors of export commodities. [4]. After the exchange rate changes, the prices of imported consumer goods and raw materials change first, followed by those processed with imported raw materials or similar domestic commodities.

When foreign currencies appreciate, imported goods become more expensive, which increases production costs for producers of exported goods (mainly imported raw materials) and reduces their competitiveness in international markets. The better off the manufacturer is. Fed meeting Evans said he was satisfied with one rate hike each in 2021 and 2022. At the company news level, Tesla's stock price rose nearly 4%, setting a record closing record, and its total market value increased by \$70 billion. Therefore, it can be seen from this passage that the Fed's interest rate hike is beneficial to Tesla [5].

U.S. consumer prices rose to a 40-year high in February 2022 year-on-year amid rising gasoline, food, and housing costs, according to the Federal Reserve. The consumer price index (CPI) rose by 7.9% year-on-year, which is the second increase after the 7.5% year-on-year increase in January [6]. The Fed raised rates by 25 quarter-point as scheduled at its March meeting and decided to raise the range to 0.25-0.5%. It was the first U.S. rate hike since December 2018 [7]. As inflation gets worse, it will get worse if interest rates are not raised. The Fed raised rates by 25 quarter-point as scheduled at its March meeting and decided to raise the range to 0.25-0.5%. It was the first U.S. rate hike since December 2018 [8].

In this paper, we organize the following sections: Section 2 is the study design, including data sources, unit root testing, VAR model specification, ARMA-GARCH model specification; Section 3 is empirical results and analysis, including VAR order determination, impulse response, ARMA order, ARMA-GARCH estimation results; the fourth part is the discussion, including the research results of this paper, the research inspiration; The fifth part is the conclusion of the study.

2. Research Design

2.1 Data source

The Federal Reserve and Tesla's Composite Index in this article are from CSMAR and Choice financial terminals. The CSMAR and Choice financial terminals collect various important financial data from Tesla and the Federal Reserve.

Unit Root Test This article will confirm that the Tesla data matches the Fed data. Since trading markets have trading days, closes are closed, and stock prices only change within trading days, the study ignores data from non-trading days and sorts and rennumbers data by date. In this paper, we organize the following sections: Section 2 is the study design. In this study, Stata was used as the most commonly used tool to solve the problems encountered in the further exploration of this study.

If there are no new confirmed cases for more than one consecutive day, the addition of one case to the original sequence does not affect the final outcome. In this study, Stata is most commonly used tool to address the problems encountered in further exploration of this study.

2.2 Unit Root Test

A single root test (Process) is used to check that the time series is stable. Most quantitative analysis of time series presupposes sequence stability. Consequently, before starting the research.

The stationarity condition of data must be checked. If any sequence is not fixed, we need to find possible methods to improve the results. When doing Unit Root Test, it is usually assumed that the time series x_t can be written.

$$x_t = c_t + \beta x_{t-1} + \sum_{i=1}^{p-1} \phi_i \Delta x_{t-i} + \varepsilon_t \quad (1)$$

The invalidation hypothesis of the test is the coefficient $\beta=1$, indicating that the sequence has a unit root, is not stationary, and the alternative hypothesis is $\beta<1$, indicating that the tested series is stationary. Table 1 gives us the test results so raw data as well as the processed series.

Table 1. ADF test

Variables	t-statistic	p-value
Price		
Tesla	-1.190	0.9125
Exchange rate	-1.515	0.8239
Yield		
Tesla	-10.425	0.0000***
Exchange rate	-11.206	0.0000***

2.3 VAR model setting

The vector autoregressive model, known as VAR models, Presented by Christopher Sims in 1980 [8]. The var model uses all current variables to regress several lag variables among all variables. The var model is constructed by using each endogenous variable in the system as a function of the lag value of all endogenous variables, thus extending the univariate autoregressive model to a "vector" autoregression consisting of multivariate time series variables.

To illustrate this, when it comes to a VAR models with two variables (x_1, x_2), considering only one lag term ($p=1$), the system should look like this:

$$x_{1,t} = c_{11}x_{1,t-1} + c_{12}x_{2,t-1} + \varepsilon_{x1,t} \quad (2)$$

$$x_{2,t} = c_{21}x_{1,t-1} + c_{22}x_{2,t-1} + \varepsilon_{x2,t} \quad (3)$$

It can be written as a vector group, for example:

$$x_t = \cdot x_{Lg} + E_t \quad (4)$$

In this case, two variables (Fed, Tesla), a $VAR(p)$ model can be written as:

$$y_t = \Gamma_0 + \Gamma_1 y_{t-1} + \dots + \Gamma_p y_{t-p} + \varepsilon_t \quad (5)$$

Where $y_t = \begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix}$, $\Gamma_0 = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix}$, $\varepsilon_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix}$, $\Gamma_1 = \begin{pmatrix} \beta_{11} & \gamma_{11} & \lambda_{11} \\ \beta_{21} & \gamma_{21} & \lambda_{21} \end{pmatrix}$, $\dots$, $\Gamma_p = \begin{pmatrix} \beta_{1p} & \gamma_{1p} & \lambda_{1p} \\ \beta_{2p} & \gamma_{2p} & \lambda_{2p} \end{pmatrix}$.

In (5), y_t refers to the three response variables. $\Gamma_0, \Gamma_1, \dots, \Gamma_p$ are coefficient matrices, and corresponding terms. ε_t is the error term matrix.

Pulse response maps are useful tools for studying interactions within or between variables in VAR systems. Response graphs generates exogenous impulses and observes how the system responds to them over time. In general, the response can be calculated as:

$$\psi_s = \frac{\partial y_{t+s}}{\partial \varepsilon_t} \quad (6)$$

Graphing between variables in a VAR model is the perfect way to visualize. All impulse responses within a VAR system can be graphed, so impulse response graphs are an essential part of analyzing a VAR model.

2.4 ARMA-GARCH model setting

ARCH is the auto-regressive process of the second moment of error. Engel proposed the LM test method for the ARCH process in 1982 [9]. Make a null hypothesis: there is no ARCH effect in the remaining sequence before the P-order. Do regression:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2 \quad (7)$$

Where σ_t is the forecast variance in period t. ε_t refers to the actual variance in period t. α_0 is constant.

In 1986, Bollerslev modified it with the generalized ARCH model (GAECH), adding the GAECH option to the original ARCH model to address the volatility of time series.

Use ε_t to represent return or return residual, assuming $\varepsilon_t = \sigma_t z_t$, where $z_t \sim N(0,1)$.

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2 \quad (8)$$

That is, independent and identically distributed, all conform to the normal distribution of expected 0 and variance 1.

If the variance is expressed by the ARMA model, the ARCH model is a variant of the 1986 the GARCH model Poleslov [10]. The GARCH (p, q) model is:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \dots + \beta_p \sigma_{t-p}^2 \quad (9)$$

3. Empirical Result

3.1 VAR Model Result

The VAR model requires very little theoretical basis. To build a VAR model, only two things need to be determined: (1) The variable being studied (whether endogenous or exogenous) and (2) the Maximum order of lag.

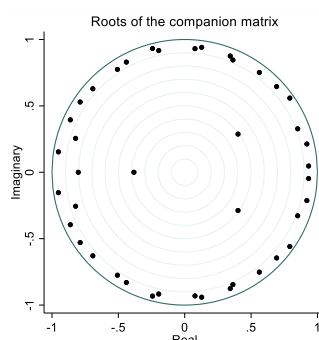
VAR models do not need to distinguish between endogenous and exogenous variables, and it is easy to predict because the explanatory variables are all lagged variables. Of course, there may be more parameters to be estimated.

In this section, the paper proposes Tesla and the Fed's selection order criteria in Stata for finding the appropriate order p for this VAR (p) model. Table 2 VAR model identification.

Table 2. VAR model identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	1365.23				3.1e-09	-13.9105	-13.897	-13.8771*
1	1374	17.531	4	0.002	3.0e-09*	-13.9592*	-13.9185*	-13.8588
2	1374.89	1.7897	4	0.774	3.1e-09	-13.9275	-13.8598	-13.7602
3	1378.01	6.2268	4	0.183	3.1e-09	-13.9184	-13.8236	-13.6843
4	1379.95	3.8984	4	0.420	3.2e-09	-13.8975	-13.7756	-13.5964
5	1384.74	9.5662	4	0.048	3.1e-09	-13.9055	-13.7565	-13.5375
6	1385.76	2.0421	4	0.728	3.2e-09	-13.8751	-13.699	-13.4402
7	1389.36	7.1995	4	0.126	3.2e-09	-13.871	-13.6679	-13.3693
8	1390.02	1.3284	4	0.857	3.4e-09	-13.837	-13.6067	-13.2683
9	1394.85	9.6477	4	0.047	3.3e-09	-13.8454	-13.5881	-13.2098
10	1399.03	8.366	4	0.079	3.3e-09	-13.8472	-13.5629	-13.1448
11	1399.59	1.1254	4	0.890	3.4e-09	-13.8122	-13.5007	-13.0428
12	1399.83	.48488	4	0.975	3.6e-09	-13.7738	-13.4353	-12.9376
13	1400.53	1.3902	4	0.846	3.7e-09	-13.7401	-13.3745	-12.8369
14	1402.32	3.5789	4	0.466	3.8e-09	-13.7175	-13.3248	-12.7475
15	1404.44	4.2415	4	0.374	3.9e-09	-13.6984	-13.2786	-12.6614
16	1409.64	10.395	4	0.034	3.8e-09	-13.7106	-13.2637	-12.6067
17	1414.71	10.136	4	0.038	3.8e-09	-13.7215	-13.2475	-12.5507
18	1418.49	7.5775	4	0.108	3.8e-09	-13.7193	-13.2183	-12.4817
19	1419.8	2.6045	4	0.626	3.9e-09	-13.6918	-13.1637	-12.3872
20	1420.95	2.31	4	0.679	4.0e-09	-13.6628	-13.1075	-12.2913
21	1433.62	25.342*	4	0.000	3.7e-09	-13.7512	-13.1689	-12.3129
22	1435.29	3.3379	4	0.503	3.8e-09	-13.7275	-13.1181	-12.2222
23	1436.94	3.3064	4	0.508	3.9e-09	-13.7035	-13.067	-12.1314
24	1437.61	1.3242	4	0.857	4.1e-09	-13.6695	-13.0059	-12.0304

After the VAR model is established, after estimating vector regression parameters, the stability condition of eigenvalues is tested by using the variable tools in Stata. A visualization of the unit circle is displayed. If all the points representing the eigenvalues lie within the unit circle, Then the VAR estimate in Figure 1 is stable, and aresult graph is given to show that the stability of the system is satisfactory.

**Fig. 1** VAR stability

3.2 Impulse response

From a theoretical analysis point of view, the Fed's interest rate hike will certainly lead to an increase in the demand for international hot money and dollars in the international financial market, and it further leads to exchange rate appreciation.

However, the impact of rising exchange rate on companies goes in two main directions: First, this paper assumes that the firm's product price is rigid in a short period, that is, it is difficult to adjust. As

a large multinational company operating around the world, Tesla's main revenue and financial reports are all calculated in US dollars. The appreciation of the dollar means that operating income abroad will depreciate, and the devaluation of the local currency is not conducive to exports. From this point of view, the Fed raising interest rates may be negative for Tesla. But on the other hand, International financial markets hold more dollars, and this part of the funds may flow into the stock market or bond market, thus increasing the demand for shares and further increasing the price year by year.

Based on the above analysis, it is difficult to directly determine the net effect of Fed rate hikes on Tesla stock price or yield.

Starting from the model results, this paper finds that the net effect of the appreciation of the U.S. dollar triggered by the Fed's rate hike on Tesla is positive. Specifically, it can be seen that the exchange rate yield increases by 1% in the period $t=0$, and the maximum positive effect on Tesla's earnings appears in the third period, which is about 0.25%. Although some periods have a small negative effect, the value is small, and some of these periods are also small, and the overall positive effect is still shown.

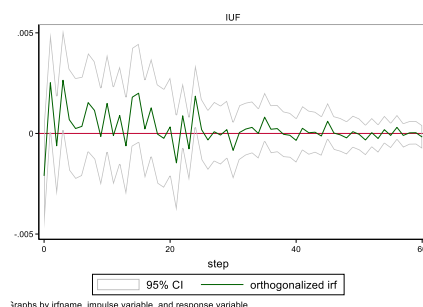


Fig. 2 Impulse and response

3.3 PACF and ACF

Check out a series the partial autocorrelation plot (PACF plot diagram) in the Stata, as shown in Figure 3, black rectangles are the basis for finding statistically significant items in AR models. Suggesting that the 26 terms that lag in the original sequence may be a signal that has a significant impact on current data.

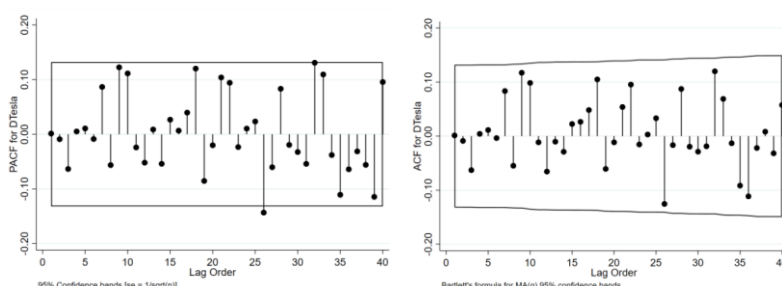


Fig. 3 PACF and ACF

3.4 ARMA-GARCH estimation results

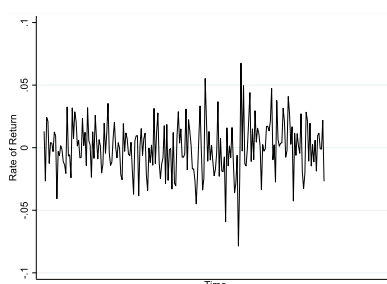


Fig. 4 Yield trend

From the timing chart, it is difficult to judge whether Tesla's stock returns are clustered, and further statistical testing is needed.

From the estimation results of the ARMA-GARCH model, the GARCH items in columns (1) to (3) are all significant, and the ARCH items in columns (2) and (3) are significant (note: one of the two is significant), it shows that Tesla stock returns have obvious conditional heteroscedasticity, which can be modeled by GARCH.

From the perspective of the exchange rate, the coefficient in column (1), the exchange rate logarithmic return increases by 1 unit, and the volatility of Tesla's return increases by 214.5, which is significant at the 1% level. After adding a lag period, this effect was found to have a hysteresis effect. That is, the exchange rate change in the period of $t=-1$ will affect the volatility of Tesla's stock return in the current period.

Table 3. ARMA-GARCH estimation results

	(1)	(2)	(3)
Variance equation			
T=0	214.5*** (39.86)	72.02 (86.80)	78.32 (92.22)
T=-1		194.0*** (60.54)	205.1*** (66.04)
T=-2			-30.40 (70.42)
ARCH (-1)	-0.0664 (0.0474)	-0.0978** (0.0466)	-0.0940* (0.0480)
GARCH (-1)	0.731*** (0.114)	0.647*** (0.104)	0.650*** (0.104)
Constant	-9.169*** (0.426)	-8.853*** (0.299)	-8.896*** (0.304)
Mean equation			
L.ar	0.376 (0.499)	0.347 (0.438)	0.362 (0.479)
L2.ar	-0.0206 (0.0729)	0.0101 (0.0690)	0.0077 (0.0692)
L3.ar	-0.0870 (0.0843)	-0.115 (0.0790)	-0.124 (0.0806)
L4.ar	0.0536 (0.0857)	0.0528 (0.0854)	0.0614 (0.0905)
L5.ar	0.00706 (0.0813)	0.00348 (0.0807)	0.00582 (0.0824)
L6.ar	-0.00559 (0.0805)	-0.00981 (0.0793)	-0.0138 (0.0799)
L7.ar	0.0723 (0.0719)	0.0817 (0.0677)	0.0838 (0.0704)
L8.ar	-0.0536 (0.0784)	-0.0352 (0.0800)	-0.0386 (0.0814)
L9.ar	0.127* (0.0699)	0.131* (0.0729)	0.121 (0.0751)
L.ma	-0.383 (0.510)	-0.379 (0.444)	-0.386 (0.484)
Constant	-0.0003 (0.0015)	-0.0006 (0.0015)	-0.0006 (0.0015)

4. Conclusion

From the analysis of the experimental conclusions, find that the Fed rate hike in this paper will lead to an increase in the demand for international hot money and dollars in the financial market, this has led to a further rise in exchange rate. First, changes in the price of imported consumer goods and raw materials., followed by the change in the price of imported raw material processed products or domestic products similar to imports. When exchange rate change, so do the domestic prices of exports.

As a large multinational company with global operations, Tesla's main earnings and financial reports are denominated in dollars. From this perspective, the Federal Reserve's interest rate hike may be bad for Tesla. Backed by the dollar on international financial markets, this part of the funds may flow into the stock market or the bond market, resulting in a surge in stock prices and an increase in the demand for stocks. From the above point of view, it can be found that the Fed's interest rate hike has an impact on Tesla's stock price and yield, but it is minimal, and it cannot positively confirm that its net effect has an impact.

Experimental results in this paper show that the net impact of Fed rate hikes on the dollar's appreciation has been generally positive for Tesla.

In the exchange rate logarithmic rate of return, find that its rate of return is 214.5 times the volatility of Tesla's earnings. At the level of 1%, it can be found that there is a lag effect. When $t=1$, the exchange rate will only affect the current period. Tesla stock's earnings volatility.

The rate hike by the Federal Reserve has brought significant changes to the global economy. During this period, the volatility response of the Tesla stock price studied in this article has also varied. This paper examines the impact of Tesla vs. Fed rate hikes, focusing on stock returns, financial statement volatility, and further research on their volatility responses. The study concluded that Fed rate hikes are proportional to Tesla yields.

References

- [1] Christopher Sims US. Vector autoregression, VAR. Cabbage, Angele Roh. Christopher Sims: 2011 Nobel Laureate in Economics. Baidu Encyclopedia (2021-12-29) [2022-09-04], https://wiki.mbalib.com/wiki/Christopher_Sims
- [2] Robert F. Engle US. Baillie R T, Bollerslev T, Mikkelsen H O. Fractionally integrated generalized autoregressive conditional heteroskedasticity. *Journal of econometrics*, 1996, 74(1): 3-30.
- [3] Sharma M. Fractional integration and fractional differentiation of the M-series. *Fractional calculus and applied analysis*, 2008, 11(2): 187-191.
- [4] Tesla homepage. [2022-09-02]. <https://www.tesla.com>
- [5] Bollerslev T. Generalized autoregressive conditional heteroskedasticity. *Journal of econometrics*, 1986, 31(3): 307-327.
- [6] Investing homepage. [2022-09-02]. <https://cn.investing.com>
- [7] Wang Jian. Restoring the Real Federal Reserve. 2013 [2022-09-05]. http://www.wenqujingdian.com/Public/editor/attached/file/20180329/20180329151251_97816.pdf
- [8] Chen Fengxian. The Predicament of the Fed's Interest Rate Raising and Its Possible Impact. *China Economic and Trade Tribune*, 2015 (10): 30-34.
- [9] Luo Hui, Yang Kezhan, Zeng Cihang. The Rise of Electric Vehicle Tesla. *Small and Medium Enterprises in China*, 2013 (7): 68-71.
- [10] Zhou Yongxiang. Continue to be optimistic about the hype of Tesla concept stocks. *Analysis of Stock Market Dynamics*, 2013 (19): 30-30.