



Robert Michaud

CIO
New Frontier

Robert Michaud is the co-holder of four U.S. patents in portfolio optimization and asset management and is the Chief Investment Officer at New Frontier. He holds a Masters in Mathematics from Boston University and pursued a PhD in finance from the Anderson School of Management at the University of California at Los Angeles before joining New Frontier. His research interests include risk models, empirical asset pricing, and international finance. He is the co-author of *Efficient Asset Management: A Practical Guide to Stock Portfolio Optimization and Asset Allocation*, (2nd ed. Oxford University Press, 2008) and research articles in refereed journals.

The Statistical Oddity of the Dow and 20,000

January 26, 2017

The Dow finally hit 20,000. I wouldn't ordinarily put much importance on an arbitrary milestone (see *The Dow 20,000...Should We Care?*), but the long hover just below this level was extraordinary. This is not to say that markets need behave in any predictable manner. Daily movements of the market tend to behave like random walks, and random walks commonly exhibit long streaks and other seemingly unusual behavior. But the recent history of the Dow went far beyond what can be easily explained as a random walk.

The aftermath of the US presidential election began a period of rapidly rising stock prices in the US, where the Dow went from approximately 18,000 just before the election to 19,757 on December 9, 2016. With 20,000 within a historically typical day's volatility (a 1.2% increase), the financial media began to buzz with talk of the Dow 20,000. But the following days had small market movements. This in itself would not be surprising, but days turned to weeks of small declines and advances where the Dow neither exceeded 20,000 nor fell much below it. Can this period be explained by statistics as a random walk, or is it possible the market places significance on the Dow milestone and is expressing doubt about the expectations of recent events?

As it turns out, this was a period of extremely low volatility. The VIX closed yesterday at 10.8%, its low since 2014. Even more unusual was the daily standard deviation of the Dow from December 9 through January 25, a mere 35bp, which annualizes to roughly 5.5%. But the odds of the Dow staying in this narrow range (it reached as high as 19,999.63 on January 6th) are vanishingly small. (Monte Carlo simulations showed the probability at less than 1 in 10,000, or much, much lower depending on volatility assumptions used—a penny would have been expensive for an option that paid \$10 if the Dow remained above 19,700, but below 20,000.) Yet that's what happened. The analysis is included in the table below, but I will draw my conclusions now. Extraordinary investor uncertainty about the intentions of the new administration as well as a variety of speculative reasons abound for why the market stalled so close to this milestone, but we can state with very high confidence that the market did not follow a random walk for 30 trading days—a contradiction of reliable financial theory of normal functioning markets. The good news for those of us who believe in rational markets is that I see no reason for this to persist or be repeated in the future. Now that it's over, I'll go back to expecting the unexpected ups and downs of the market.

Appendix

To get as robust an estimate as possible on the distribution of daily returns on the Dow, I used both the normal distribution (where future daily returns are drawn from a normal distribution fit from past daily returns) as well as the empirical distribution (where future daily returns are drawn from past daily returns). For these, I chose two time periods for the data: the last 20 years, and the lower volatility period beginning in 2010. While these give slightly different values, the overall answer is clear. It's highly improbable that markets are behaving normally, and some weight should be given to possibility that investors are wary of the 20,000 mark in the Dow.

The following table lists the Dow's closing price and shortfall from 20,000 followed by four measures of the probability it will reach 20,000 on the next day based on normal/empirical distributions based data since 2010/1996 followed by the cumulative probability of each of those daily events not happening.

Date	Close	Return for 20K	Normal Distribution				Empirical Distribution			
			1998-2016 Volatility		2010-2016 Volatility		1998-2016 Volatility		2010-2016 Volatility	
			1 Day	Cumulative	1 Day	Cumulative	1 Day	Cumulative	1 Day	Cumulative
1/24/2017	19912.71	0.4%	63.9%	63.9%	67.0%	67.0%	69.6%	69.6%	72.1%	72.1%
1/23/2017	19799.85	1.0%	80.2%	51.2%	85.8%	57.5%	86.0%	59.8%	88.9%	64.1%
1/20/2017	19827.25	0.9%	76.7%	39.2%	82.0%	47.1%	83.2%	49.8%	86.2%	55.2%
1/19/2017	19732.4	1.4%	87.4%	34.3%	92.7%	43.7%	91.6%	45.6%	94.0%	51.9%
1/18/2017	19804.72	1.0%	79.6%	27.3%	85.2%	37.2%	85.4%	39.0%	88.5%	45.9%
1/17/2017	19826.77	0.9%	76.7%	20.9%	82.1%	30.5%	83.3%	32.4%	86.3%	39.6%
1/13/2017	19885.73	0.6%	68.2%	14.3%	72.2%	22.1%	74.7%	24.2%	77.7%	30.8%
1/12/2017	19891	0.5%	67.3%	9.6%	71.2%	15.7%	73.8%	17.9%	76.8%	23.6%
1/11/2017	19954.28	0.2%	56.9%	5.5%	58.2%	9.2%	60.0%	10.7%	61.8%	14.6%
1/10/2017	19855.53	0.7%	72.7%	4.0%	77.6%	7.1%	79.9%	8.6%	83.2%	12.2%
1/9/2017	19887.38	0.6%	67.9%	2.7%	71.9%	5.1%	74.4%	6.4%	77.4%	9.4%
1/6/2017	19963.8	0.2%	55.3%	1.5%	56.2%	2.9%	57.7%	3.7%	59.3%	5.6%
1/5/2017	19899.29	0.5%	66.0%	1.0%	69.6%	2.0%	72.3%	2.7%	75.3%	4.2%
1/4/2017	19942.16	0.3%	59.0%	0.6%	60.8%	1.2%	62.8%	1.7%	64.6%	2.7%
1/3/2017	19881.76	0.6%	68.8%	0.4%	73.0%	0.9%	75.7%	1.3%	78.8%	2.1%
12/30/2016	19762.6	1.2%	84.4%	0.3%	90.0%	0.8%	89.0%	1.1%	91.3%	2.0%
12/29/2016	19819.78	0.9%	77.6%	0.3%	83.1%	0.7%	84.2%	0.9%	87.0%	1.7%
12/28/2016	19833.68	0.8%	75.8%	0.2%	81.1%	0.5%	82.6%	0.8%	85.7%	1.5%
12/27/2016	19945.04	0.3%	58.5%	0.1%	60.2%	0.3%	62.1%	0.5%	64.1%	0.9%
12/23/2016	19933.81	0.3%	60.4%	0.1%	62.6%	0.2%	64.6%	0.3%	66.2%	0.6%
12/22/2016	19918.88	0.4%	62.9%	0.0%	65.7%	0.1%	68.1%	0.2%	70.4%	0.4%
12/21/2016	19941.96	0.3%	59.0%	0.0%	60.9%	0.1%	62.9%	0.1%	64.6%	0.3%
12/20/2016	19974.62	0.1%	53.5%	0.0%	53.8%	0.0%	54.8%	0.1%	55.9%	0.2%
12/19/2016	19883.06	0.6%	68.6%	0.0%	72.7%	0.0%	75.4%	0.1%	78.6%	0.1%
12/16/2016	19843.41	0.8%	74.4%	0.0%	79.6%	0.0%	81.5%	0.0%	84.9%	0.1%
12/15/2016	19852.24	0.7%	73.2%	0.0%	78.1%	0.0%	80.4%	0.0%	83.8%	0.1%
12/14/2016	19792.53	1.0%	81.1%	0.0%	86.7%	0.0%	86.6%	0.0%	89.4%	0.1%
12/13/2016	19911.21	0.4%	64.1%	0.0%	67.3%	0.0%	69.9%	0.0%	72.5%	0.1%
12/12/2016	19796.43	1.0%	80.6%	0.0%	86.2%	0.0%	86.2%	0.0%	89.0%	0.1%
12/9/2016	19756.85	1.2%	85.0%	0.0%	90.6%	0.0%	89.5%	0.0%	92.0%	0.0%

This note was posted as an entry on New Frontier's investment blog on January 26, 2017. Read this entry and other posts at: newfrontieradvisors.com/blog.