INSIDE THE BLACK BOX

A SIMPLE GUIDE TO SYSTEMATIC INVESTING, THIRD EDITION

BY RISHI K. NARANG

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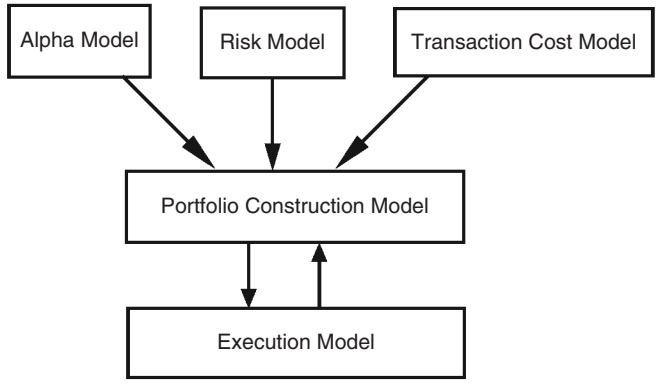


EXHIBIT 2.1 Basic Structure of a Quant Trading Strategy

EXHIBIT 2.2 Moving from an Existing Portfolio to a New Target Portfolio

	Current Portfolio	New Target Portfolio	Trades to Execute
S&P500 Index	Short 30%	Short 25%	Buy to Cover 5%
EUROSTOXX Index	Long 20%	Long 25%	Buy 5%
U.S. 10-Year Treasury Notes	Long 40%	Long 25%	Sell 15%
German 10-Year Bunds	Short 10%	Short 25%	Sell Short 15%

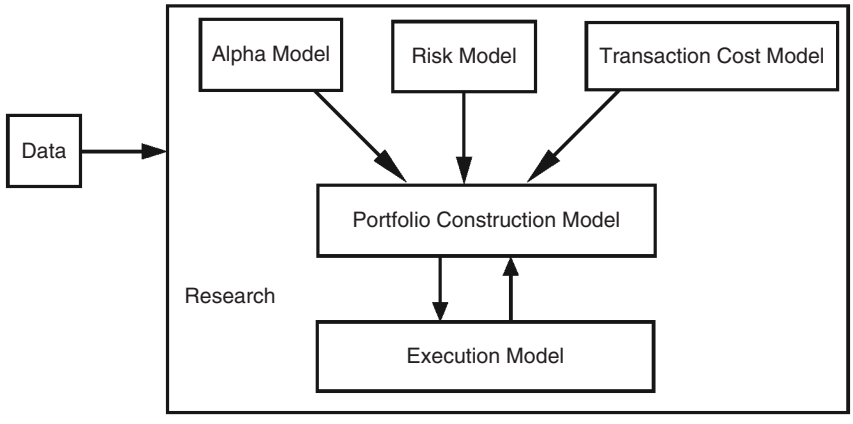


EXHIBIT 2.3 The Black Box Revealed

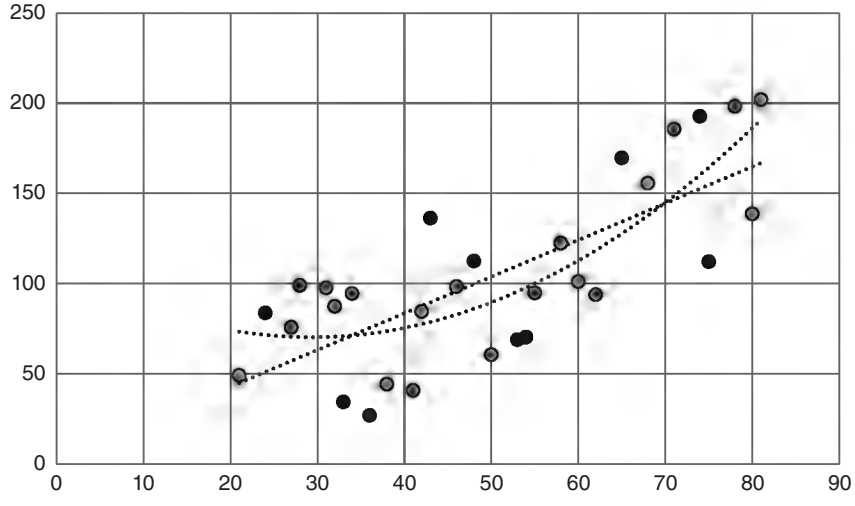


EXHIBIT 3.1 Linearity of a Relationship

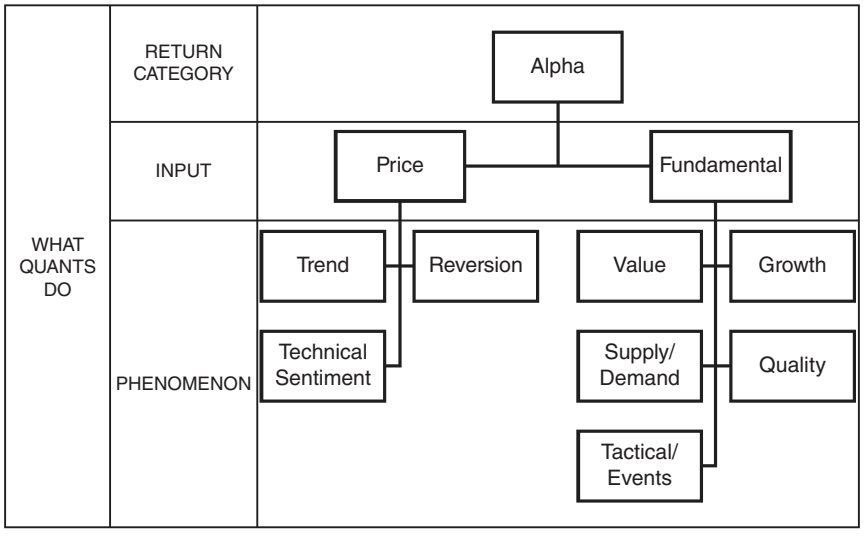


EXHIBIT 3.2 A Taxonomy of Theory-Driven Alpha Models

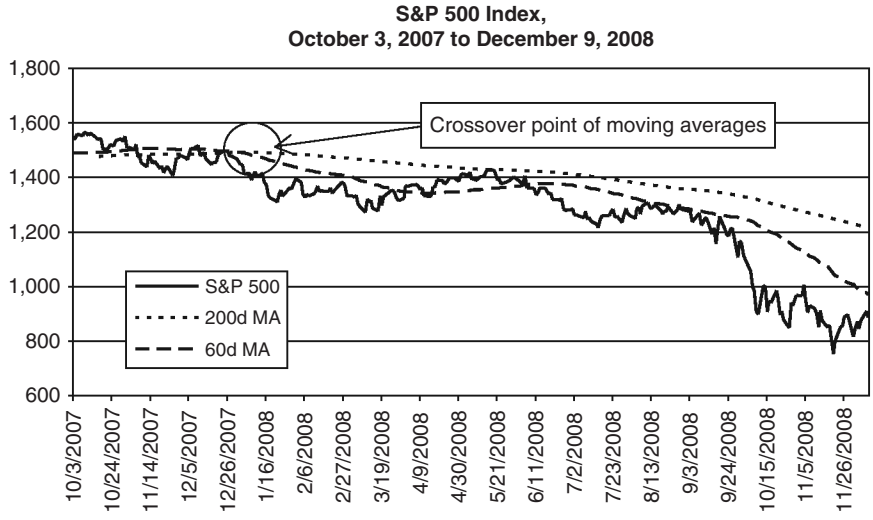


EXHIBIT 3.3 S&P 500 Trend

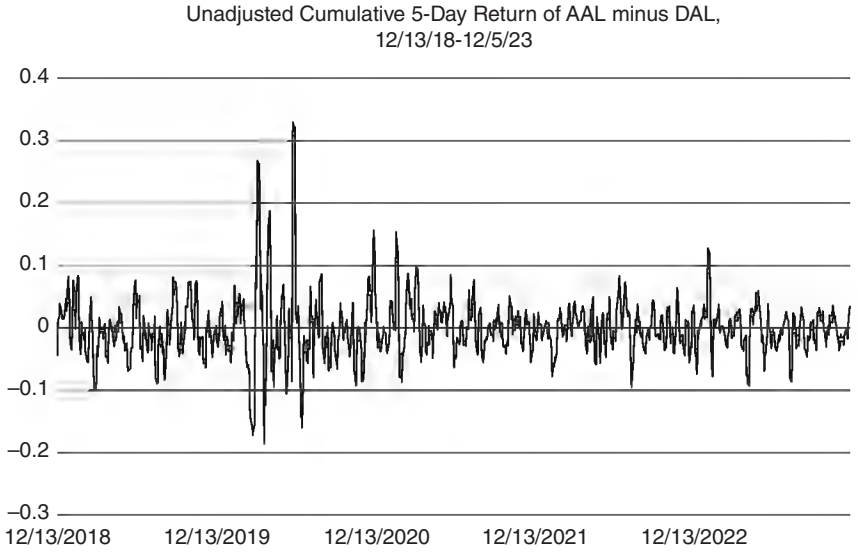
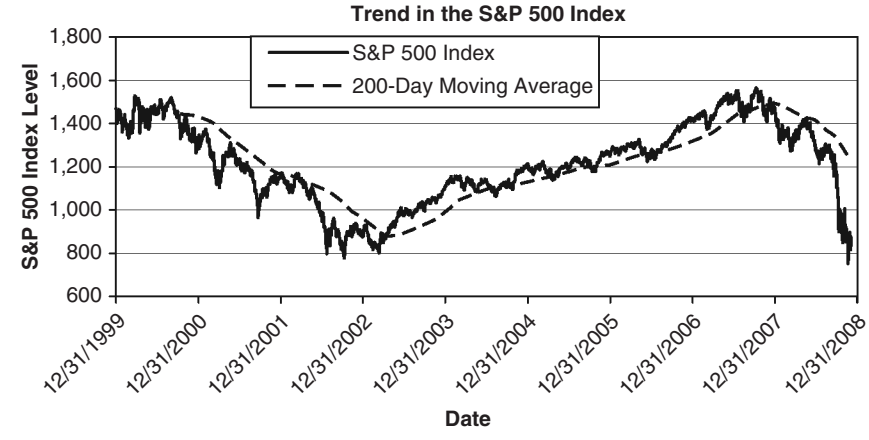


EXHIBIT 3.4 Mean Reversion Between AAL and DAL



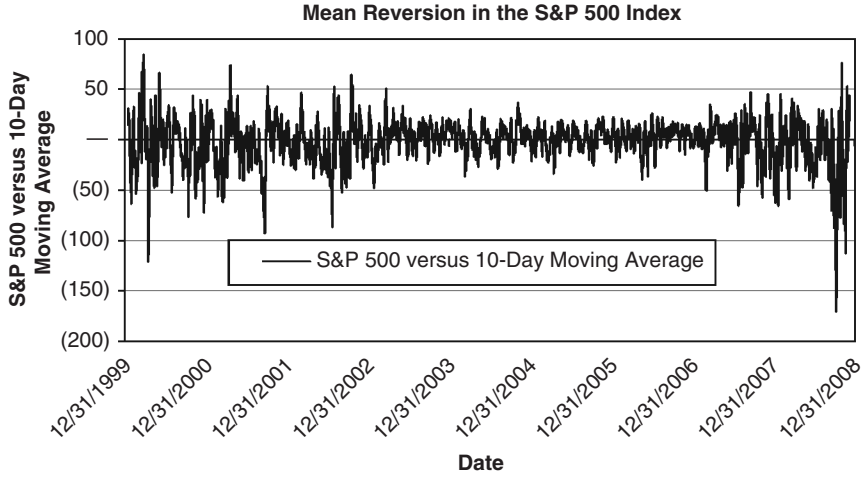


EXHIBIT 3.5 Trend and Reversion Coexisting

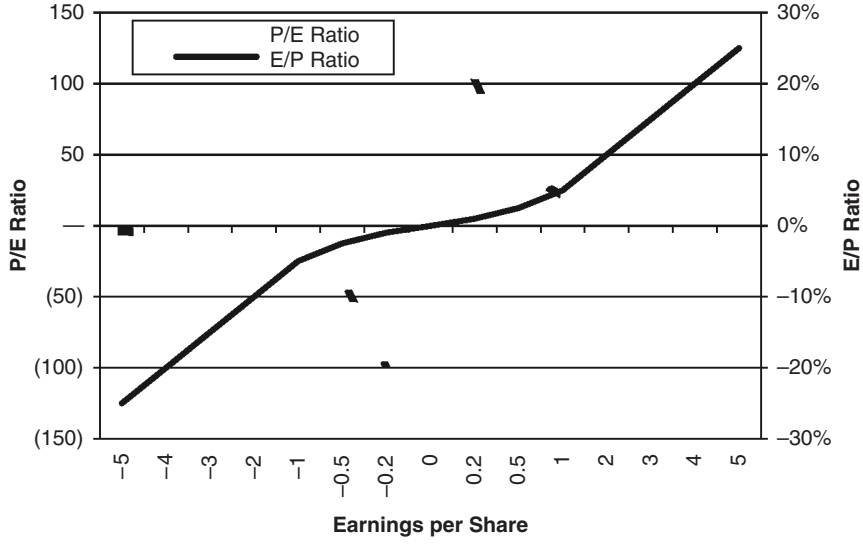


EXHIBIT 3.6 P/E versus E/P ("Earnings Yield")

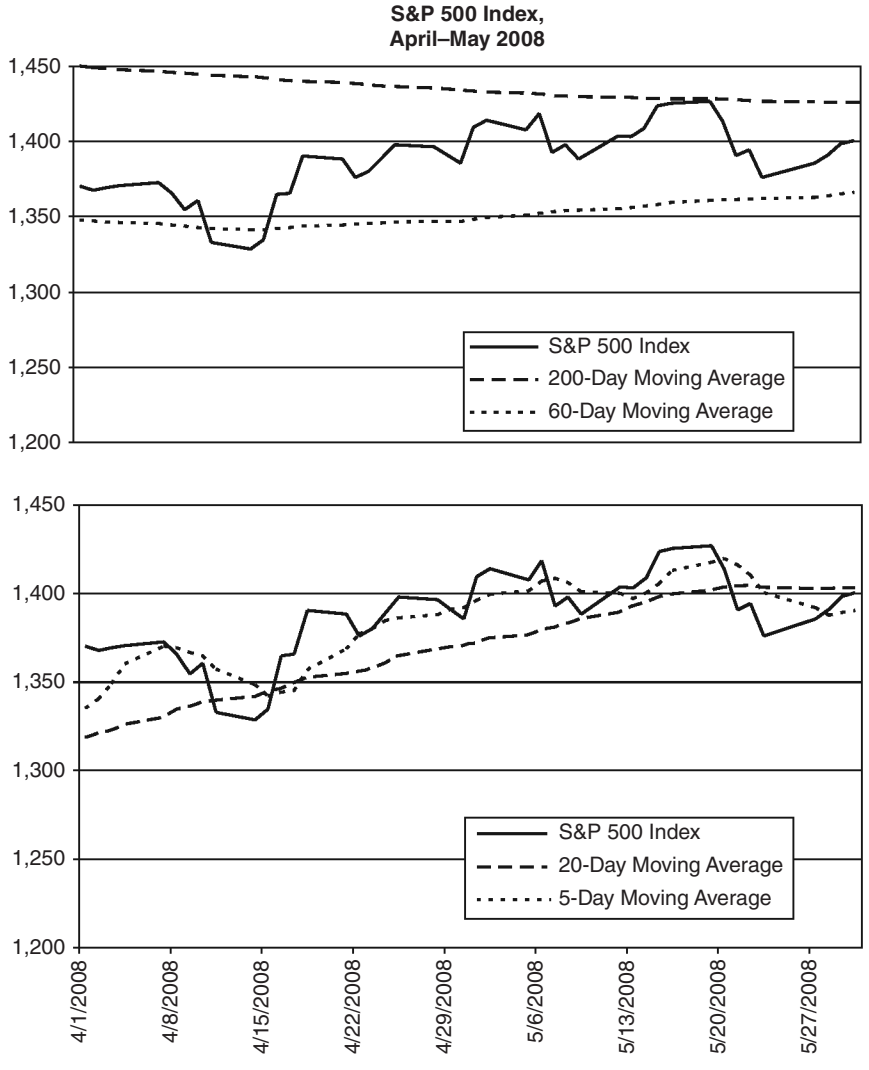


EXHIBIT 3.7 Same Strategy on Different Time Horizons

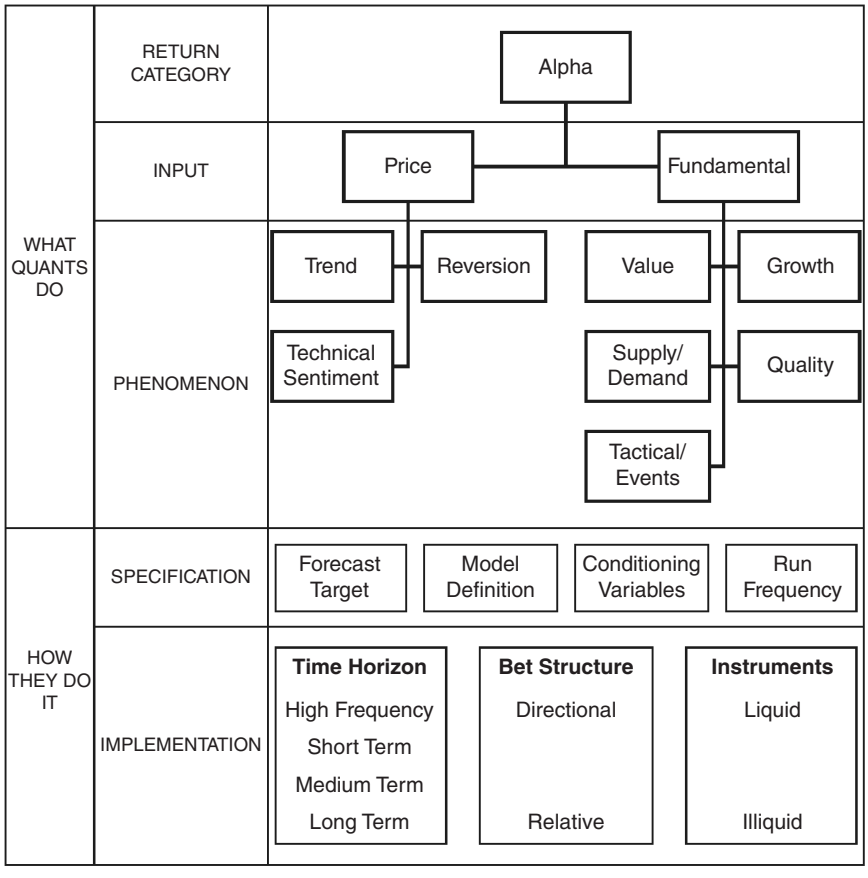


EXHIBIT 3.8 Taxonomy of Theory-Driven Alpha Models and Their Implementations

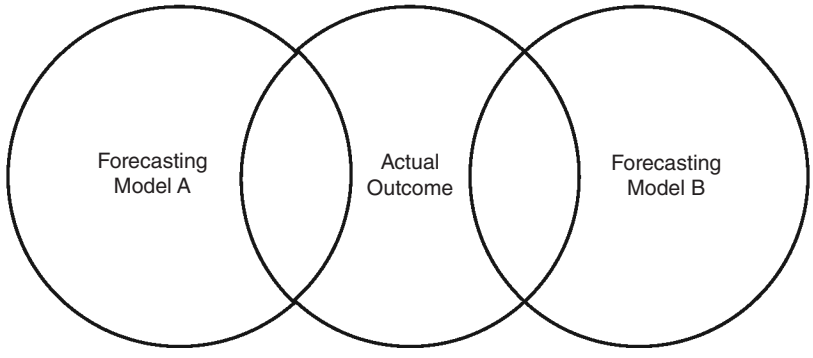


EXHIBIT 3.9 A Visualization of Multiple Forecasts

EXHIBIT 3.10 A Simple Conditional (Nonlinear) Model for Blending Alphas

Value and Momentum Disagree	**Value**	**Momentum**	**Signal**
	Long	Short	None
Value and Momentum Agree	**Value**	**Momentum**	**Signal**
	Long	Long	Long

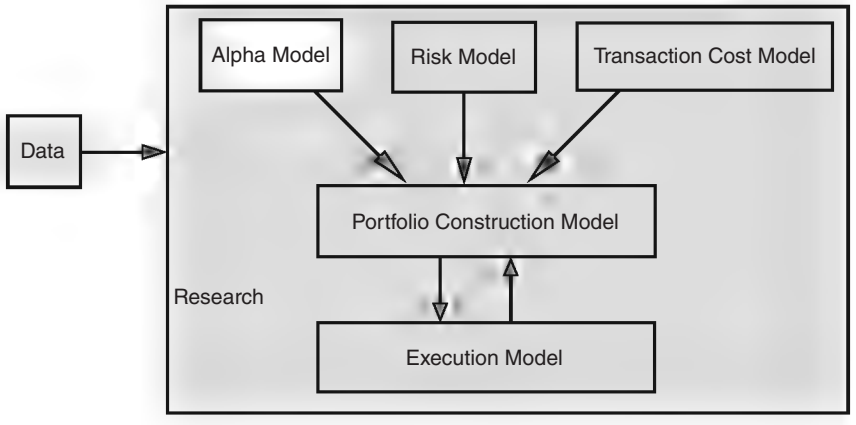


EXHIBIT 3.11 Schematic of the Black Box

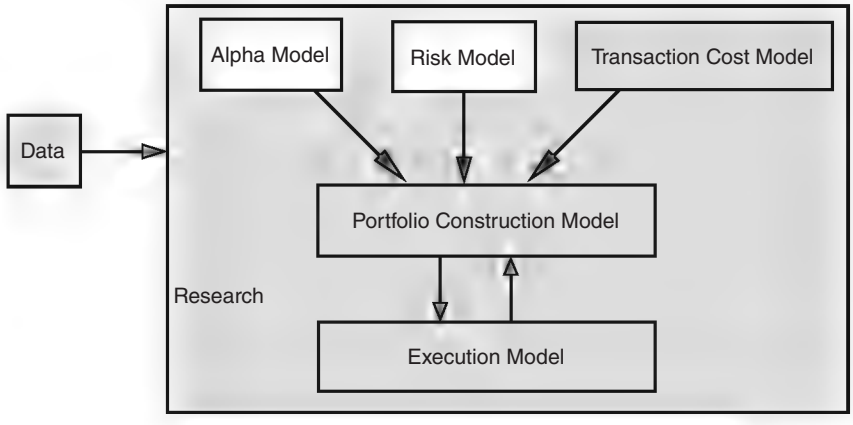


EXHIBIT 4.1 Schematic of the Black Box

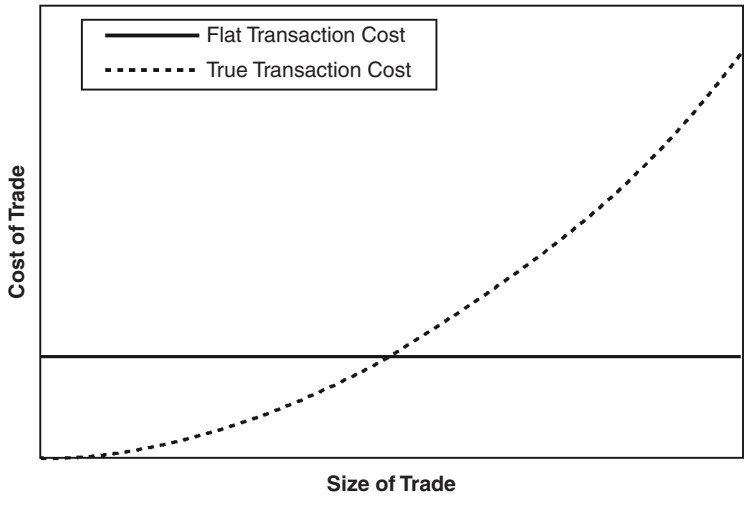


EXHIBIT 5.1 Flat Transaction Cost Function

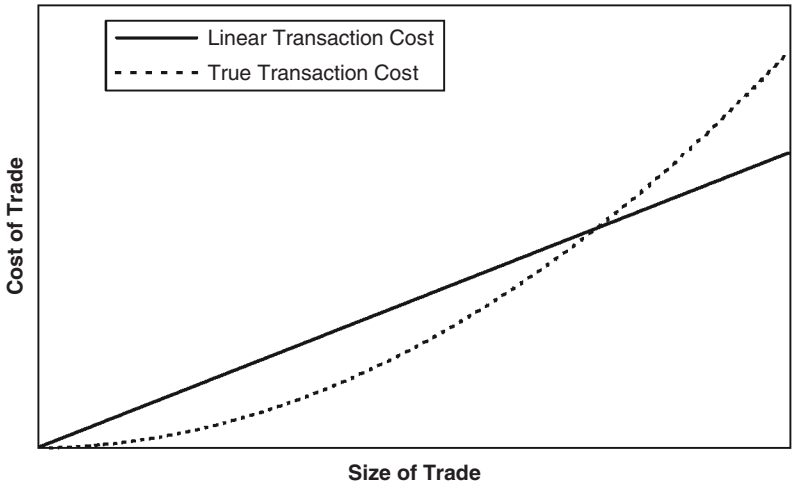


EXHIBIT 5.2 Linear Transaction Cost Function

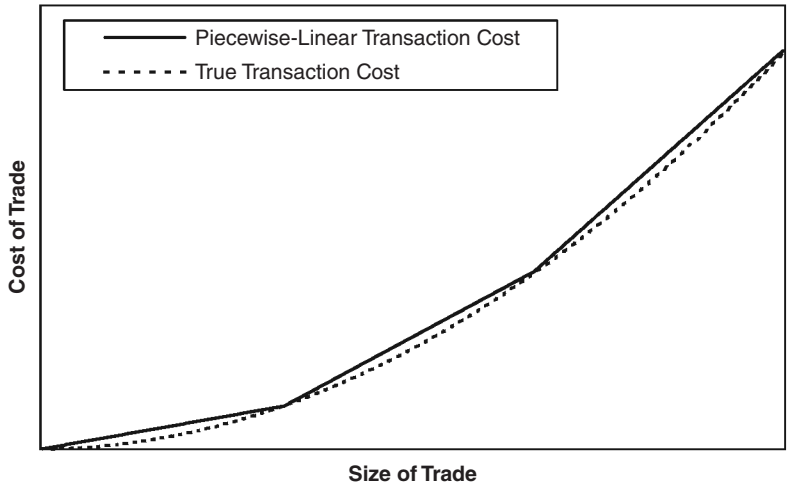


EXHIBIT 5.3 Piecewise-Linear Transaction Cost Function

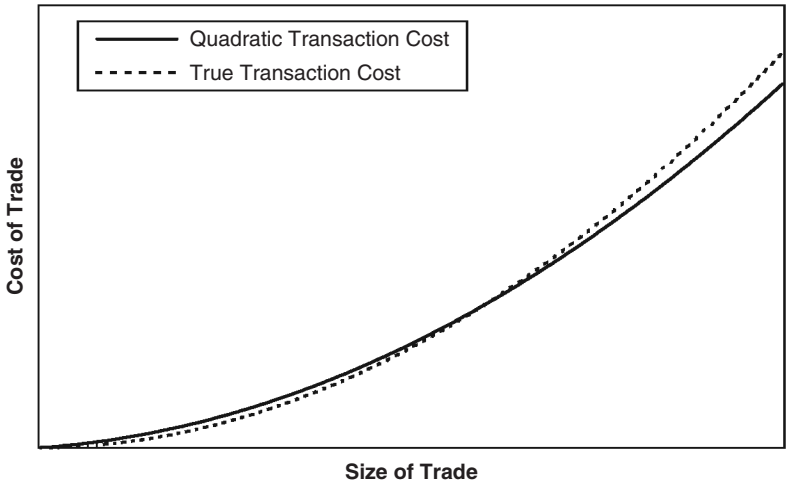


EXHIBIT 5.4 Quadratic Transaction Cost Function

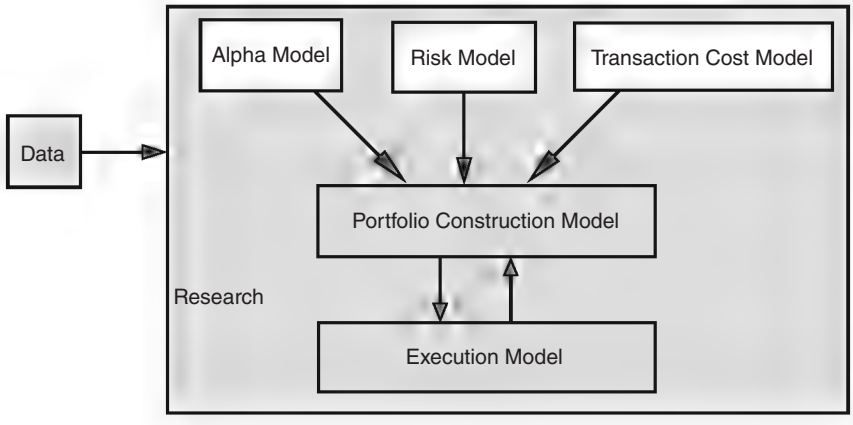


EXHIBIT 5.5 Schematic of the Black Box

EXHIBIT 6.1 A Simple Equal Risk Weighted Portfolio

	Equal Weight (%)	Volatility (%)	Volatility-Adjusted Weight (%)
GOOG	50	2.5	39
XOM	50	2.0	61

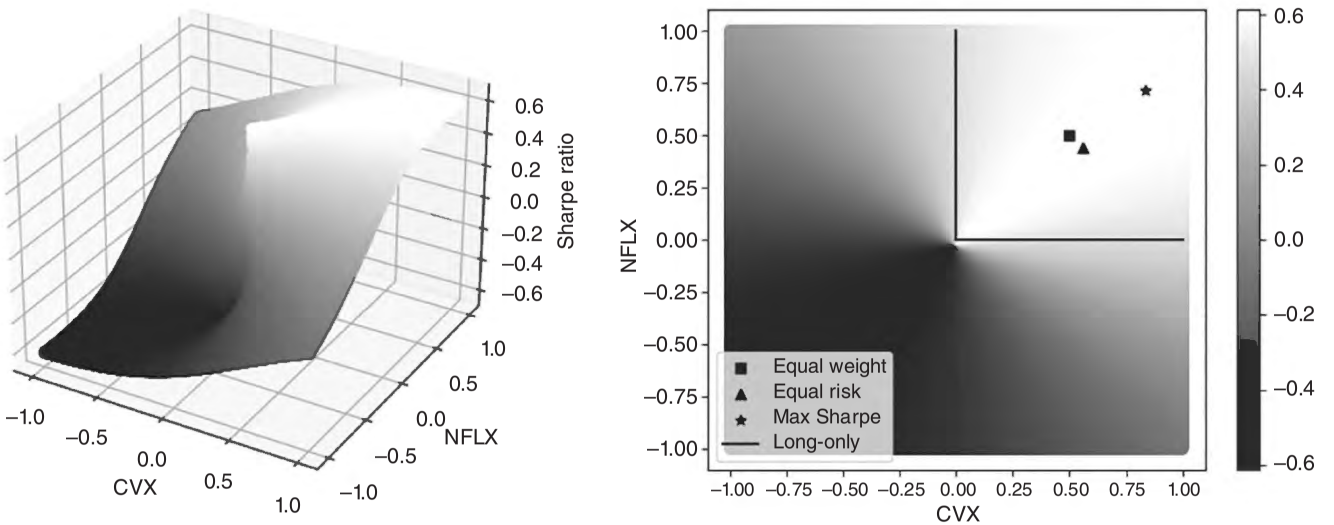


EXHIBIT 6.2 Visual Representations of the Search Space for an Optimization

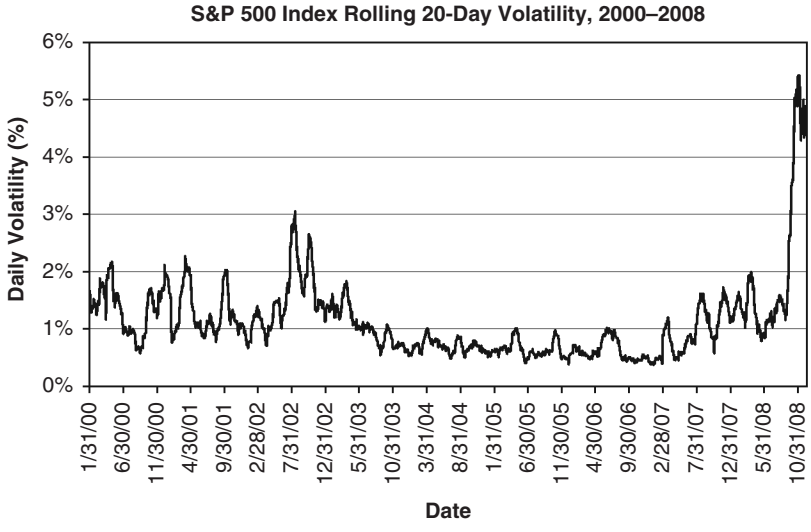


EXHIBIT 6.3 Historical S&P 500 Volatility

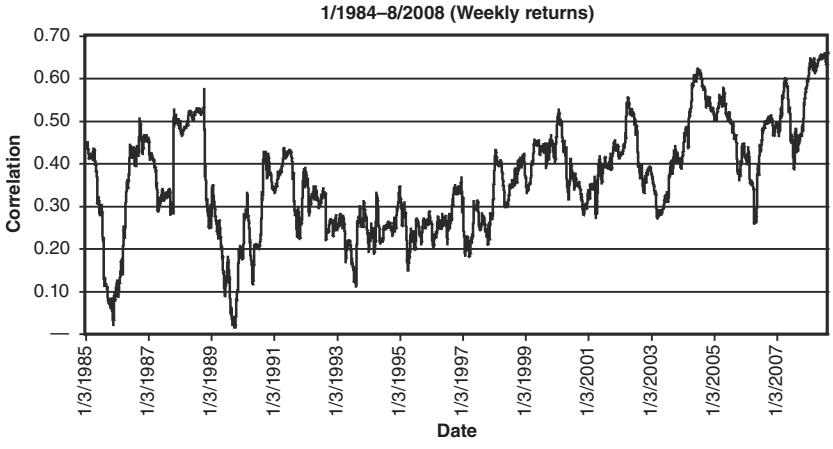


EXHIBIT 6.4 Rolling Yearly Correlation Between S&P 500 and Nikkei 225

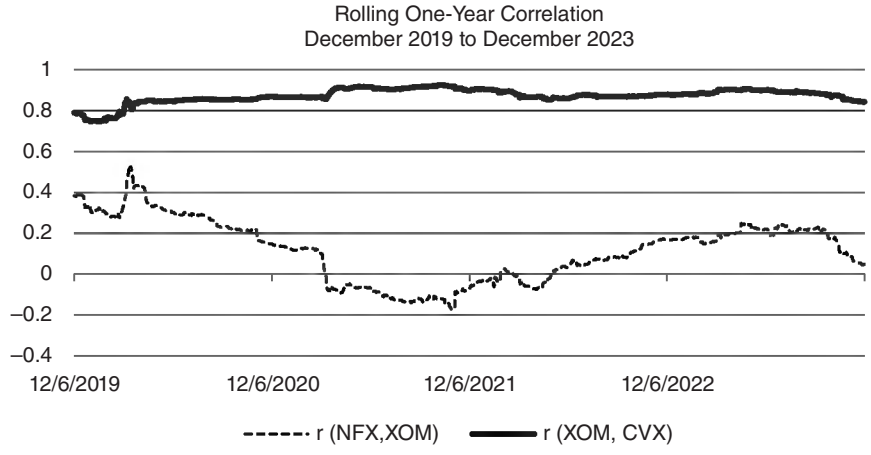


EXHIBIT 6.5 Correlation Over Time Between Similar and Dissimilar Instruments

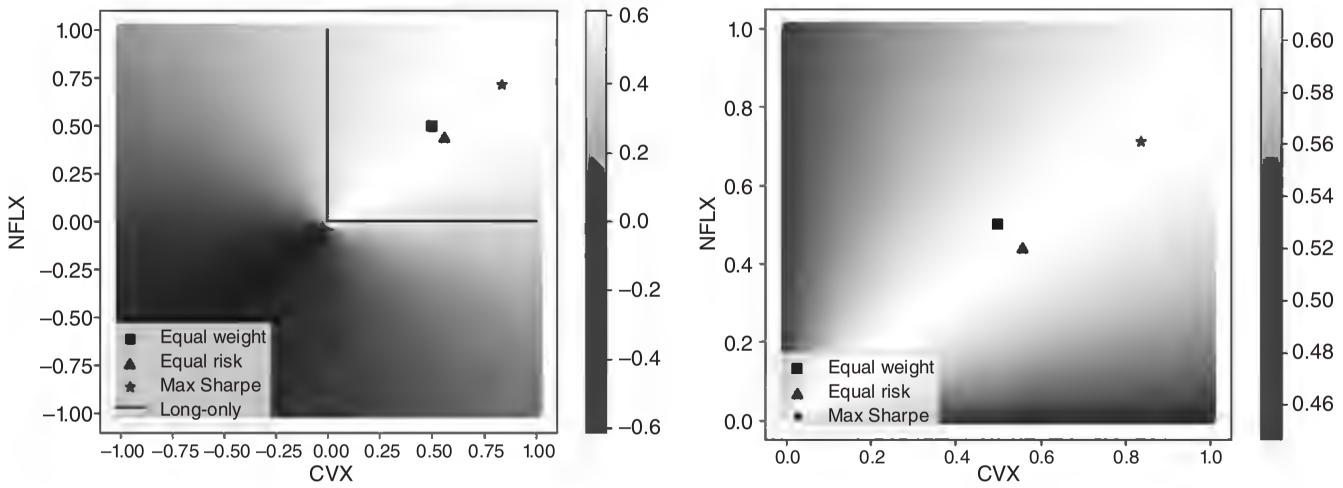


EXHIBIT 6.6 Visual Representation of Constraining the Search Space for an Optimization

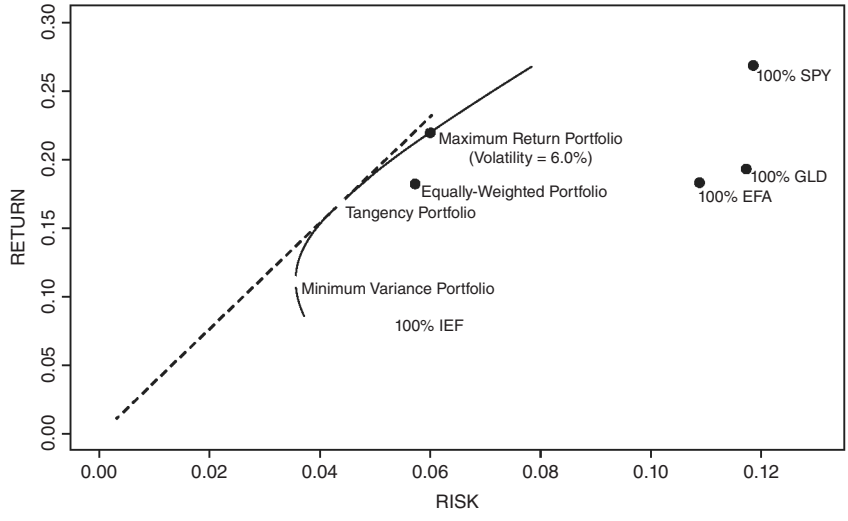


EXHIBIT 6.7 The Efficient Frontier.
Source: Adapted from Daniela Hanicova, "Markowitz Model," www.quantpedia.com/markowitz-model

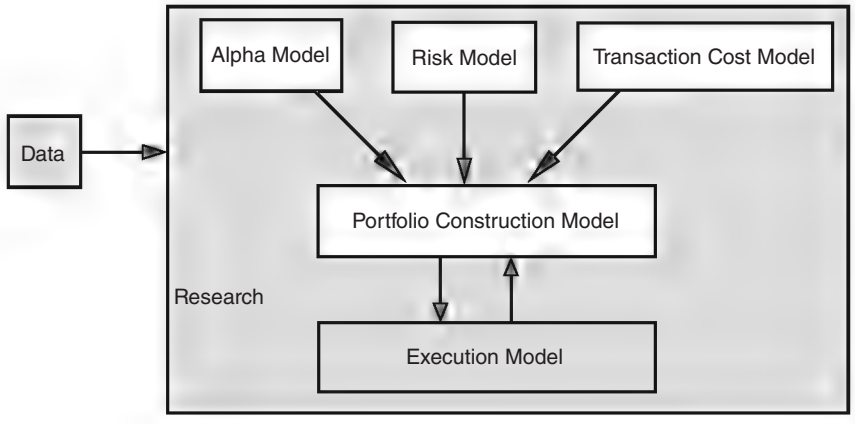


EXHIBIT 6.8 Schematic of the Black Box

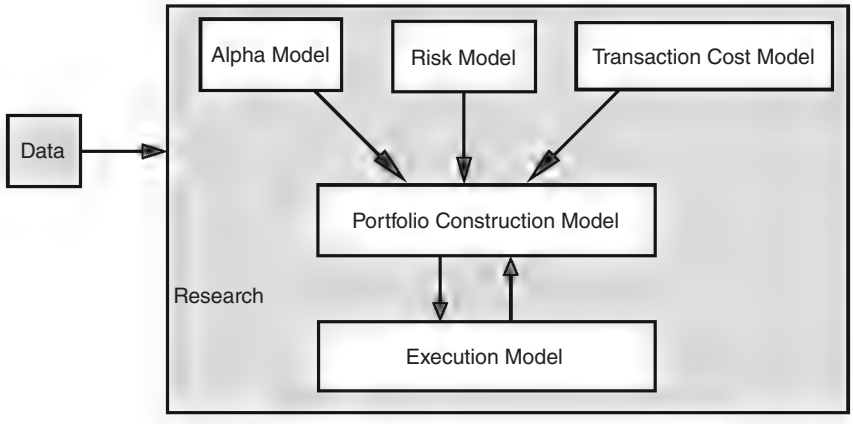
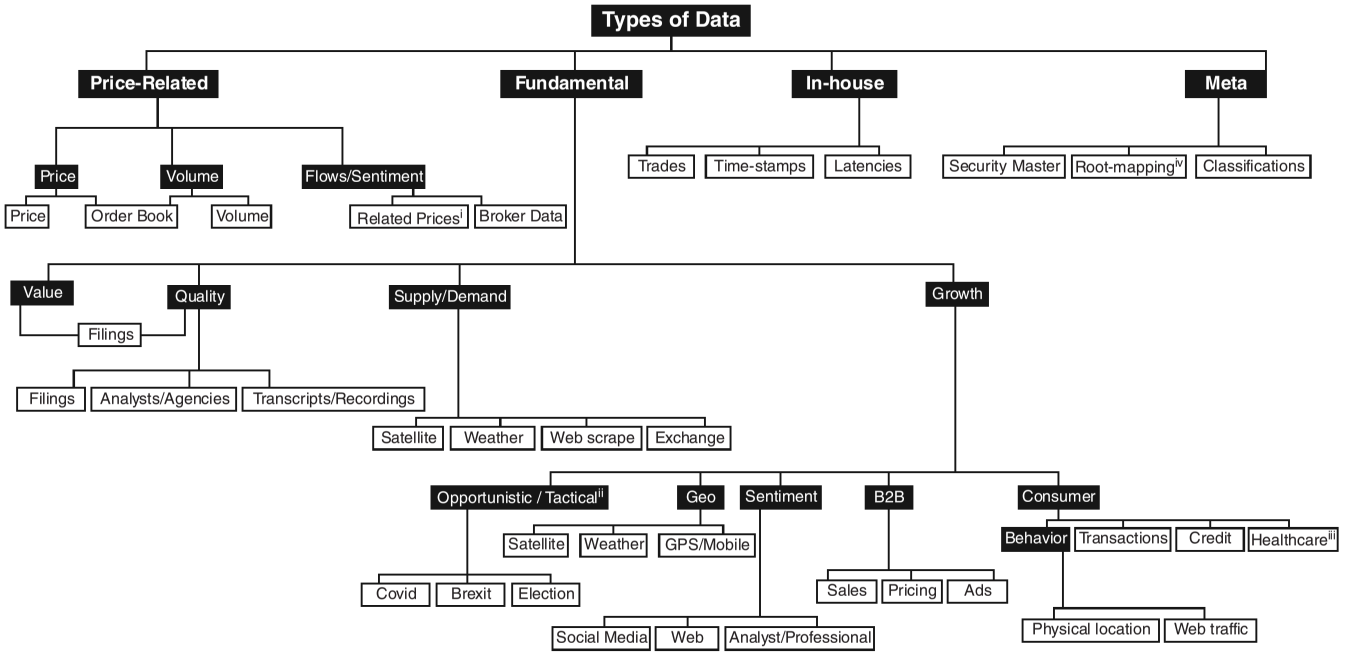


EXHIBIT 7.1 Schematic of the Black Box



legend

category
item or source

Notes

i. the prices of related instruments, for example, options on the same underlying instrument, or price action of correlated instruments.

ii. these are historical examples.

iii. healthcare data are a newer area, not really available yet, and questionably included in this category.

iv. we mean the mapping of a given instrument to the underlying asset. For example, there may be many bonds issued by a single issuer, but they all need to be mapped back to that issuer.

EXHIBIT 8.1 A Taxonomy of Data

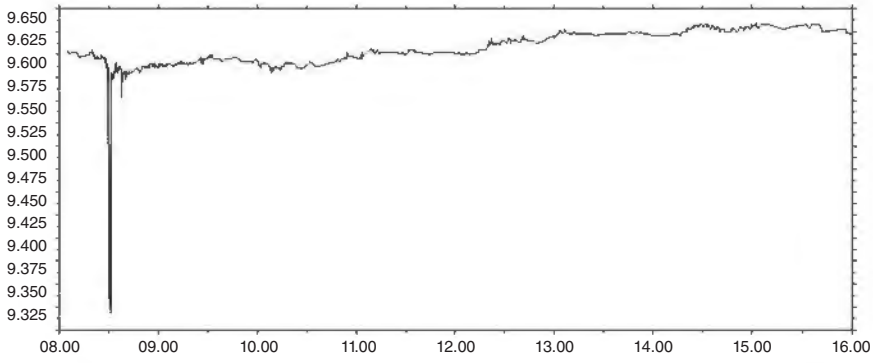


EXHIBIT 8.2 September 2008 Mexican Peso Futures Contract on July 15, 2008

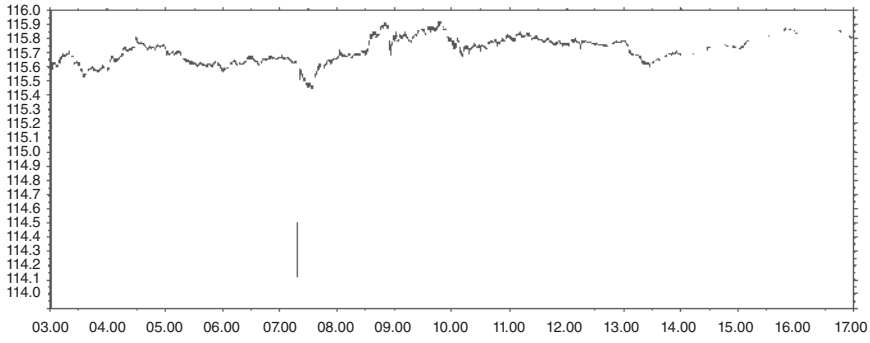


EXHIBIT 8.3 June 2008 German Bund Futures Contract on March 28, 2008

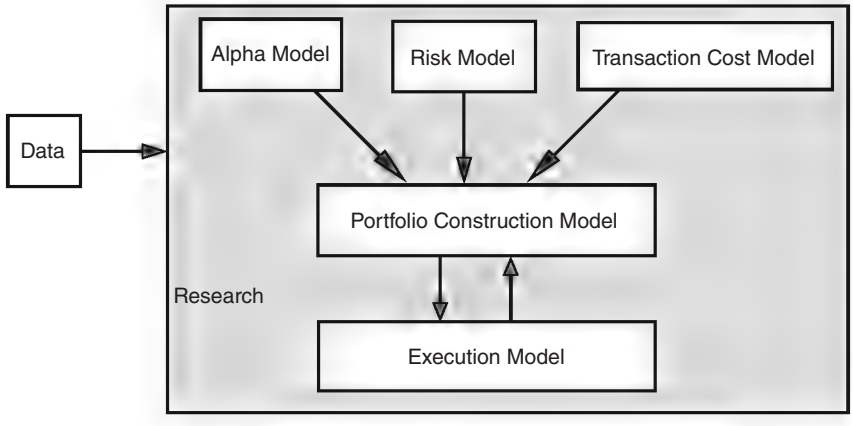


EXHIBIT 8.4 Schematic of the Black Box

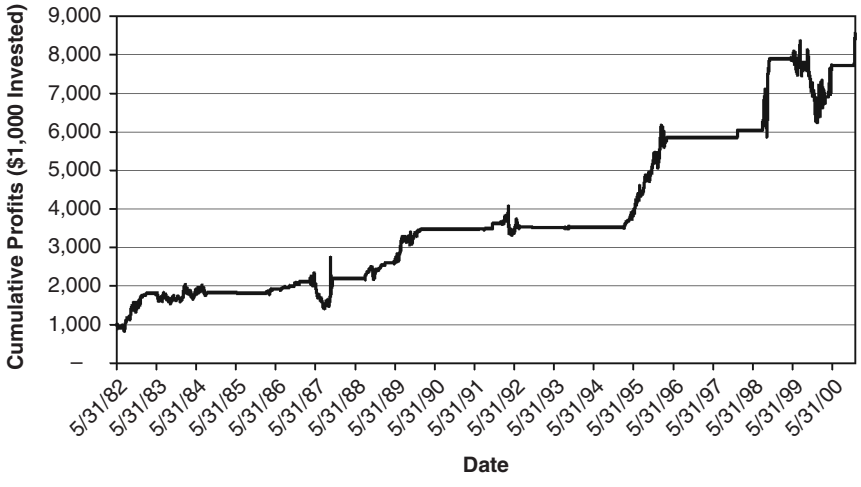


EXHIBIT 9.1 Back-Tested Cumulative Profits of the S&P 500 Strategy

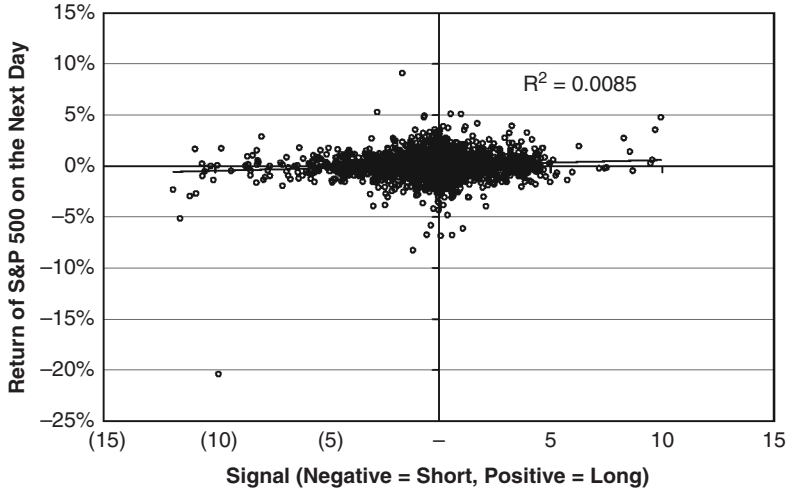


EXHIBIT 9.2 R^2 of the S&P 500 Strategy

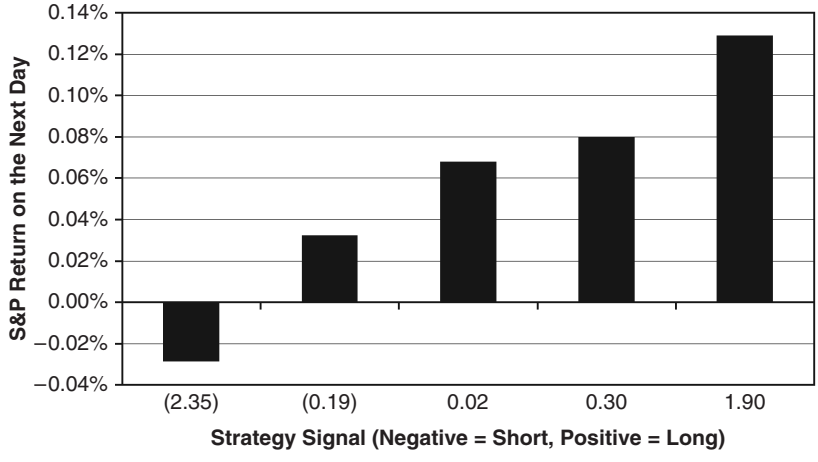


EXHIBIT 9.3 Quintile Study of S&P 500 Strategy's Signals vs. S&P 500 Returns

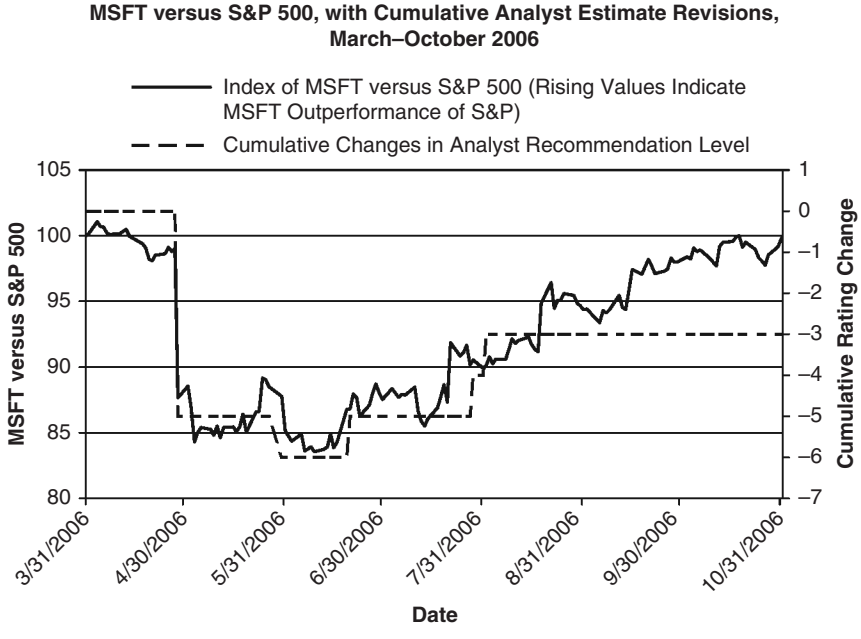


EXHIBIT 9.4 Illustration of Time Decay of Alpha

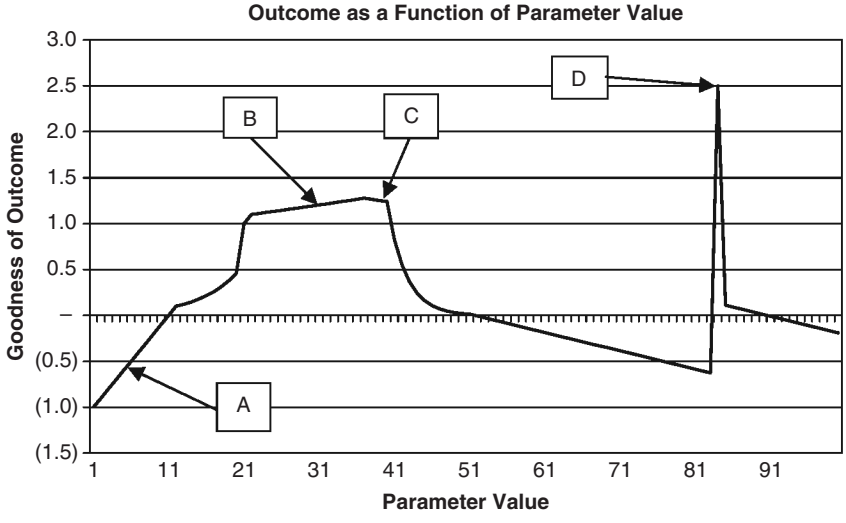


EXHIBIT 9.5 Choosing the Right Parameter Values

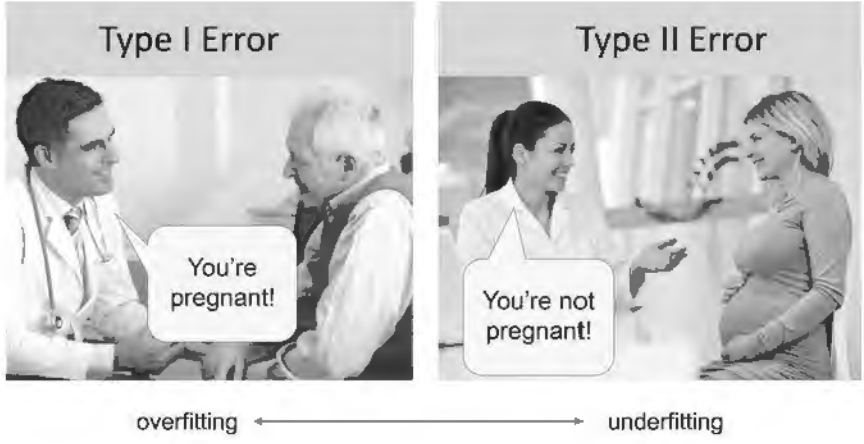


EXHIBIT 9.6 Overfitting (Type I Error) vs Underfitting (Type II Error) Images/ Shutterstock; skynesher/Getty Images

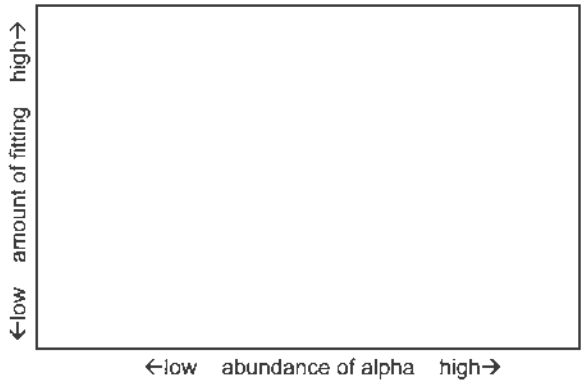


EXHIBIT 9.7 Determining the Correct Balance Between Overfitting (Type I Error) vs Underfitting (Type II Error)

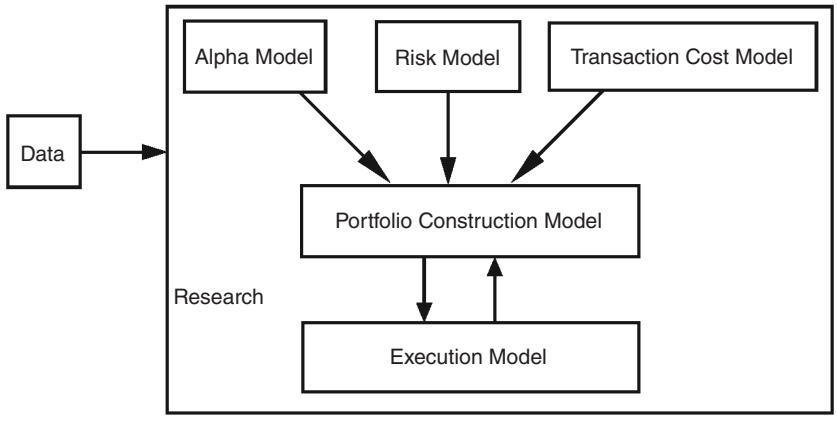


EXHIBIT 9.8 Schematic of the Black Box

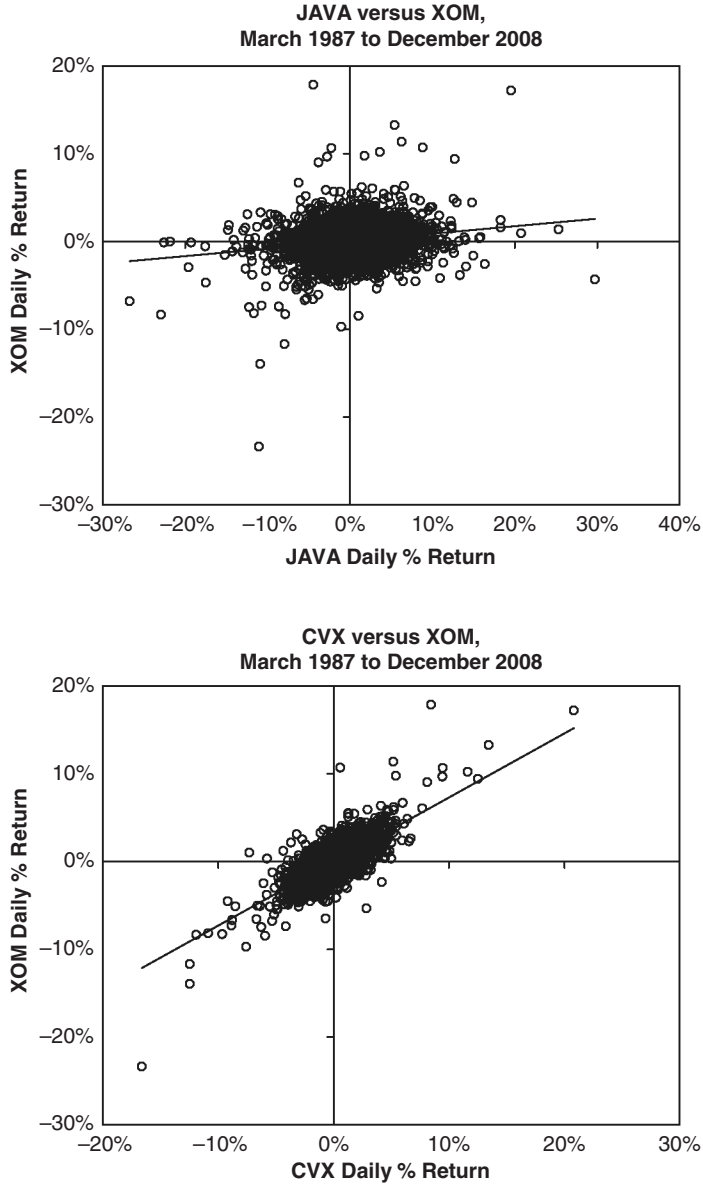


EXHIBIT 10.1 A Demonstration of Nonlinear and Linear Relationships

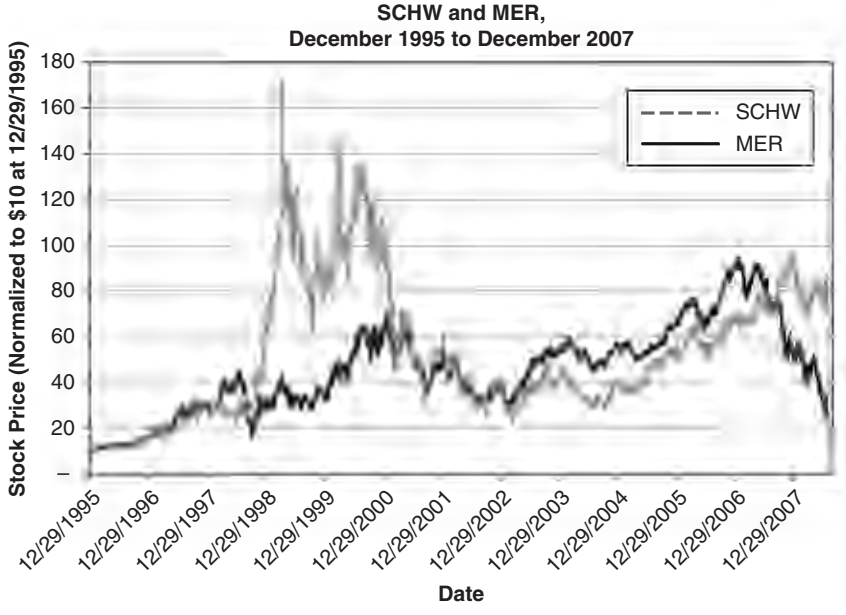


EXHIBIT 10.2 Regime Changes in a Relationship between Two Stocks

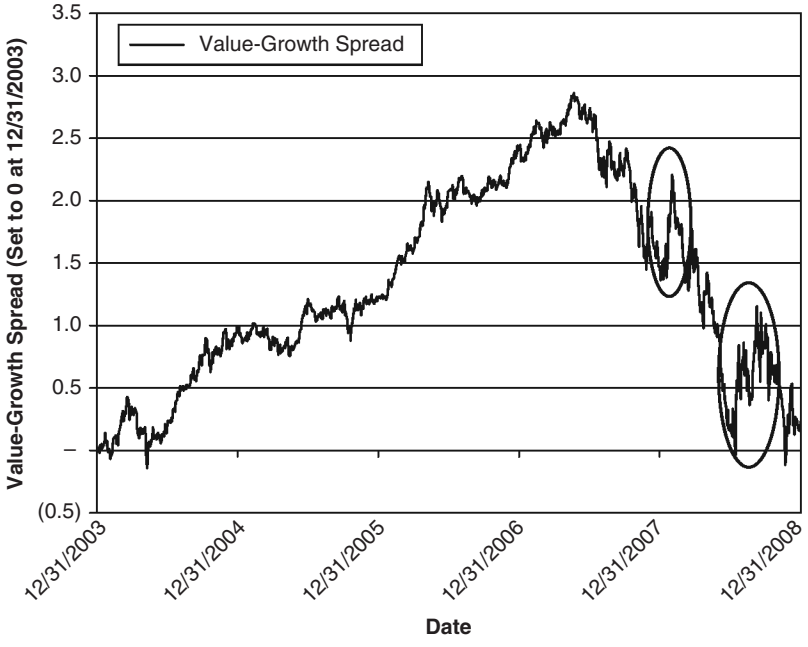


EXHIBIT 10.3 Value/Growth Spread, 2003–2008

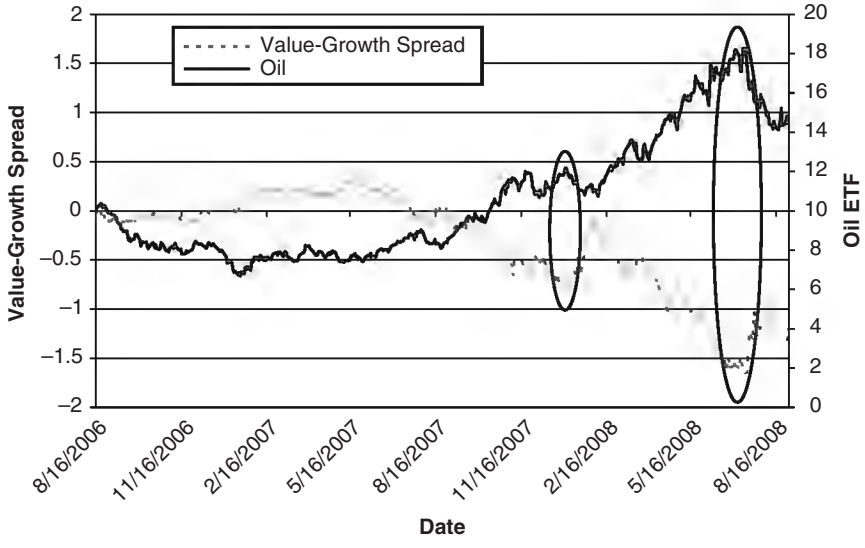


EXHIBIT 10.4 Value/Growth Spreads versus Oil Prices, Normalized to August 16, 2006

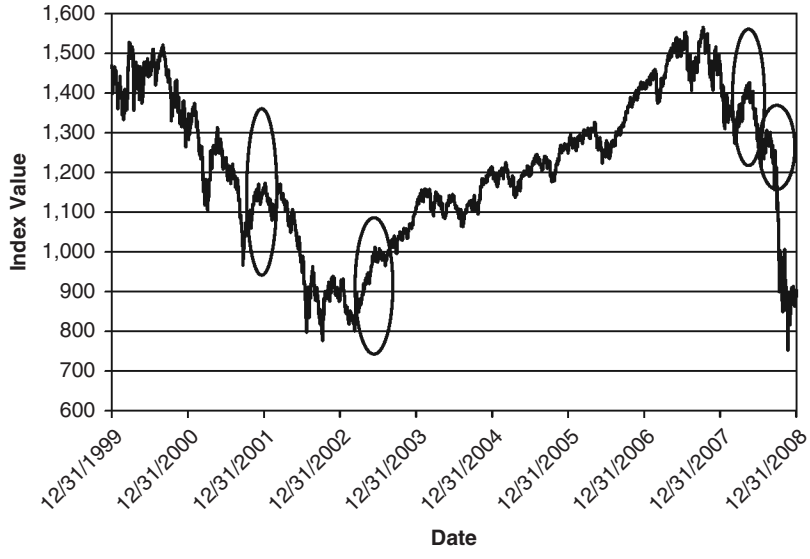


EXHIBIT 10.5 S&P 500 Price Index, December 1999–December 2008

EXHIBIT 10.6 Pulte Homes, Inc. (NYSE: PHM), May 31–August 31, 2007

PHM, Summer 2007	Price Change (%)	Average Daily Volume (millions)
May 31–July 23	–22.0	3.5
July 24–August 3	–12.5	7.2
August 6–August 9	+15.6	10.4
August 10–August 31	–22.6	5.7

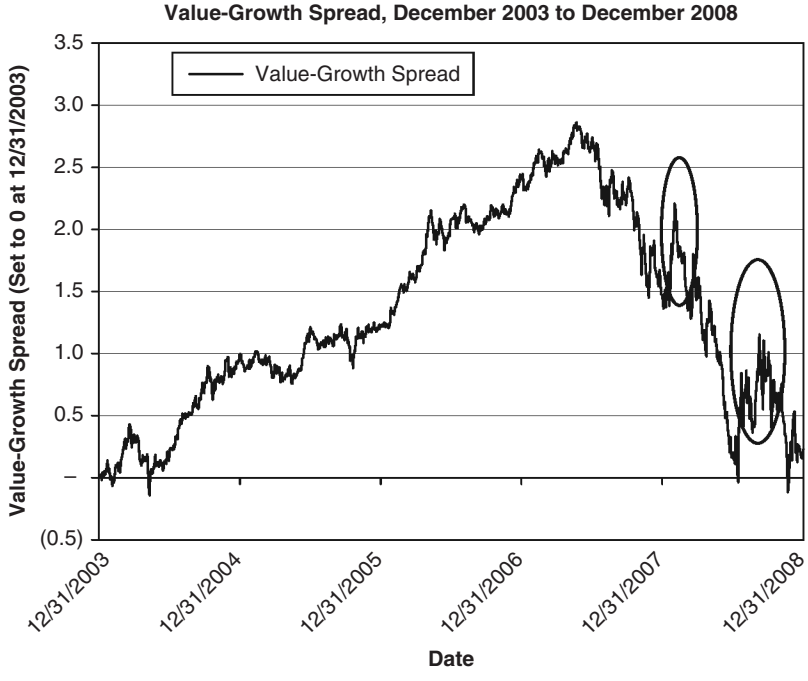


EXHIBIT 11.1 Regime Changes, as Indicated by the Value/Growth Spread

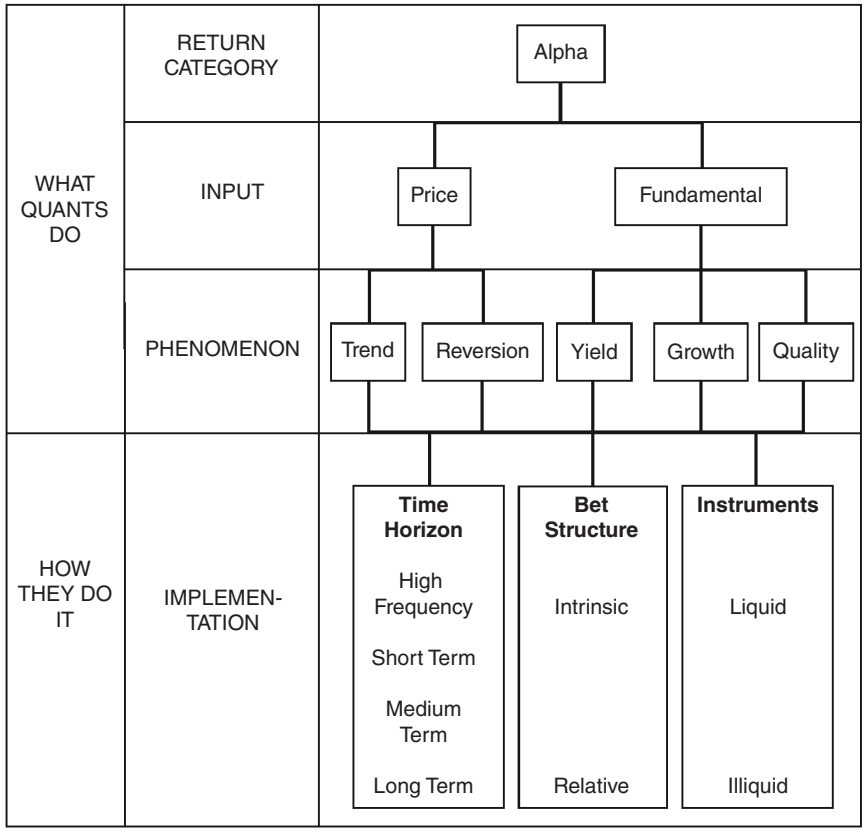


EXHIBIT 12.1 Taxonomy of Theory-Driven Alpha Strategies and Implementation Approaches

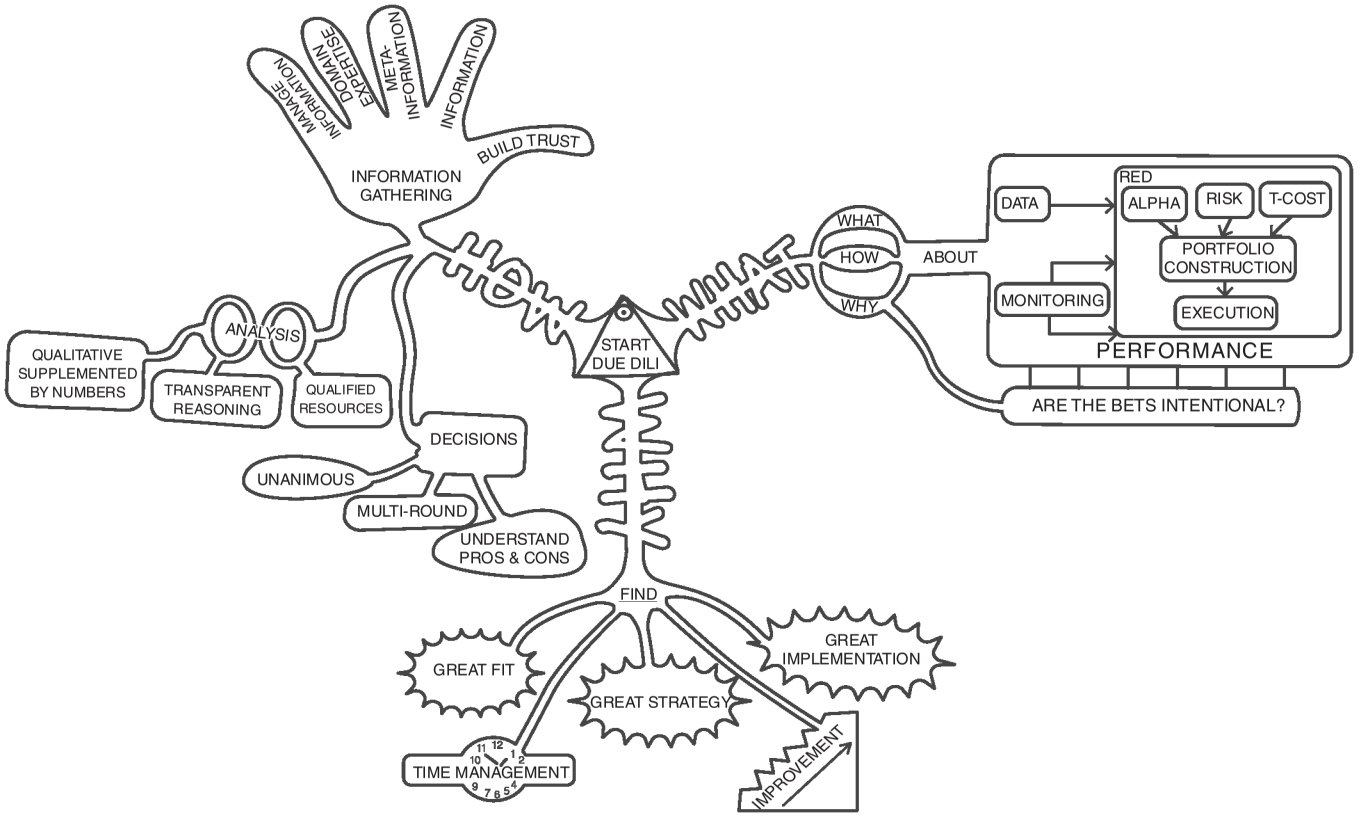


EXHIBIT 12.2 A Mind Map of the Investment Due Diligence Process

EXHIBIT 14.1 Mockup of an Order Book for a Fictitious Ticker

ID	Size	Bid	Offer	Size	ID
Bid1	55	100.00	100.01	2,000	Offer1
Bid2	1,000	100.00	100.02	2,950	Offer2
Bid3	3,100	99.99	100.02	600	Offer3
Bid4	200	99.99	100.03	300	Offer4
Bid5	5,000	99.98	100.04	1,000	Offer5

EXHIBIT 14.2 Mockup of an Order Book for a Fictitious Ticker After a Large Market Order to Buy

ID	Size	Bid	Offer	Size	ID
Bid1	55	100.00	100.02	1,950	Offer2
Bid2	1,000	100.00	100.02	600	Offer3
Bid3	3,100	99.99	100.03	300	Offer4
Bid4	200	99.99	100.04	1,000	Offer5
Bid5	5,000	99.98			

EXHIBIT 14.3 Mockup of an Order Book for a Fictitious Ticker after a Limit Order to Sell at the Bid

ID	Size	Bid	Offer	Size	ID
Bid2	55	100.00	100.02	1,950	Offer2
Bid3	3,100	99.99	100.02	600	Offer3
Bid4	200	99.99	100.03	300	Offer4
Bid5	5,000	99.98	100.04	1,000	Offer5

EXHIBIT 14.4 Mockup of an Order Book for a Fictitious Ticker after a Limit Order to Sell, which Joins the Best Offer

ID	Size	Bid	Offer	Size	ID
Bid2	55	100.00	100.02	1,950	Offer2
Bid3	3,100	99.99	100.02	600	Offer3
Bid4	200	99.99	100.02	1,000	Offer6
Bid5	5,000	99.98	100.03	300	Offer4
			100.04	1,000	Offer5

EXHIBIT 14.5 Mockup of an Order Book for a Fictitious Ticker after a Limit Order to Sell, which Improves the Best Offer

ID	Size	Bid	Offer	Size	ID
Bid2	55	100.00	100.01	2,000	Offer7
Bid3	3,100	99.99	100.02	1,950	Offer2
Bid4	200	99.99	100.02	600	Offer3
Bid5	5,000	99.98	100.02	1,000	Offer6
			100.03	300	Offer4
			100.04	1,000	Offer5

EXHIBIT 14.6 Mockup of an Order Book for a Fictitious Ticker

ID	Size	Bid	Offer	Size	ID
Bid1	3,100	99.99	100.01	2,000	Offer1
Bid2	200	99.99	100.02	2,950	Offer2
Bid3	5,000	99.98	100.02	600	Offer3
			100.03	300	Offer4
			100.04	1,000	Offer5

EXHIBIT 14.7 Mockup of an Order Book for a Fictitious Ticker with Additional Bids

ID	Size	Bid	Offer	Size	ID
Bid4	1,000	100.00	100.01	2,000	Offer1
Bid5	6,000	100.00	100.02	2,950	Offer2
Bid1	3,100	99.99	100.02	600	Offer3
Bid2	200	99.99	100.03	300	Offer4
Bid3	5,000	99.98	100.04	1,000	Offer5

EXHIBIT 14.8 Mockup of an Order Book for a Fictitious Ticker After 1,000 Shares Have Been Removed from the Bid

ID	Size	Bid	Offer	Size	ID
Bid5	6,000	100.00	100.01	2,000	Offer1
Bid1	3,100	99.99	100.02	2,950	Offer2
Bid2	200	99.99	100.02	600	Offer3
Bid3	5,000	99.98	100.03	300	Offer4
			100.04	1,000	Offer5

EXHIBIT 14.9 Mockup of an Order Book for a Fictitious Ticker after All $100.00 Shares Have Been Removed from the Bid

ID	Size	Bid	Offer	Size	ID
Bid1	3,100	99.99	100.00	2,000	Offer6
Bid2	200	99.99	100.01	2,000	Offer1
Bid3	5,000	99.98	100.02	2,950	Offer2
			100.02	600	Offer3
			100.03	300	Offer4
			100.04	1,000	Offer5

EXHIBIT 14.10 Mockup of an Order Book for a Fictitious Ticker After Two 2,000 Share Bids at $100.01

ID	Size	Bid	Offer	Size	ID
Bid4	2,000	100.01	100.02	2,950	Offer2
Bid1	3,100	99.99	100.02	600	Offer3
Bid2	200	99.99	100.03	300	Offer4
Bid3	5,000	99.98	100.04	1,000	Offer5

EXHIBIT 14.11 Breakdown of Messages at Various Intervals and Percentiles for EBAY on July 20, 2012

	50th Percentile	99th Percentile	99.9th Percentile	99.99th Percentile	99.999th Percentile
1 second	13	259	546	1755	4179
100 milliseconds	0	13	84	863	1306
10 milliseconds	0	1	7	269	557
1 millisecond	0	0	1	56	106

EXHIBIT 15.1 Mockup of an Order Book for a Fictitious Ticker

ID	Size	Bid	Offer	Size	ID
Bid1	1,000	100.00	100.01	2,000	Offer1
Bid2	3,100	99.99	100.02	3,000	Offer2
Bid3	2,000	99.99	100.02	1,000	Offer3
Bid4	5,000	99.98	100.03	4,000	Offer4
Bid5	6,000	99.97	100.04	1,000	Offer5

EXHIBIT 15.2 Mockup of an Order Book for a Fictitious Ticker after a Market Order to Buy 10,000 Shares Is Mostly Filled by a CMM Acting as an Agent of the Customer

ID	Size	Bid	Offer	Size	ID
Bid1	1,000	100.00	100.03	500	Offer4
Bid2	3,100	99.99	100.04	1,000	Offer5
Bid3	2,000	99.99			
Bid4	5,000	99.98			
Bid5	6,000	99.97			

EXHIBIT A.1 Average Price Movement in SPY (%)

	2000–2006	2007–2012	% Difference
close:close	0.84	1.03	+23
open:close (intraday)	0.76	0.82	+8
close:open (overnight)	0.37	0.59	+59
high:low	1.47	1.72	+17

EXHIBIT A.2 Median Price Movement in SPY (%)

	2000–2006	2007–2012	% Difference
close:close	0.62	0.67	+8
open:close (intraday)	0.55	0.53	−3
close:open (overnight)	0.26	0.39	+51
high:low	1.26	1.33	+5

EXHIBIT A.3 Frequency of 3% or Greater Moves in SPY (%)

	2000–2006	2007–2012	% Difference
close:close	2.56	5.87	+129
open:close (intraday)	1.53	2.69	+75
close:open (overnight)	0.11	0.83	+629
high:low	6.20	10.91	+76

EXHIBIT A.4 Frequency of 4% or Greater Moves in the SPY (%)

	2000–2006	2007–2012	% Difference
close:close	0.68	2.97	+335
open:close (intraday)	0.28	1.38	+386
close:open (overnight)	0.11	0.48	+325
high:low	1.65	5.73	+248