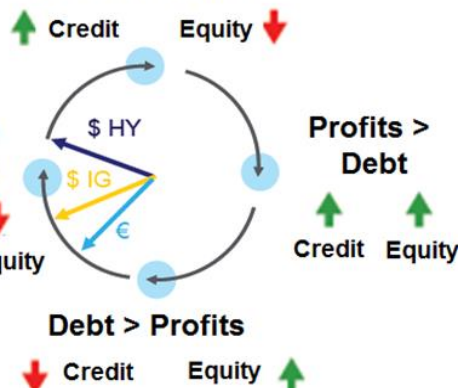


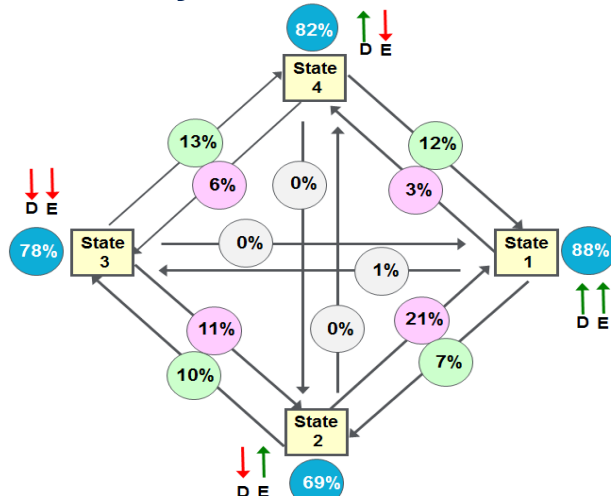
## The Leverage Cycle Clock

Debt Reduction

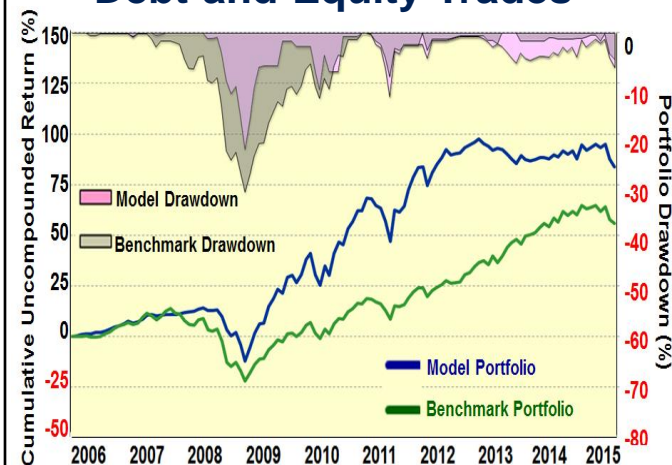


Jan-16

## Monthly State Transitions



## Returns and Draw-Downs on Debt-and-Equity Trades



March 7, 2016

# Understanding the Credit Cycle: Modeling the Debt/Equity Return Cycle for Fun and Profit

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- 1. Introduction and Background**
  2. The Leverage Clock and Regime Switching Model
  3. Quantifying the Debt-Equity Credit Cycle
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# Objectives

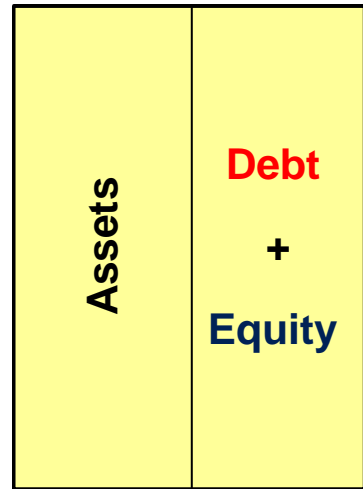
The purpose of this report is to understand and model the dynamics of divergence between equity and debt market returns and develop a model to predict those returns.

- In the first portion of the presentation, we seek to understand the theoretical basis for the divergence between equity and debt returns
  - We begin by describing the corporate leverage cycle which has been hypothesized to drive divergences between equity and debt returns
  - We next present analyses of risk premia in the equity and debt markets as they relate to the corporate leverage cycle
  - The section concludes with a brief description of regime switching models that have been proposed to describe equity and debt market dynamics
- An important part of the presentation is the identification assignment of historical periods to states (i.e., regimes) in the corporate leverage cycle
  - We do this by analyzing one-year forward equity and debt returns each month from 1976 to 2014
  - This enables us to compute transition probabilities among regime states in the corporate leverage cycle
  - It also provides us with values of the dependent variable for a predictive model of regime state changes
- The final section describes a “walk-forward” model based on a set of macro economic and market variables that we use to generate a multinomial conditional state transition model
  - We evaluate the out-of-sample performance of the model relative to a fixed portfolio of 60% equity and 40% debt over the period from 2006 through mid-2014

# Debt ↔ Equity Relationship – The Theory

Miller-Modigliani, Black-Scholes, and Merton have laid the theoretical foundations for the relationship between firms' equity and debt.

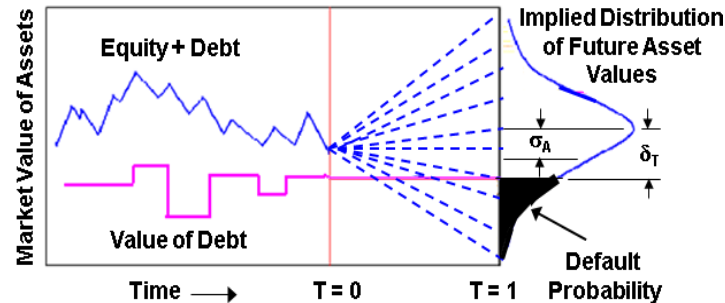
## Miller-Modigliani Theorem



Projects that add to the firm's value must be financed either by equity or debt

Investors and managers should be indifferent to financing via equity or debt

## Black-Scholes Option Pricing Theory



**Black & Scholes (1973)** suggested that their option pricing formula might be useful for pricing of corporate liabilities

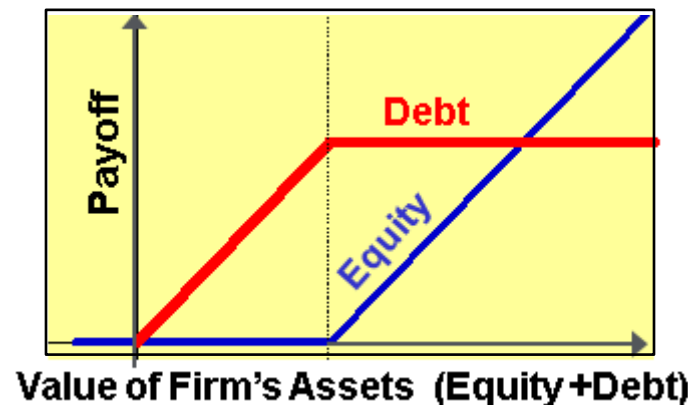
$$C = SN(x) - Ke^{-rt}N(x - \sigma\sqrt{t})$$

$$x \equiv \frac{\log(S / Ke^{-rt})}{\sigma\sqrt{t}} + \frac{1}{2}\sigma\sqrt{t}$$

## Merton's Theory of the Debt/Equity Relationship

Merton (1974) modeled the owner of a corporate bond as short a put on the underlying value of the firm

Equity investors, are long a call on the assets of the firm and profit as its value rises



Merton's insight was that the value of the firm's assets and asset volatility can be estimated from equity prices

If so, methods derived from options theory can be used to value a firm's debt

# Returns on Corporate Debt and Equity

Although theory suggests that equity and debt returns ought to be correlated, and they often are, returns on firms' bonds and stock often diverge for long periods of time.

- The relationship between firms' debt and equity as formulated by Miller-Modigliani and Black-Sholes-Merton imply a fairly strong relationship between equity and debt returns
- Indeed, long-term Sharpe ratios are similar for equity and debt markets (see table on right)
  - However, this is more a consequence of Sharpe's theory than the debt-equity relationship
  - In fact, Sharpe ratios across all major asset classes are roughly similar at 0.5
- Although directional annual returns from equity and debt markets are similar 14 of 20 years tested (i.e. 70%), they often diverge (see middle panel)
- The correlation between equity and debt market annual returns is not high (at  $R=20\%$  and  $R^2=4\%$ )
  - That relation is not significant over the 20 years tested (P-Value = 38% by chance)

## Sharpe-Ratios Across Major Asset Classes (From Hale et al., 2014)

Asset Class	Period From	Sharpe Ratio
US IG Corporate Bonds	Jul-80	0.51
US HY Corporate Bonds	Jun-89	0.53
World Broad IG Government	Jun-99	0.51
ESBI Global EM Sovereign Index	Jun-96	0.68
US Government Bonds	Aug-80	0.53
Case-Shiller US House Price	Jan-45	0.39
S&P 500 Equity Index	Aug-80	0.52
CDX Main OTR	Nov-03	0.40

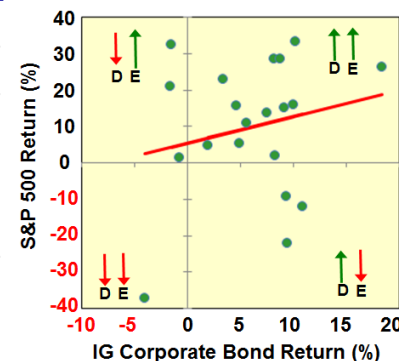
## Annual Returns from Equity and Investment-Grade Corporate Debt



## Correlation: Equity and Debt Returns

### Regression Summary

Multiple R = 20.9%  
 $R^2 = 4.3\%$   
 P-Value = 0.38  
 $R_E = 0.55\% + (0.73 * R_D)$



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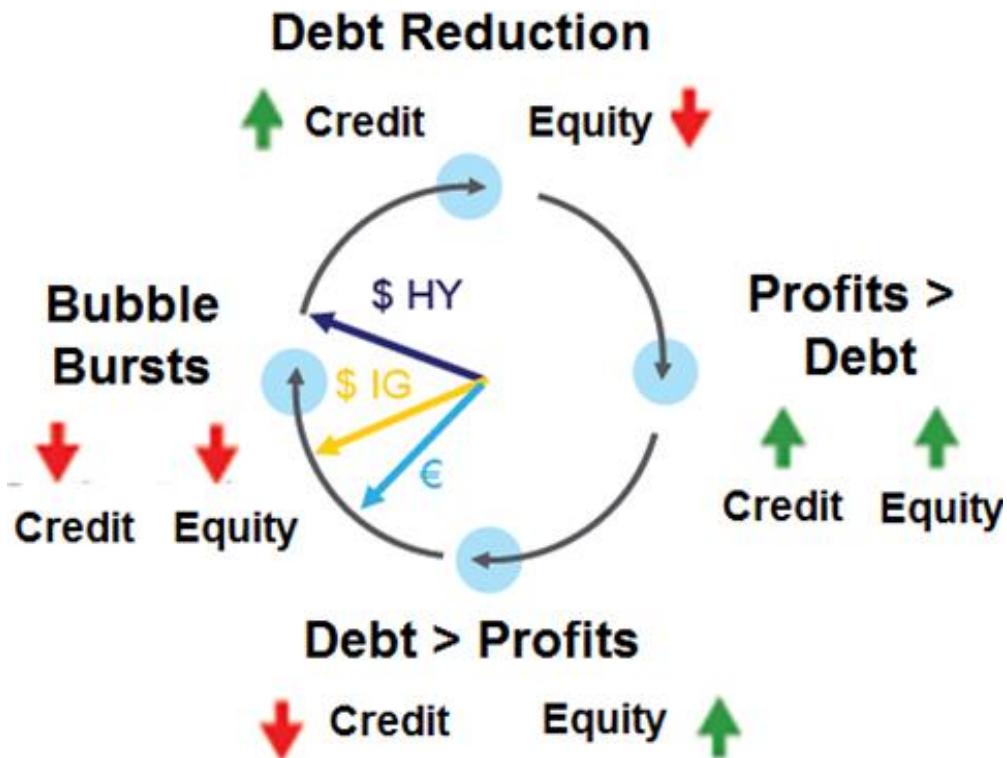
# The Leverage Clock – Equity/Debt Divergence

The Modigliani-Miller and Black-Scholes-Merton formulations provide the theoretical foundations for the leverage cycle relations between equity and debt market returns.

## The Corporate Leverage Cycle

- The Merton model assumes that the debt and equity risk premiums are perfectly correlated
- Matt King proposes that equity and debt risk premiums are only correlated in two parts of the credit cycle
  - Both are positive when profits are rising faster than debt
  - When debt grows faster than profits, credit declines while equity rallies
  - Both are negative when overleveraged firms become unprofitable
  - Credit rallies when debt decreases, but equities decline amid poor profitability

## The Credit Cycle Clock – Jan 2016



Source: King, M. *I'll Buy (Only) if You Will*, Citi, January 2016

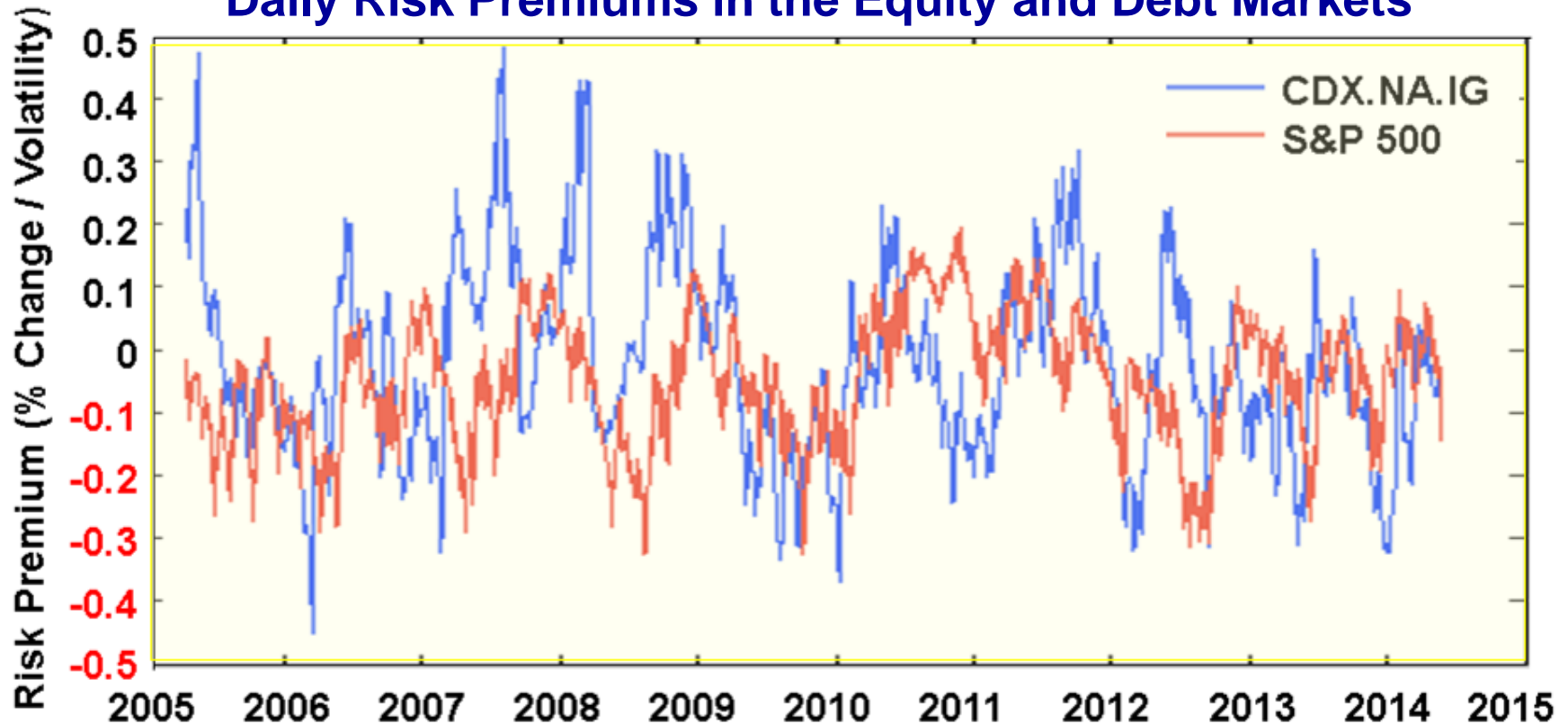


# Equity and Debt Market Risk Premiums

We calculated the time-series of levels and differences of the risk premiums for the S&P 500 and that for the investment-grade CDS index (CDX.NA.IG).

- For both the equity and debt markets, we calculated the risk premiums as the percent daily returns over their trailing volatilities
- Although there appears to be some positive relationship between equity and debt risk premiums, there are large deviations at times

## Daily Risk Premiums in the Equity and Debt Markets



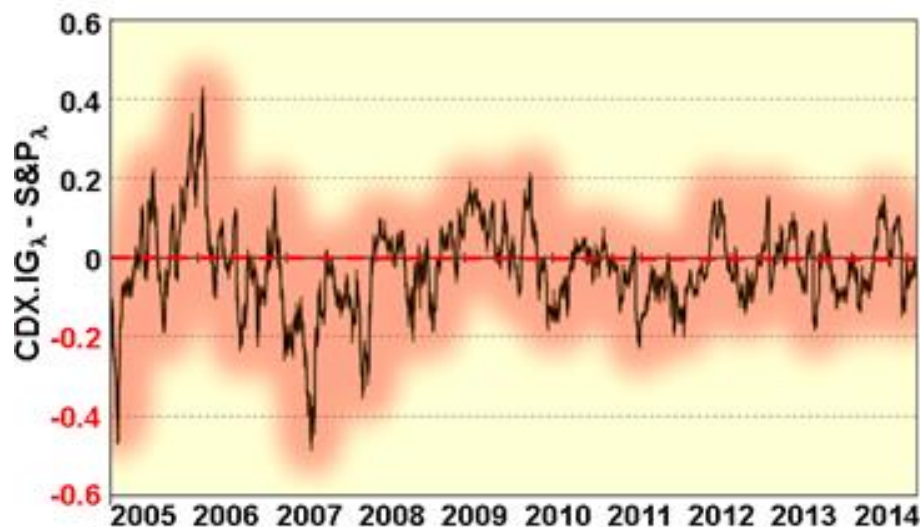


# Evidence for the Leverage Clock

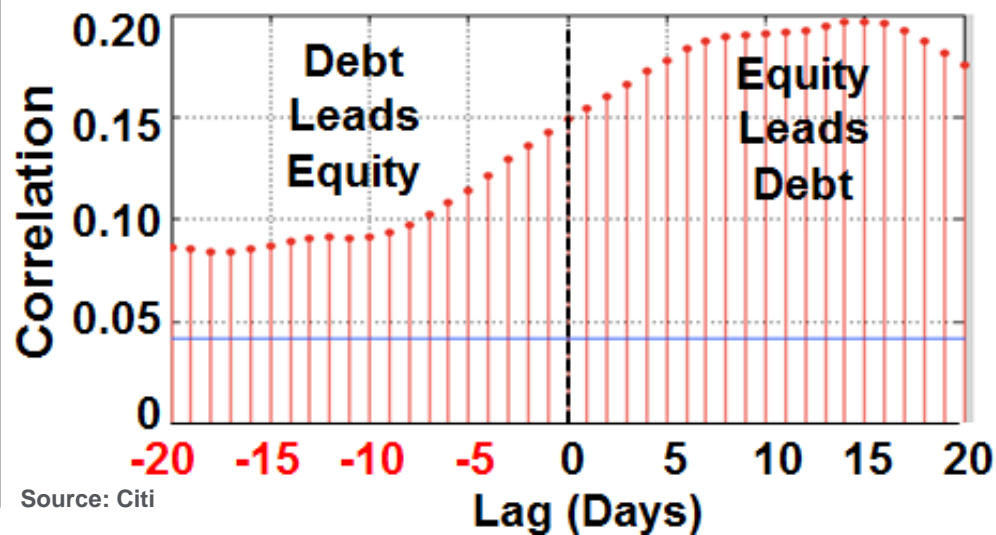
Analysis of the pattern of daily equity and debt risk premiums indicate that they diverge over the credit cycle and, when coincident, the equity market leads by about 15 days.

- Differences in risk premiums between the US credit default swap index (CDX.NA.IG) and the S&P 500 equity index:
  - Differences exhibit longer-term (on the order of 2-3 years) cyclicity with short term divergences superimposed
- The lower plot shows lagged correlations between risk-adjusted returns in equity and debt markets
  - Although the daily return correlations are not high, the largest correlations of roughly 0.20 are for the equity market leading the bond market by 10-15 days

## CDS Minus Equity Risk Premiums



## Cross-Correlation Equity vs Debt



Source: Citi

# The Regime Switching Model – Some Precedents

Several theorists have attempted to apply regime-switching models to the debt-equity return cycle, but none have proven satisfactory.

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- The perspective underlying regime-switching models is that the real economy follows some latent process that jumps over time and we can use observed economic variables to approximate these shifts
- The regime switching concept is not new and its formulation has seen improvement over time, but none have proven satisfactory for modeling the debt-equity return cycle
  - Hamilton (1989) describes a model for the U.S. GNP, which uses the regime-switching structure
    - Hamilton's version was a state-switching ARMA model where the auto-regressive parameters could change depending on the state
    - Hamilton assumes that the underlying economic states are unobservable so the process must be estimated through an algorithm that he defines
    - In addition, the model had to be simplified owing to a relative lack of computational power at that time
  - Diebold (1994) introduced a time-varying component to the transition probability matrix
    - Previous models had a constant probability transformation matrix that did not see the transition probabilities as endogenous
    - Diebold uses a logistic model to transform the explanatory variables of the state-switching probabilities
  - Nielson (2014) introduced a model that divides equity cycle into 4 distinct phases—despair, hope, growth, optimism
    - Although these states do not perfectly coincide with the ones used in our model, they do paint a broad picture of the equity cycle
    - The framework describes the relationship between earnings growth and price performance as it changes over the cycle by analyzing the economic context and the drivers of stock market return for each phase.
    - The model we propose uses similar equity variables but adds measures of aggregate leverage

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Hamilton, J. *A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle*, *ECONOMETRICA* 56 (2), 357-384, 1989

Diebold, F., Lee, J., & Weinbach, G. *Regime Switching with Time-Varying Transition Probabilities*, C. Hargreaves (ed.), *NONSTATIONARY TIME SERIES ANALYSIS AND COINTEGRATION*, 283-302, 1994

Nielson, A. *Hide and Seek: Profiting by Finding Hidden States of Financial Markets in Real Time*. Global Strategy Paper, 14, 2014

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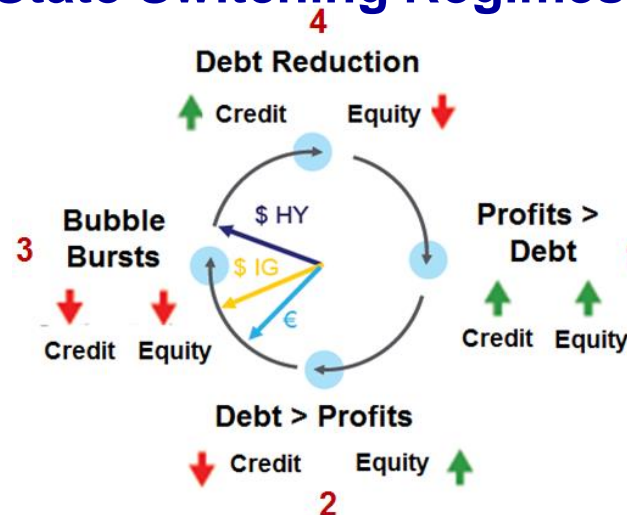
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# Quantifying the Debt-Equity Return Cycle

In order to derive predictive models of the debt-equity return cycle, it is necessary to determine the historical relationship between credit-equity states over time.

- We assign each month from Jan-76 until Jul-14 to regimes 1 to 4 based on subsequent one-year returns on equity and debt
  - Proxy for the debt market returns: Barclays US Aggregate Bond Index (LBSTRUU)
  - Proxy for the Equity Market: S&P 500 (SPX)
- The idea is to use historical monthly one-year returns on equity and debt to back out the implied state one year prior
  - For example, if for a given month, the next year's excess equity and debt returns are both positive, we assign that month to credit state 1
  - Conversely, if excess returns from both debt and equity are negative, state 3 is assigned to that month
  - States 2 and 4 are assigned to positive equity negative debt and vice versa, respectively
- Once we have assigned credit cycle states to each month, we use data up until that month to predict that state in order to predict subsequent equity and debt returns

## State Switching Regimes



## State Definition

State	Equity Market	Debt Market
1	Up	Up
2	Up	Down
3	Down	Down
4	Down	Up

## Example

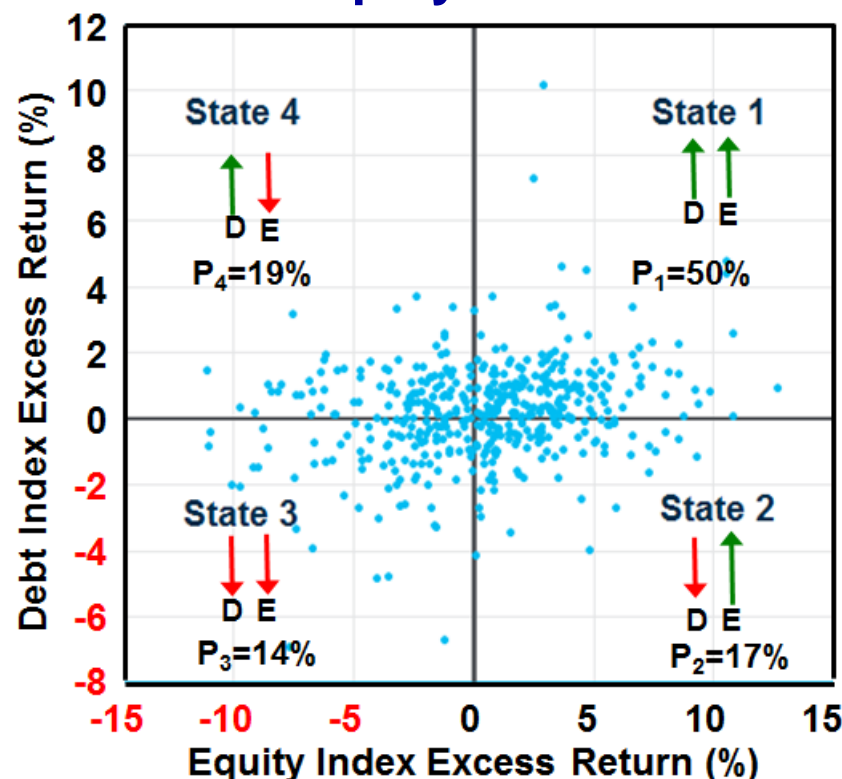
Date	SP 500 Level	Bar Cap Level	State
1/31/11	1,286.12	1,643.01	1
...	...	...	...
1/31/12	1,312.41	1,785.33	...

# Measuring Historical Regime Switching

Each month, we determine subsequent one-year equity and debt market returns and assign that month to credit cycle states 1-4 and, from those, calculate monthly state transitions.

- The top panel plots monthly one-year equity and debt risk adjusted returns for each month from Jan-76 until Jun-14
- Each monthly pair of one-year equity and debt returns can be assigned to regime states 1 to 4
  - Historical probabilities ( $P_1$ - $P_4$ ) of being in each state are also shown
  - For example, the probability of positive 1-year returns in both equity and debt markets is highest at 50%
- Probabilities of transitioning between states can be derived from monthly state assignments
- The lower table shows historical probabilities of monthly transitions among credit cycle states
  - For example, the monthly probability of transitioning from State 1 to State 2 is 7.3%

## Bond and Equity Excess Returns



## Historical State Switching Matrix

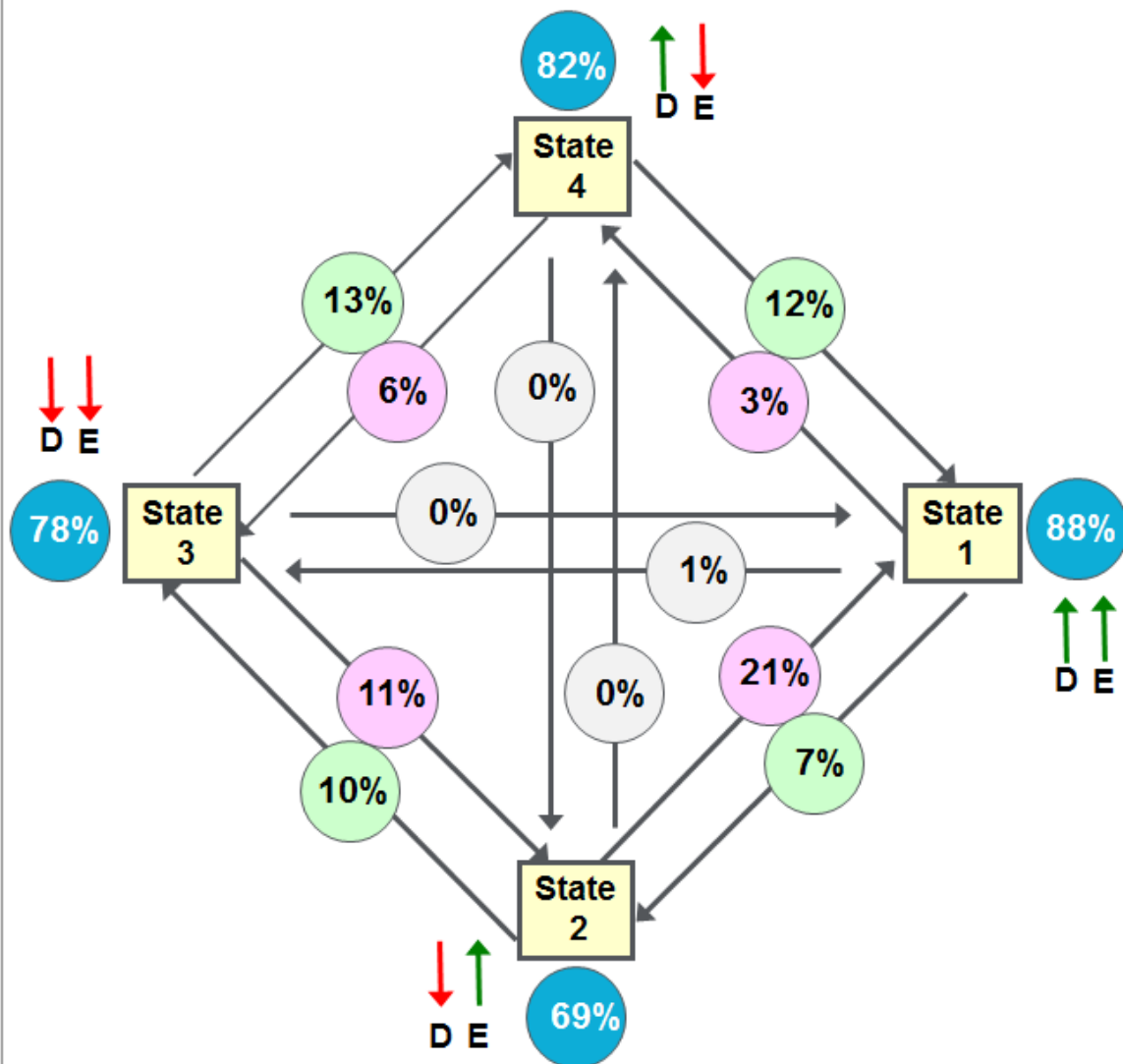
		Future State						
		1	2	3	4	Long Term		
Current State	1	88.5%	7.3%	0.9%	3.4%	50.4%	UP	UP
	2	20.8%	68.8%	10.4%	0.0%	16.6%	UP	DOWN
	3	0.0%	11.1%	76.2%	12.7%	13.6%	DOWN	DOWN
	4	12.2%	0.0%	5.6%	82.2%	19.4	DOWN	UP

# Analysis of Regime State Switching

Analysis of the historical transitions between debt-equity returns reveals almost no moves between states 1 and 3 and between 2 and 4.

- The plot presents historical monthly probabilities of transitioning among all credit states
- Results generally support the notion of a dominant clockwise direction of the leverage cycle
  - Probabilities of transitioning in a clockwise direction are either higher or equal except for between States 1 and 2
- Notice that transitions to non-neighboring states on the leverage clock almost never occur
  - That is, transitions between States 4 and 2 never occur and between 3 and 1 are rare

## Monthly Probabilities of State Transitions



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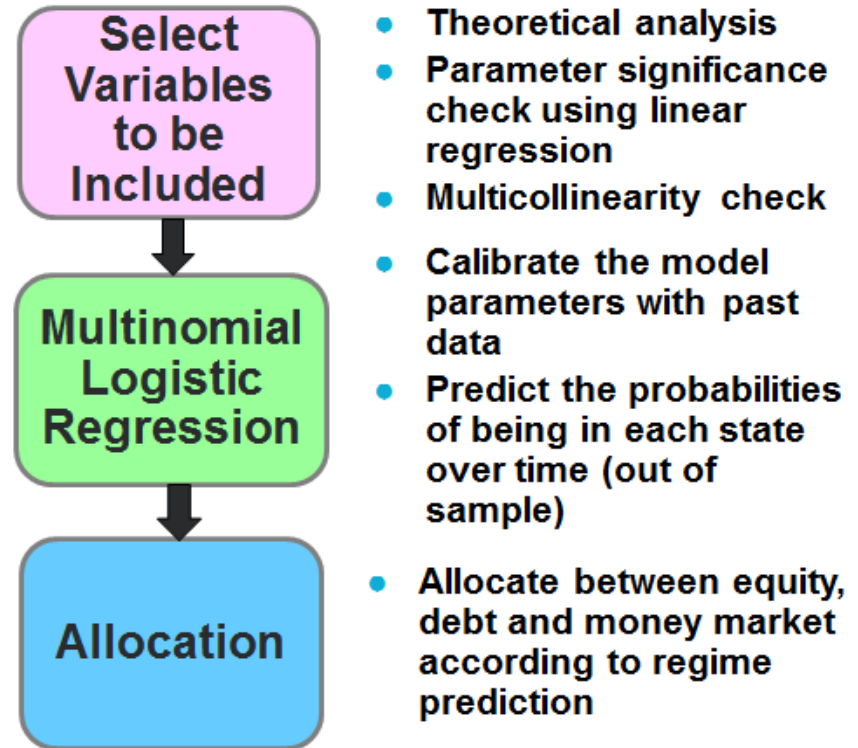
# Predicting Regime State Transitions - Methods

Recall our objective is to predict equity and debt market returns. Our approach is to predict the regime state transitions and thereby predict equity and debt market returns.

- **MODELING OBJECTIVES:**

- Generate predictions of monthly credit cycle states 1-4
- Allocate a portfolio among equity, debt and money market based on the state predictions
- Measure performance relative to a 60/40 Equity/Debt benchmark portfolio
- The modeling paradigm involved dividing the historical sample into:
  - CALIBRATION SAMPLE: Jan-76 to Jan-06 and rolling forward each month
  - TEST SAMPLE: Jan-06 to Sep-14
- A set of predictive variables was selected that included:
  - MACROECONOMIC: Unemployment Rate, ISM, Risk-Free Rate, Inflation ...
  - EQUITY: Leverage, Inventories, VIX ...
  - DEBT: Private saving, yield curve slope, credit risk premium, high yield return
- Perform multinomial logistic regression on inputs to predict credit state
- Allocate monthly one-year portfolios among debt, equity and money market based on regression model

## State Transition Model Paradigm

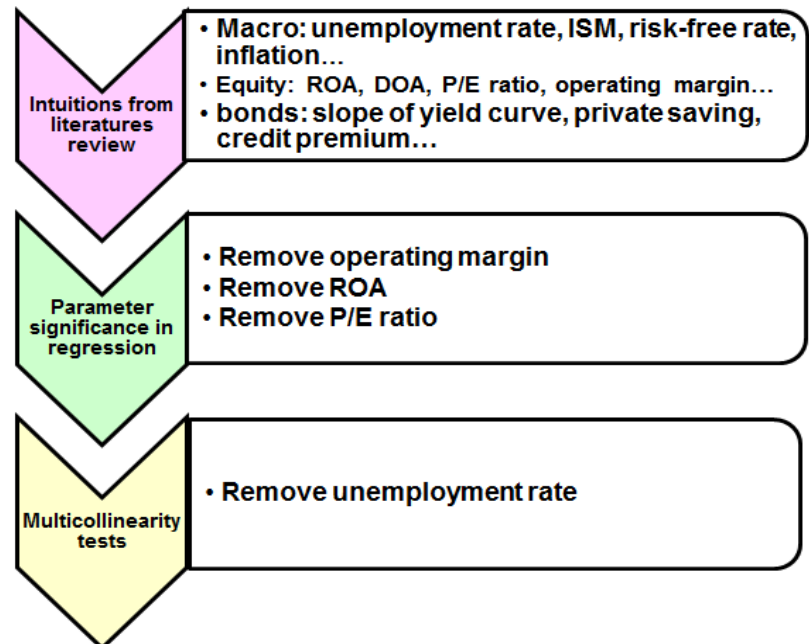
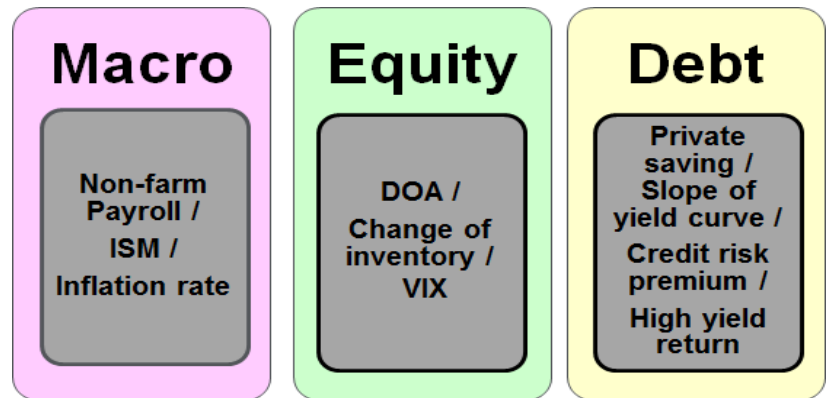


# Selecting Input Variables

Macro economic indicators and equity and debt market predictors are analyzed for their significance and eliminated if non-predictive or for multicollinearity.

- The model is simultaneously predicting debt and equity market returns
- The variables tested included macro-economic indicators, and equity and debt market factors (see upper right panel)
- Regressions were performed using all the variables on the one-year forward returns on debt and equity
  - This indicated which data might have some predictive power in the multinomial regressions
  - Aggregate return on assets, operating margin, and the price to earnings, as they were not significant
- We checked multicollinearity by calculating VIF (Variance Inflation Factor) for each variable
  - Unemployment rate was removed due to its multicollinearity with other factors

## Candidate Variables and Variable Elimination Criteria



# Model Construction

A multinomial logistic regression model in a “walk-forward” procedure was used to generate monthly predictions of credit regimes and one-year equity and debt returns.

- Recall that monthly one-year returns in equity and debt markets were used to back out the implied credit regime a year before
- To construct the predictive credit state model, we use the data up to one month prior to the predicted month to generate the next month’s credit state
  - We used an initial training sample from January 1976 to January 2006 to generate the monthly predicted credit state in January 2006
  - To predict subsequent monthly credit states to July 2015, the training sample was expanded by rolling it forward each subsequent month from January 2006 to incorporate data up to the month of prediction
- During model training, we assign each month into one of the four different states described above
  - Because we are interested in predicting conditional transition probabilities, we separate the training series into each of the four states and derive a model to predict the regime state in the following period
- The state generated in a given period is used to select the multinomial logistic regression used to predict next month’s state
  - For example, conditional on being in State 1 in month  $t$ , we apply four multinomial regressions from variables up to that time to derive probabilities of transitioning into each of the four credit dates
  - One of the transitions from each state is set to 0, as reflected in the absence in transitions across the leverage clock (i.e., between States 1 and 3 and between States 2 and 4)

# The Multinomial Regression Model

The multinomial regression model is a linear regression analysis that is useful with a nominal dependent variable with more than two potential values.

- In the Diebold (1994) model described earlier, logistic regressions are used to specify transition probabilities across two states
- We extend this specification to four states by using a multinomial logistic model. The fitted dependent variables from the regression give the log odds between two states:

$$\ln \left( \frac{\Pr[Y_t = j]}{\Pr[Y_t = K]} \right) = \beta_j X_t$$

where  $K$  is the base state in the regression at  $t - 1$  and  $j$  is some other state.  $X_t$  is the vector of independent variables at time  $t$

- Using this specification, we can imply conditional transition probabilities for each state:

$$\Pr[Y_t = 1] = \frac{e^{\beta_1 X_t}}{1 + \sum_{i=1}^{K-1} e^{\beta_i X_t}}$$

$$\Pr[Y_t = 2] = \frac{e^{\beta_2 X_t}}{1 + \sum_{i=1}^{K-1} e^{\beta_i X_t}}$$

$\vdots$

$$\Pr[Y_t = K - 1] = \frac{e^{\beta_{K-1} X_t}}{1 + \sum_{i=1}^{K-1} e^{\beta_i X_t}}$$

where  $K$  is the base state, and

$$\Pr[Y_t = K] = \frac{1}{1 + \sum_{i=1}^{K-1} e^{\beta_i X_t}}$$

The probabilities sum to 1.0 by construction. This four state regression is done four times, conditional on each of the four states. One of these probabilities is restricted to 0 in each of the regressions

# The Model (cont.)

The result of the multinomial regression model is a set of monthly 4x4 matrix of transitions from the current state out to 12 months.

- Within the training sample, we break each month up into one of four different states based on the method described above
- We are interested in *conditional transition* probabilities, so we separate the series into each of the four states and look at the state in the *following* period
- The states in each following period become the state variables for each respective multinomial logistic regression
  - For example, when performing the multinomial regressions conditional on state 1, we look at all the states in the month directly following state 1 and perform a multinomial regression of these states on the variable values from the previous month
  - The results of this regression can then be translated into four state switching probabilities, one of which we set to 0, due to the movement of the leverage clock
- The result of these four regressions is a 4×4 matrix:

$$T = \begin{pmatrix} p_{11} & \cdots & p_{14} \\ \vdots & \ddots & \vdots \\ p_{41} & \cdots & p_{44} \end{pmatrix} ,$$

where  $p_{ij}$  is the probability of moving from state  $i$  to state  $j$  and, as indicated above, we set  $p_{13} = p_{24} = p_{31} = p_{42} = 0$

# Generating Predicted States

The transition matrix contains all the important information from the training set and is the primary mechanism through which the debt equity allocations change

- Once we have obtained a transition matrix from the training set, we can use it to roll forward the probabilities of being in each of the states into the next month. That is,  $P_t = T \times P_{t-1}$ , where  $P$  is a  $4 \times 1$  vector
- At the end of every month, the model generates probabilities of the next month being in each of the 4 states and we use that to allocate between debt and equity
- Because of cancellation effects of different states, we only take the highest two probabilities at each time and then re-normalize so that they add up to one. We call this new vector  $P_t'$ 
  - For example, State 2 is positive equity, negative debt and State 4 is positive debt, negative equity. So, if equal probabilities are given to the two states there will be zero dollars invested in either state
  - We find that at each monthly prediction there tends to be two probabilities that dominate
- Thus, for each monthly prediction, we remove the lowest two transition probabilities and normalize to add to 1.0 as shown on the right

## Regime States

	Equity	Debt
State 1	UP	UP
State 2	UP	DOWN
State 3	DOWN	DOWN
State 4	DOWN	UP

	State 1	State 2	State 3	State 4
Probability	70%	7%	3%	20%

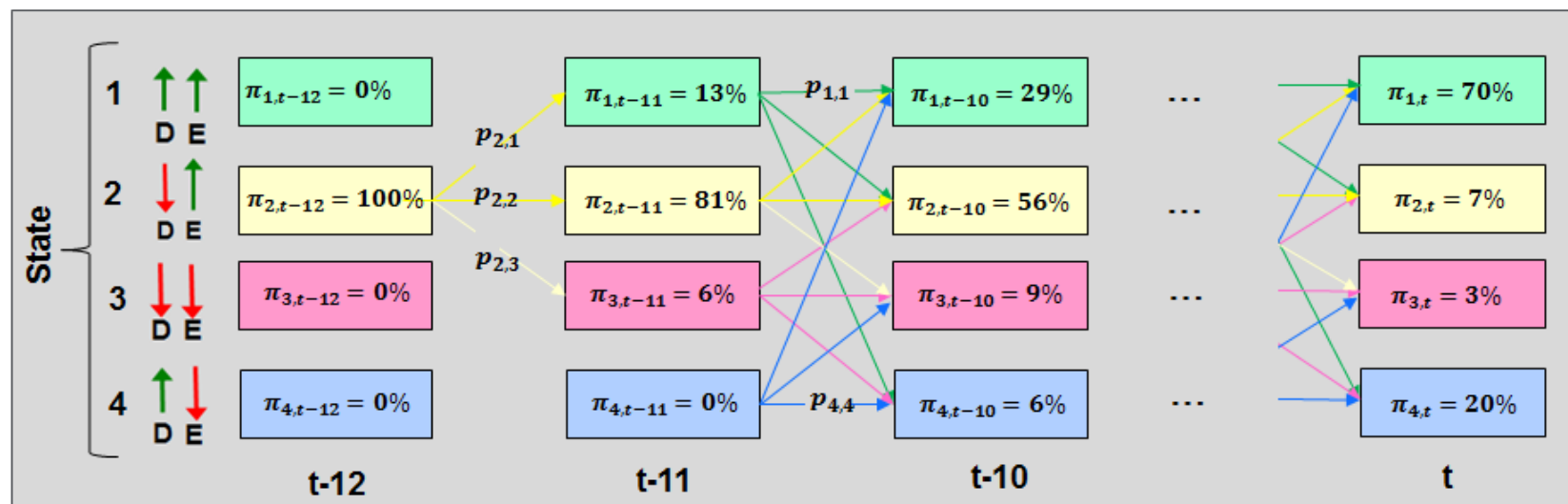


	State 1	State 2	State 3	State 4
Probability	78%	0%	0%	22%

# State Transition Prediction Model

We illustrate how transition-state model generates predictions for the current month's one-year allocation are derived from a known state one-year prior.

## Diagram of Transition State Model for Debt-Equity Return Cycle



Predictions start from a known credit state one year prior to the month of prediction, in this example, State 2

Values of  $\pi_i$  are probabilities of being in each of the four states

Only three states have potential probabilities from any one state as transitions between states 1 and 3 and 2 and 4 are zero

In any month, the transition values from state  $i$  to state  $j$  is calculated as

$$p_{ij} = \sum_{i=1}^4 \pi_i \sum_{j=1}^4 \beta_{ij} X_t$$

where  $\beta_j$  is the vector of weights on the input variable set  $X_{t-11}$  and the resulting probability of being in any state  $j$  is calculated as

$$\pi_j = \frac{\sum_{i=1}^4 p_{ij}}{\sum_{i=1}^4 \sum_{j=1}^4 p_{ij}}$$

The process continues each month until the present, time  $t$ , to generate the final state probabilities that are input to the debt, equity, and money market allocation

The actual state assignment uses only the two highest probabilities, 70% and 20% in this example (as the others are mirror images)

We then normalize so that probabilities in the two states add to 1.0

The result is a 78% allocation to State 1 and 22% to State 2

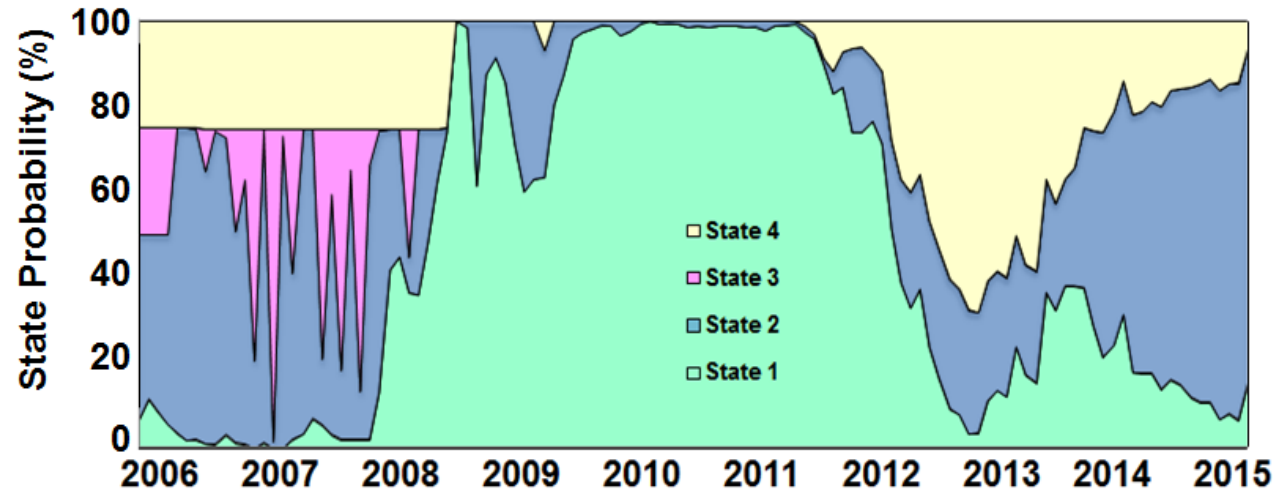


# Analysis of Predicted States

The resulting time series of monthly model predicted state probabilities is dominated by State 1 (equity and debt returns positive), with least presence in State 3 (both negative).

- We analyze monthly predicted probabilities of being in regime states 1-4
- State 1 (positive predictions of debt and equity) is dominant
  - $P(\text{State 1}) = 49\%$
- State 3 (predicted negative equity and debt returns) is least frequent
  - $P(\text{State 3}) = 5\%$
- The pattern of predicted and actual states is similar, but
  - State 3 (recession) is under-predicted by 9% and State 2 is over-predicted by 9%

## Predictions of Monthly Presence in Regime States

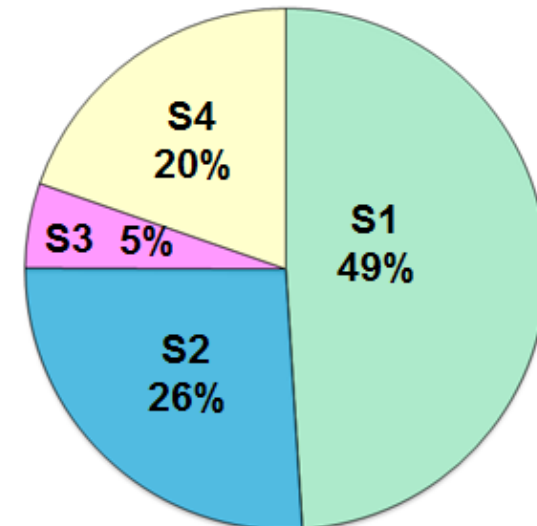


## Regime State Predicted Probabilities

State	From Calibration Period	Average Predicted Probability
1	50%	49%
2	17%	26%
3	14%	5%
4	19%	20%

## Regime States

	Equity	Debt
State 1	UP	UP
State 2	UP	DOWN
State 3	DOWN	DOWN
State 4	DOWN	UP



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# Generating Monthly Portfolio Allocations

Each month, we put on a debt-equity-money market trade and hold that position for one year. We examine those returns relative to a static 60%/40% equity/debt allocation.

- The monthly allocation weights on debt and equity for each of the states are based on the regime definitions:
  - If equity or debt returns are **UP** in the predicted state, we assign it a weight of +1
  - If equity or debt returns are **DOWN** in the predicted state, we assign a -1
  - Thus, the weight allocation matrix  $W$  is a 4 x 2 matrix of values of 1 and -1 (see below)
- The final allocations to debt,  $d_t$ , and equity,  $e_t$ , is given by:  $(d_t, e_t) = P_t' \times W$
- Because  $d_t$  and  $e_t$ , do not necessarily add to 1.0, we borrow or lend the difference,  $m_t$  from 1.0 (i.e.,  $m_t = 1 - d_t - e_t$ ) such that the resulting allocation equals 1.0

- **EXAMPLE:** Given the following state probabilities for month  $t$ :

	State 1	State 2	State 3	State 4
Probability	78%	0%	0%	22%

4 x 2 Matrix

	Equity Market	Debt Market	Equity Position	Debt Position	Prob
State 1	Up	Up	+1	+1	78%
State 2	Up	Down	+1	-1	0%
State 3	Down	Down	-1	-1	0%
State 4	Down	Up	-1	+1	22%

- The final allocations to debt,  $d_t$ , equity,  $e_t$ , and money market,  $m_t$ , are given by:

## Allocation

State 1 = 78% Equity + 78% Debt

State 2 = 0% Equity + 0% Debt

State 3 = 0% Equity + 0% Debt

State 4 = -22% Equity + 22% Debt

State 1-4 = (78%-22%) Equity + (78%+22%) Debt

= 56% Equity + 100% Debt

Money Mkt = 100% - 156% (Equity + Debt)

= -56%

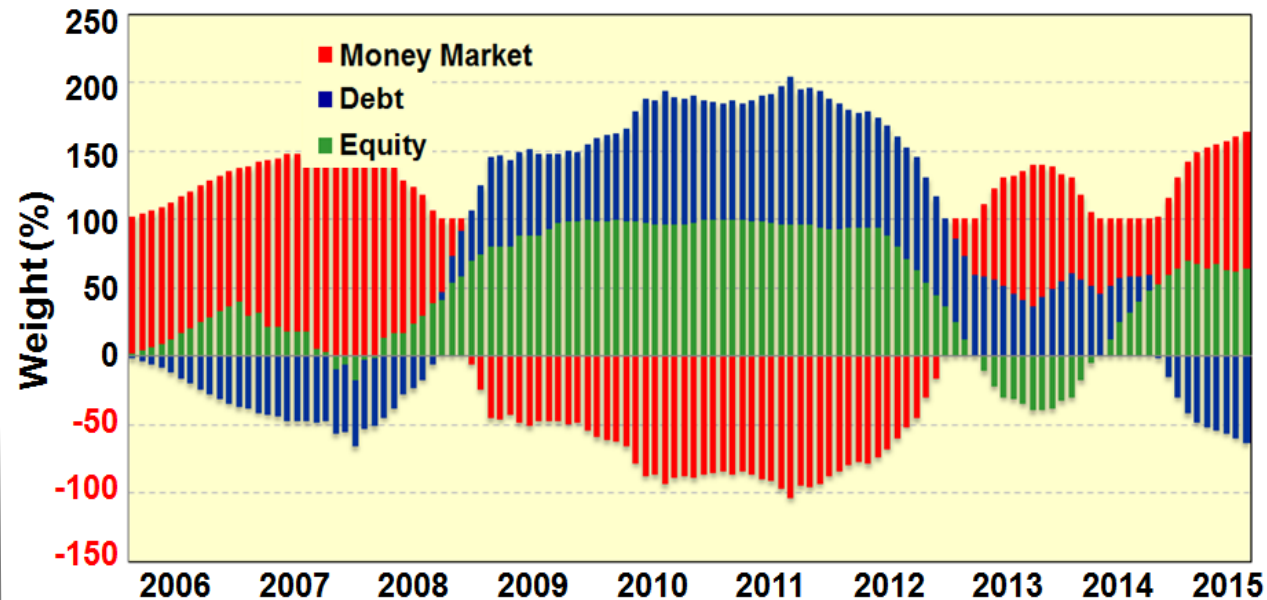
Total = 56% Equity + 100% Debt + -56% Money Mkt

# Back Testing Equity-and-Debt Trades

We analyze the percent of equity, debt and money market allocations in monthly trades over the out-of-sample testing period beginning in January of 2006.

- Each month, we put on a simulated debt-equity-money market trade and hold that position for one year
  - After an initial 12-month ramp-up period, we have a continuous set of 12 one-year trades
  - Each month, one trade matures and a new one-year trade begins
- The sum of all three positions (equity + debt + money market) in any given month add up to 100%
- The figure shows that, over the test period from 2006-2015, there is roughly an equal allocation to each asset (equity, debt, and money-market)
  - Money market investments dominate in 2006 through the credit crisis of 2007-2008 with equity and debt markets dominating until early 2013, when the signal turned to short equity, long debt and money market.
  - After a brief short position in equity in 2013, the signal was to be long both equity and debt, turning short debt and long equity and money market since mid-2014

## Weights of Debt, Equity and Money Market in Monthly One-Year Trades



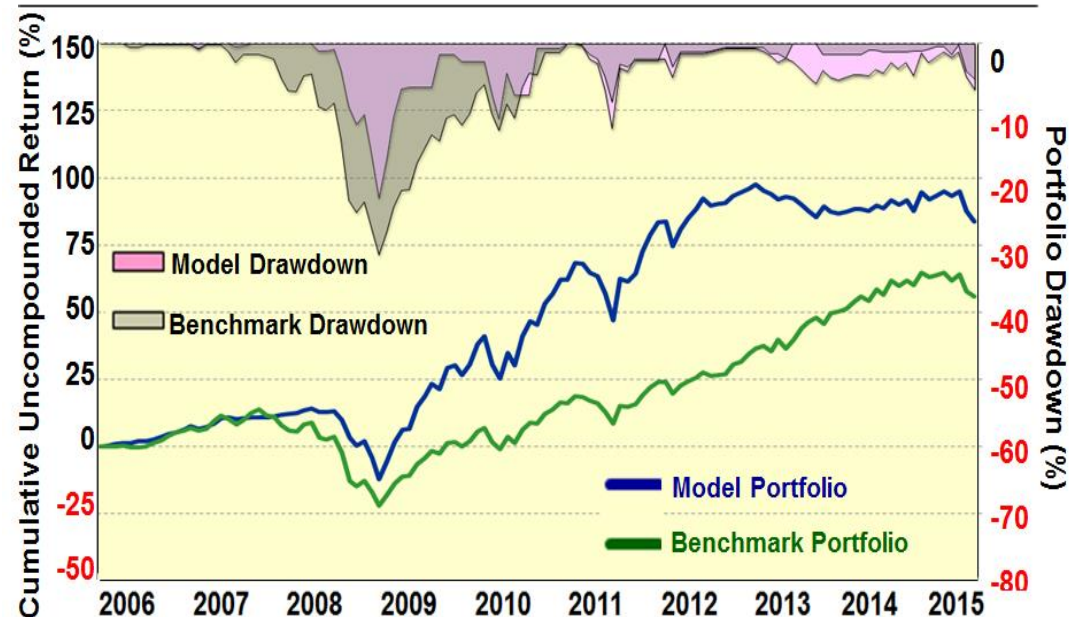
# Results: Out-of-Sample Testing

We test the allocations predicted by the state transition model relative to a constant benchmark portfolio of 60% equity and 40% debt.

- Recall that the model is calibrated using the historical data from 1976 through 2005
- The out-of-sample testing period is from Jan-06 to Jul-15
- Each month a model portfolio of equity + debt + money market is constructed and held for one year
- The model portfolios outperformed the 60%/40% equity/debt benchmark
  - The model outperformed the benchmark by 2.28% annually (uncompounded), but with slightly higher volatility
  - The model Sharpe ratio is 0.61 versus 0.48 for the benchmark
  - The maximum drawdown for the model is 23% versus 31% for the benchmark

## Portfolio Returns and Drawdowns

	Model Portfolio	60%/40% Equity/Debt Benchmark
Arithmetic Mean Return (Monthly)	0.66%	0.47%
Geometric Mean Return (Monthly)	0.61%	0.43%
Standard Deviation of Monthly Return	3.14%	2.61%
Annualized Geometric Mean Return	7.52%	5.24%
Maximum Drawdown	-23%	-31%
Arithmetic Mean Excess Return (M)	0.56%	0.36%
SD of excess ret (M)	3.15%	2.63%
Annualized SR	0.61	0.48





# Results: Testing Model Robustness

In order to explore further the multinomial model of the equity-debt return cycle, we shortened the training period and lengthened the test period.

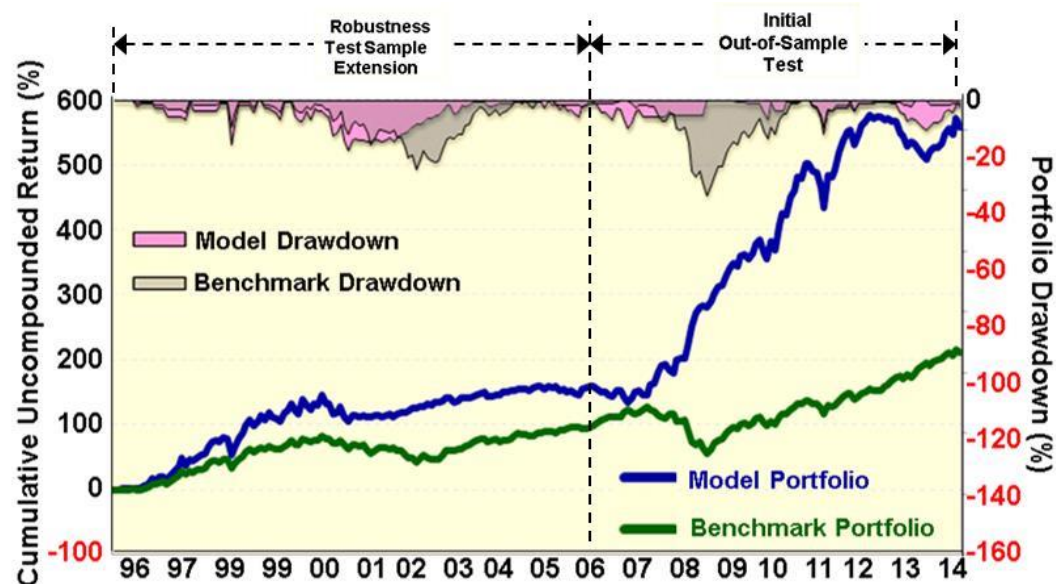
- We shortened the model calibration period from 30 years to 20 years and examined changes in model performance
- Both the 60%/40% equity/debt benchmark and the model performance was poorer over the 1996-2014 test period
  - Sharpe ratios decreased for both portfolios, but the ratio of model outperformance is roughly the same for both periods
  - The drawdown difference between model and benchmark is smaller owing to greater returns from the benchmark
- Relative to the benchmark, the model portfolio:
  - Outperformed the benchmark by 37bp monthly, 11bp more than over the 30-year calibration period

## Portfolio Returns and Drawdowns

Period 1: 1976-2006

Period 2: 1976-1996

	Calibration Period			
	1976-1996 (20 Year)		1976-2006 (30 Year)	
	Model	Benchmark	Model	Benchmark
Mean Return (Monthly)	0.96%	0.59%	0.73%	0.47%
Standard Deviation of Return (M)	3.71%	2.76%	2.30%	2.61%
Mean Return (Annual)	11.09%	6.74%	8.68%	5.24%
Maximum Drawdown	-16.52%	-22.68%	-11.55%	-31.48%
Mean Excess Return (M)	0.65%	0.28%	0.62%	0.36%
SD of excess ret (M)	3.70%	2.76%	2.32%	2.63%
Annualized SR	0.61	0.35	0.93	0.48



1. Introduction and Background
2. The Leverage Clock and Regime Switching Model
3. Quantifying the Debt-Equity Credit Cycle
4. Predicting Monthly Regime States Transitions
5. Out-of-Sample Testing

**A1: Acknowledgments**

**A2: Disclaimer**



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## Faculty Advisors

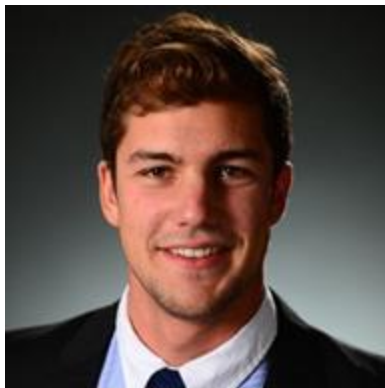


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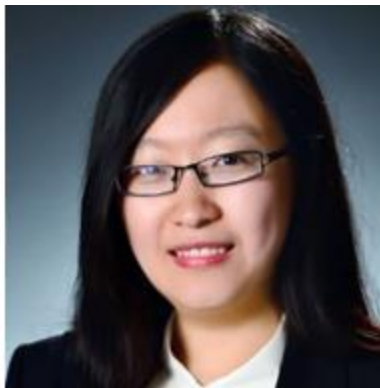


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## Student Participants



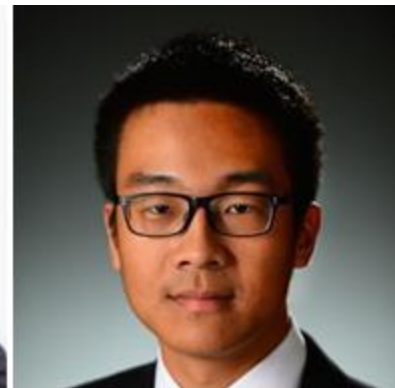
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# Disclaimer

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