# YOU CAN GAIN POLICY MAKERS' CONFIDENCE IN MODELING

Rob Firmin

Palisade Conference, 11/15/2018

OR ANY OTHER AUDIENCE

# YOU CAN GAIN PUBLIC'S CONFIDENCE IN MODELING

# AND

# GET THEM TO USE IT!

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Classic problem: getting management to incorporate modeling into actionable elements of decision making.

# INCLUDING SOPHISTICATED MODELING

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Sophisticated models can contribute to actionable elements of decisions, but how to present is critical.

# REAL EXAMPLE:

# SMALL MUNICIPALITY WITH TIGHT BUDGETS

## EXAMPLE SUBJECT:

## SMALL MUNICIPALITY WITH TIGHT BUDGETS

## MISTRUST

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Town meetings can be contentious. Incorporating modeling can contribute to public confidence.

# GAIN TRUST

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# WITH
# EFFECTIVE
# NOMENCLATURE

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Start with effective nomenclature.

# POLICY STRESS TESTS

# SIMPLY EXPLAINED

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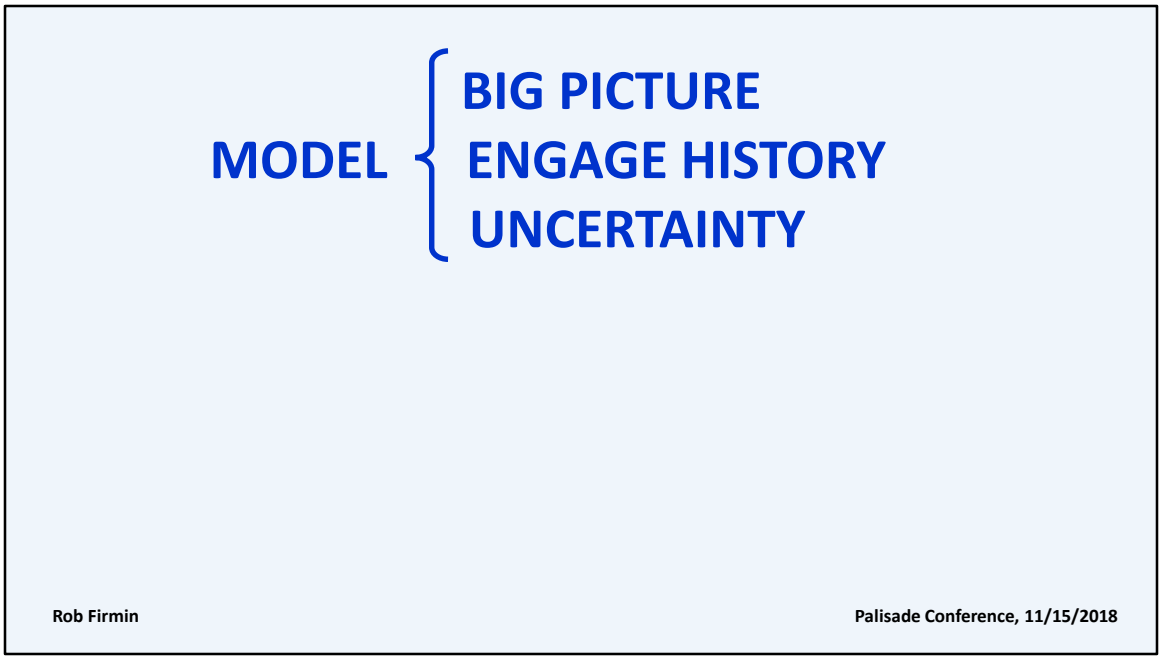
Good example of effective nomenclature




They know their history exists, some know it in detail, but not necessarily the nature of its flow over time, nor what aspects influence others.

MODEL { BIG PICTURE
ENGAGE HISTORY
UNCERTAINTY

EVOLVE CONSENSUS

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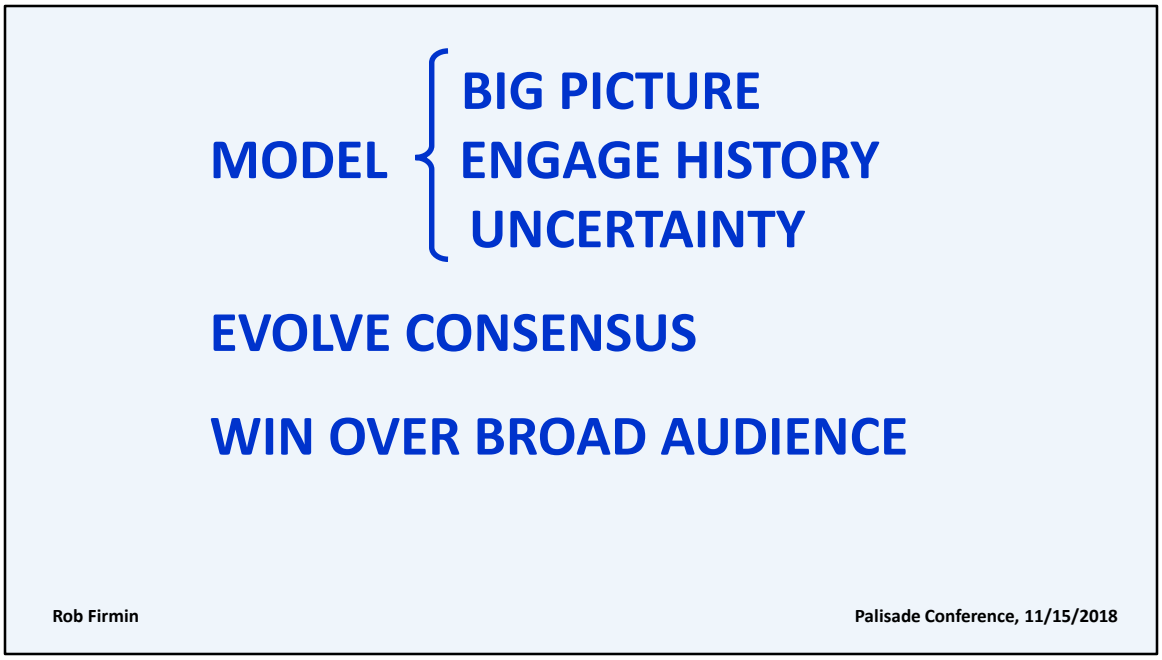
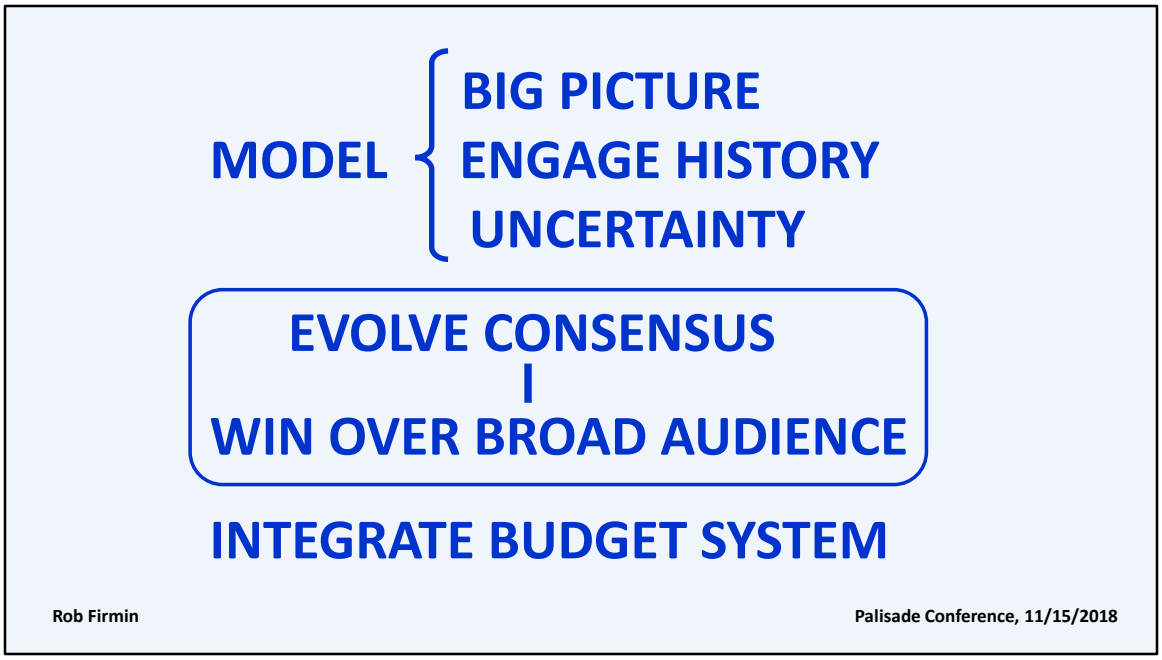
Big picture can be less threatening. Engaging history engages decision makers' experience.




Uncertainty adds, not detracts from confidence, because it is more realistic and therefore believable, and because it relieves burden of losing credibility when point estimates are not met.




We will discuss in this order.

# BIG PICTURE

# =

# CASH FLOW HISTORY

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In financial models

# HISTORY REQUIRES TIME SERIES

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Time-series statistical modeling is a different animal than conventional statistics. Conventional statistical modeling applied to time series produces invalid results. This means importantly incorrect analyses & forecasts.

# OPEN-MODEL
# ONLY ASSUMES HISTORY

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IT IS NOT PRESUMPTUOUS—IT HAS NO A PRORI ASSUMPTION OF MODEL FORM, OTHER THAN THAT A HISTORY EXISTS, FOR WHICH WE MAY OR MAY NOT HAVE DATA. MODEL BUILDING, NOT JUST FITTING. Excellent fits within a meaningless form provides meaningless non-information.

# TIME SERIES: PREDICTIVE CAUSALITY

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Nobelist Clive Granger's term—he read Box & Jenkins' pre-publication in 1968: Causality and its direction are far more easily assumed than with non-time series models.

# MODEL THE MOTION

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All time series represent the motion of what is measured—motion over time.

# MODEL THE MOTION

# MOTION = TEMPORAL STRUCTURE

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True time series creates a model of the data's motion over time—its temporal structure. Both the forecast and the model are important for understanding the phenomenon. The model structure informs about what inputs are important and how they operate on the variable being forecast.

# FIXED SALARY

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**Click on this slide again to see its animation.**

Even constant values are in motion: motion over time. Salary for example.

# MOTION AFFECTED BY MOTION

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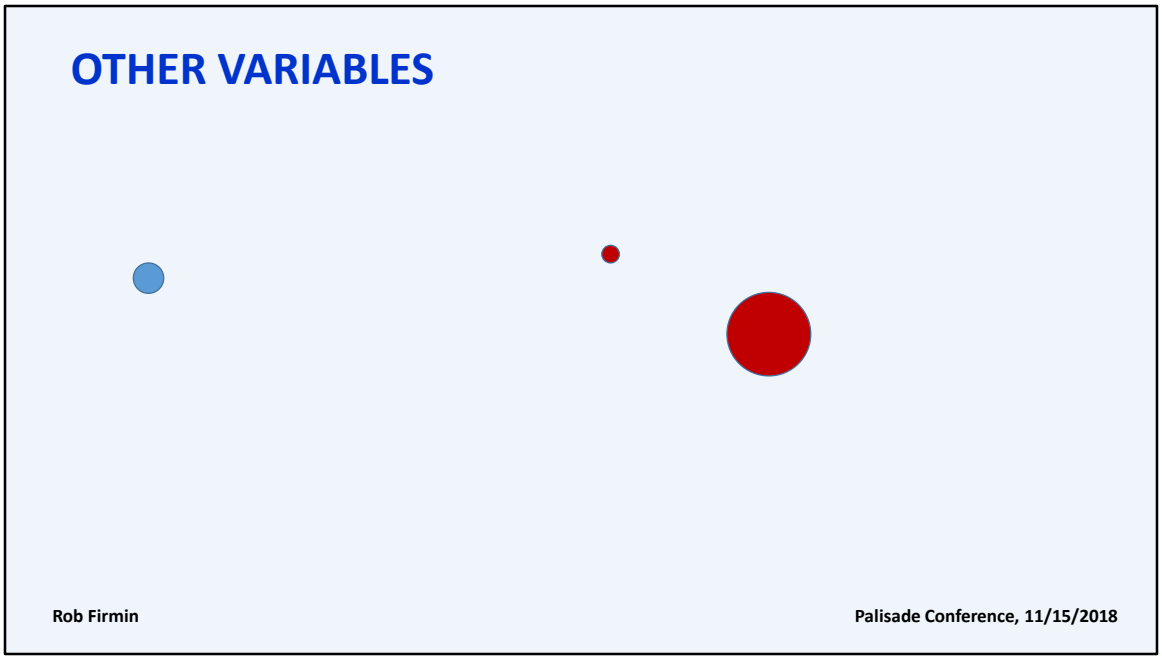
Let’s invite Johannes Kepler and Isaac Newton to the table.




Inside the jittery noise is a signal, including for multiple interacting variables—do not presume to know the form of the signal—DO NOT IMPOSE A MODEL OR MODEL TYPE ON THE DATA. LET MOTIONS' NATURE DICTATE. This could be an example of total compensation determined not only by fixed salary, but by overtime and its causes, and changes in productivity.

# TRANSFER FUNCTION RELATIONSHIP

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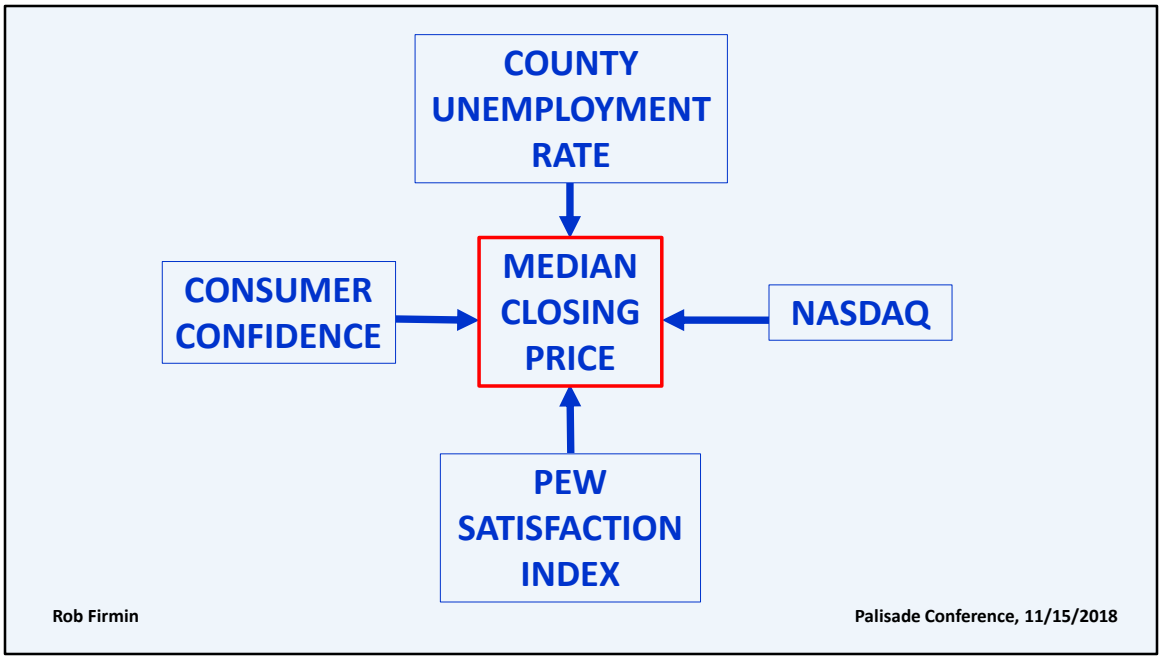
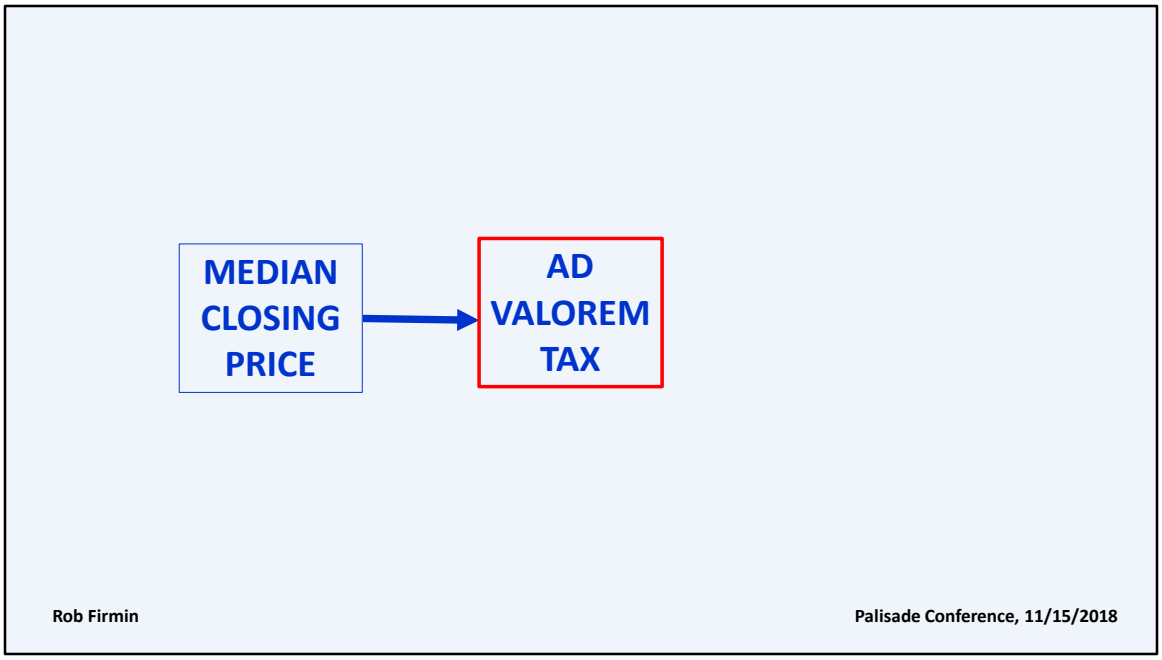
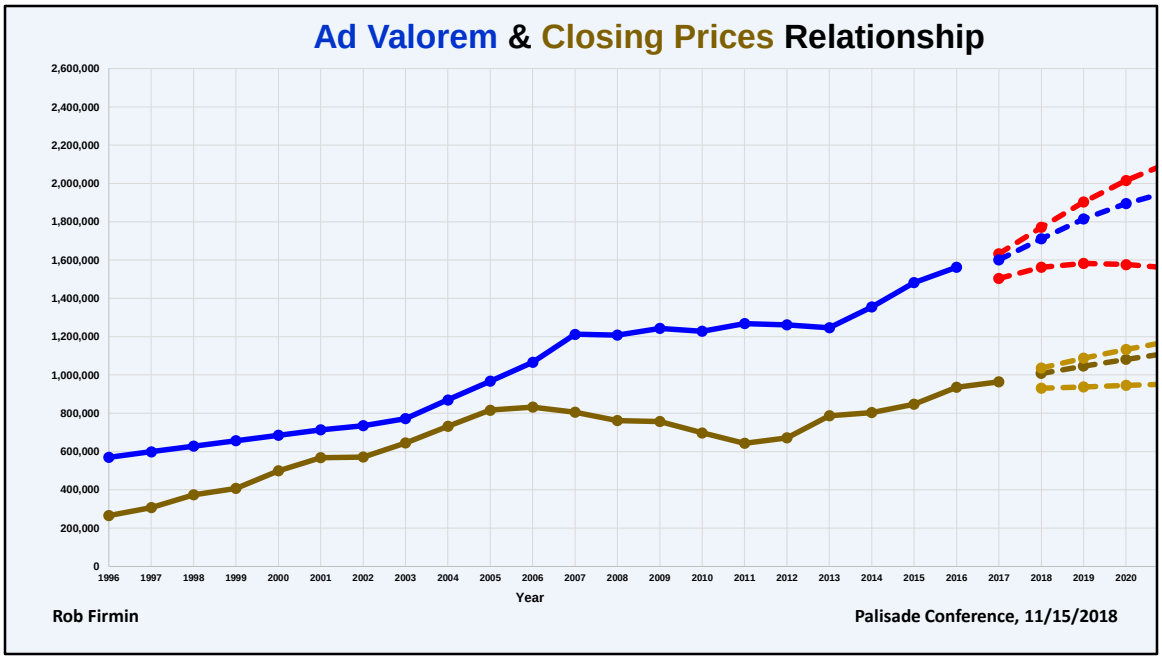
Transfer functions are a model's equations describing the temporal structure of multiple variables interacting over time—a turbocharged regression on steroids.



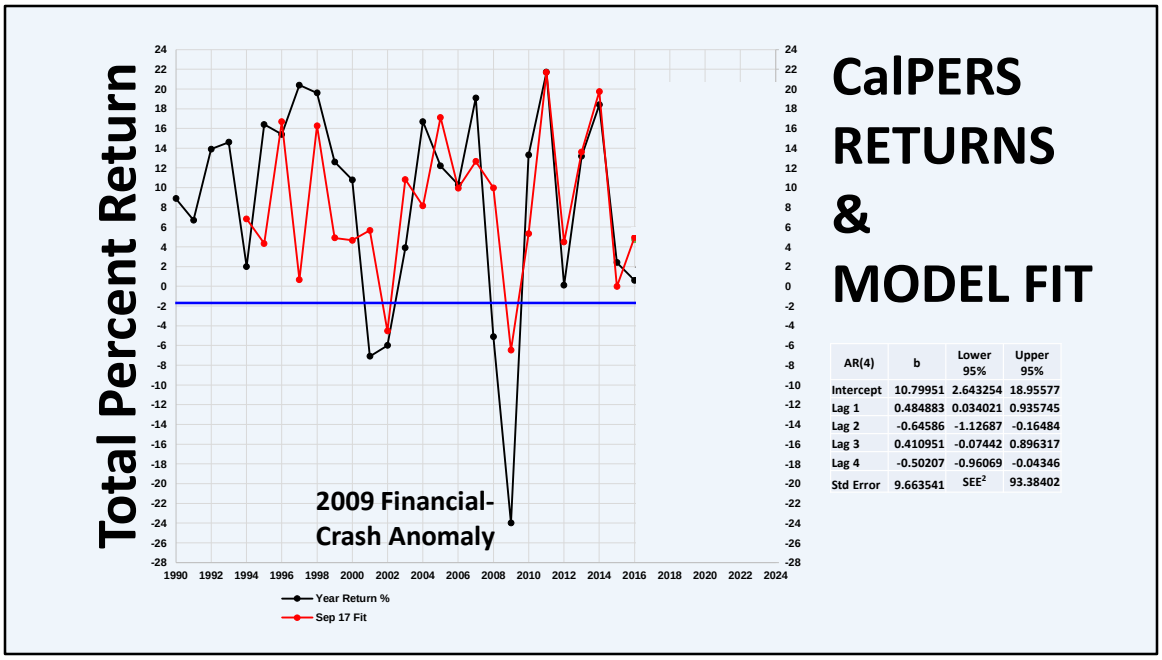

In the municipality model, Median Closing Price is found to be responsive over time to these three variables. People in the San Francisco Bay Area pay disproportionate attention to the NASDAQ Composite, for example.



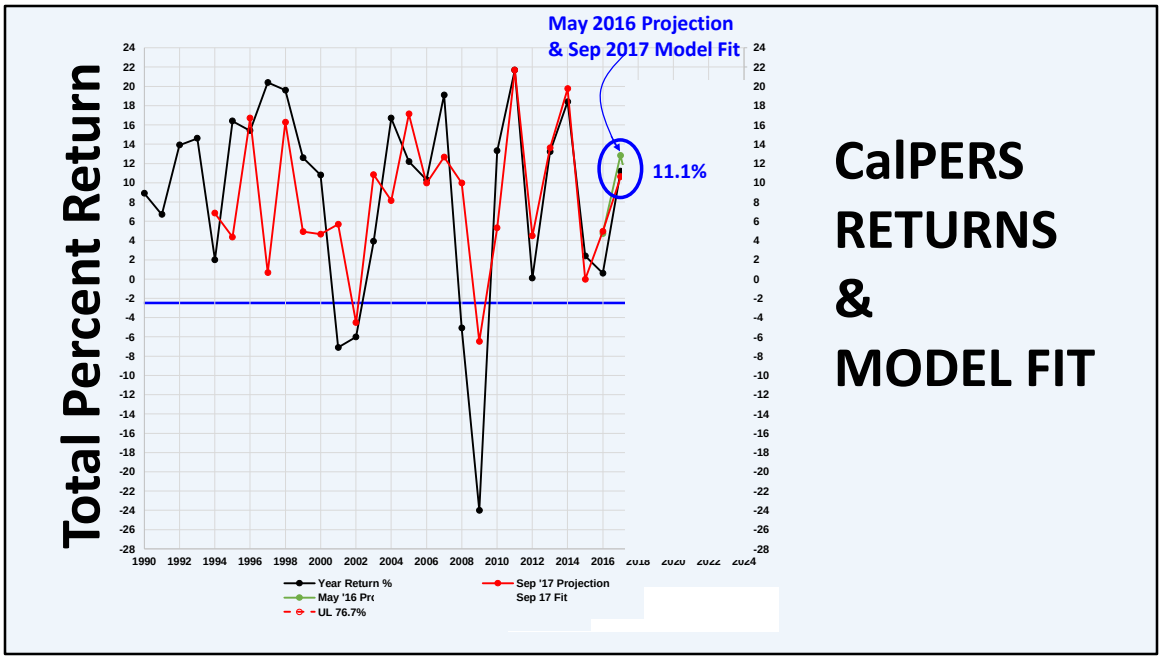

The Median Closing Price forecast model then feeds into the model relating closing price to tax revenue.



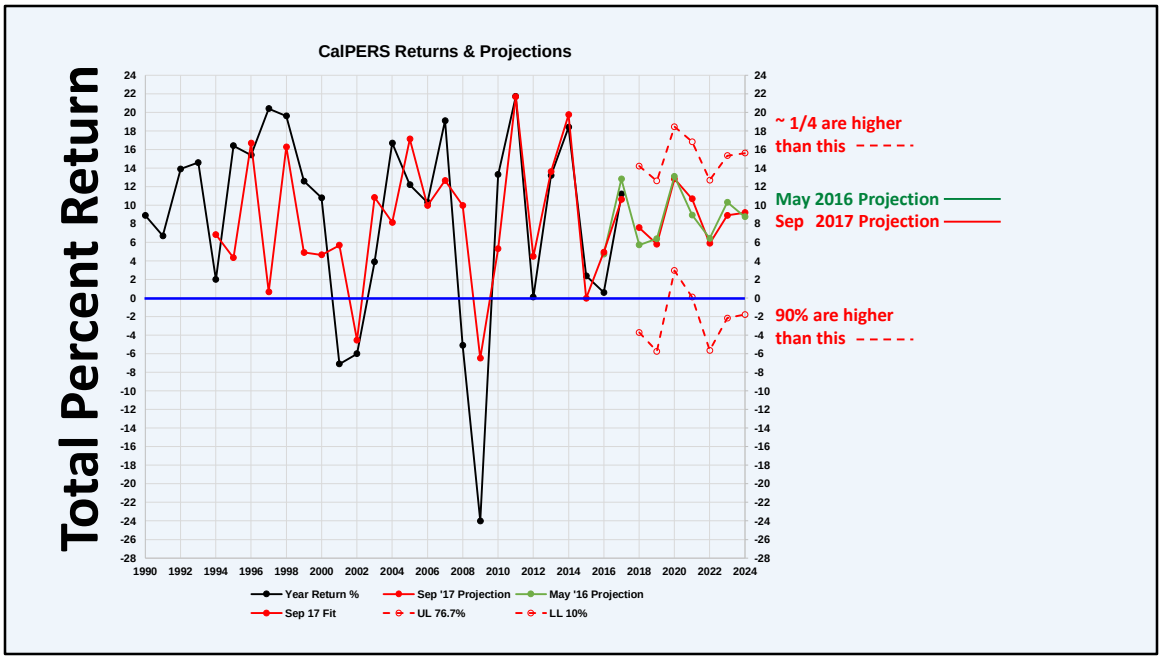

Graph of the relationship between Closing Prices (in brown) and Ad Valorem property tax revenue (in blue).



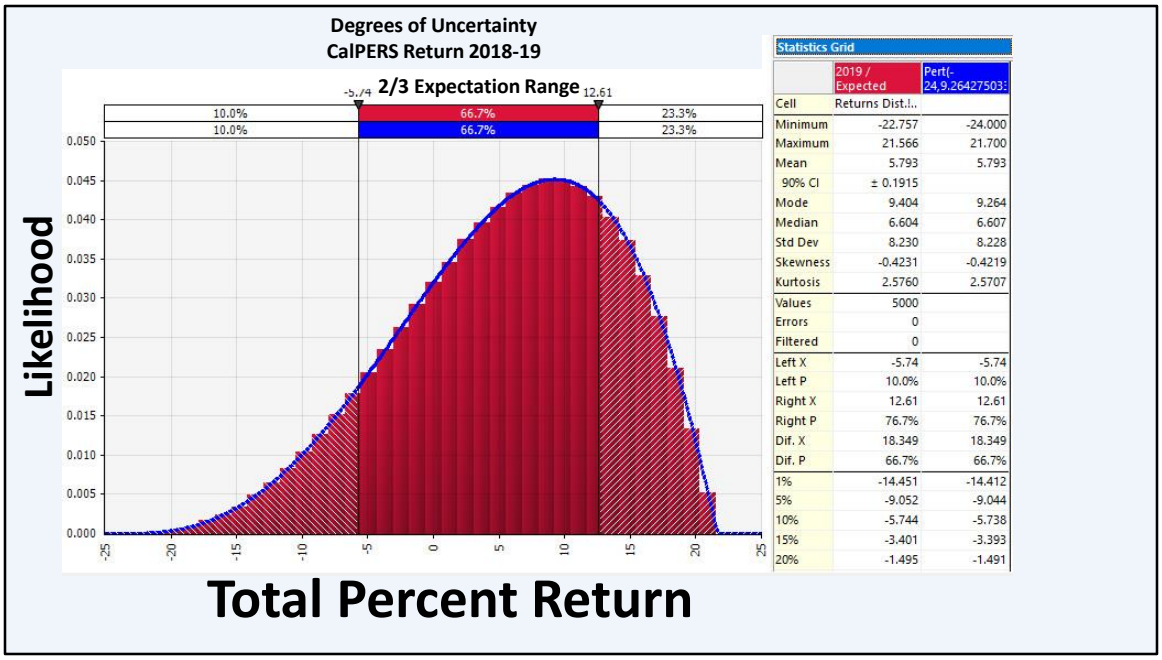

Notice the model seems to largely ignore the financial crash.



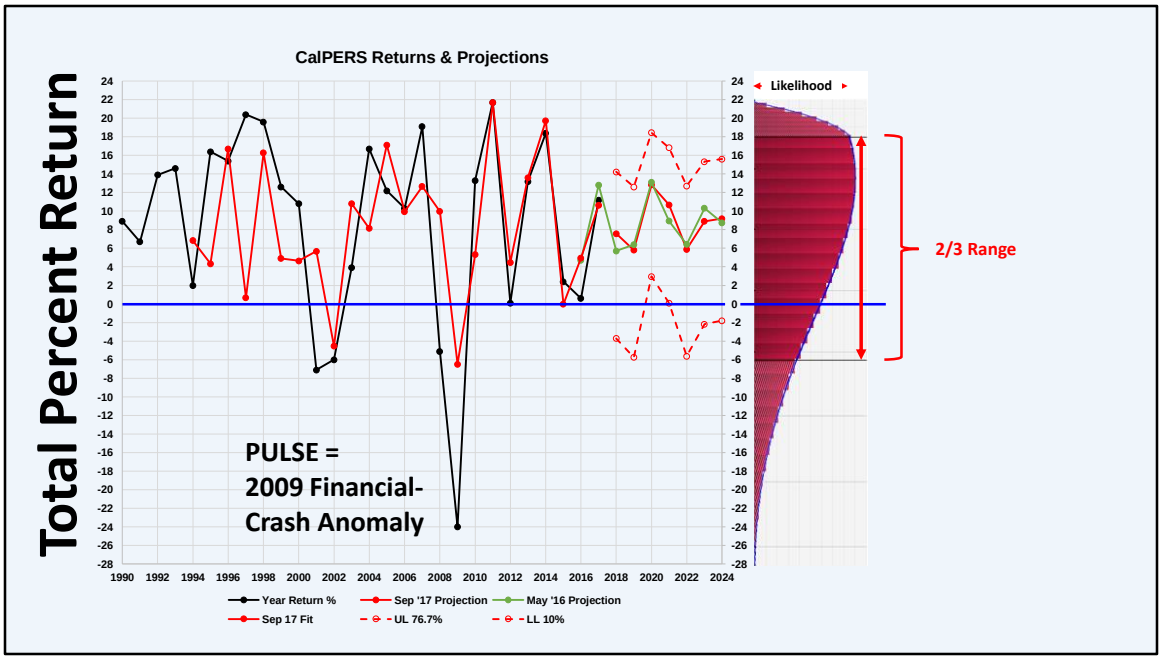

Extremely good forecast, given that market returns are supposed to be a random walk.




Forecast uncertainty distributions are propagated period by period based on feeding each forecast distribution and trailing history into the time series model. This means that each subsequent distribution may be different. But in some models the distributions remain constant.




The forecast uncertainty for the first forecast period of the CalPERS model.




The market crash anomaly is set aside from creation of the core model so as not to bias it; but it is not ignored: it contributes to the forecast uncertainty because it could happen again; and its modeled information can be used in what-if scenarios (i.e., stress testing in the event it happens again in a specific period). In this example what the model seems to be detecting is the portfolio management philosophy of the team, not just the market.

# MOTION AFFECTED
# BY
# ANOMALIES

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# ANOMALY
# IS
# TIME SERIES INFORMATION

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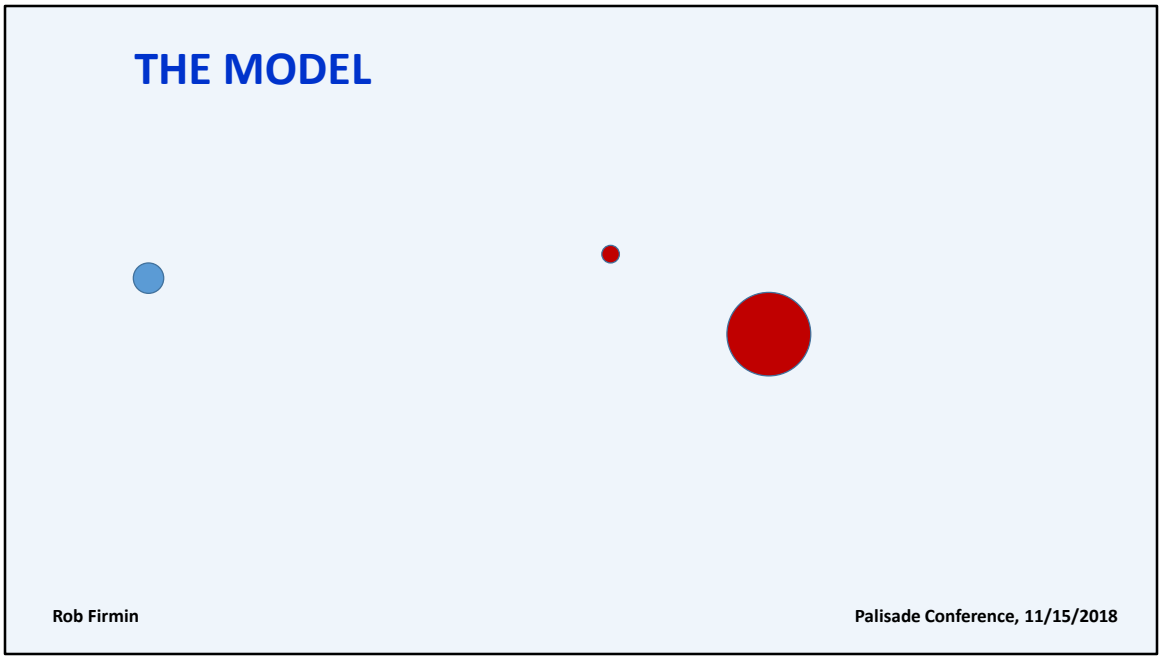
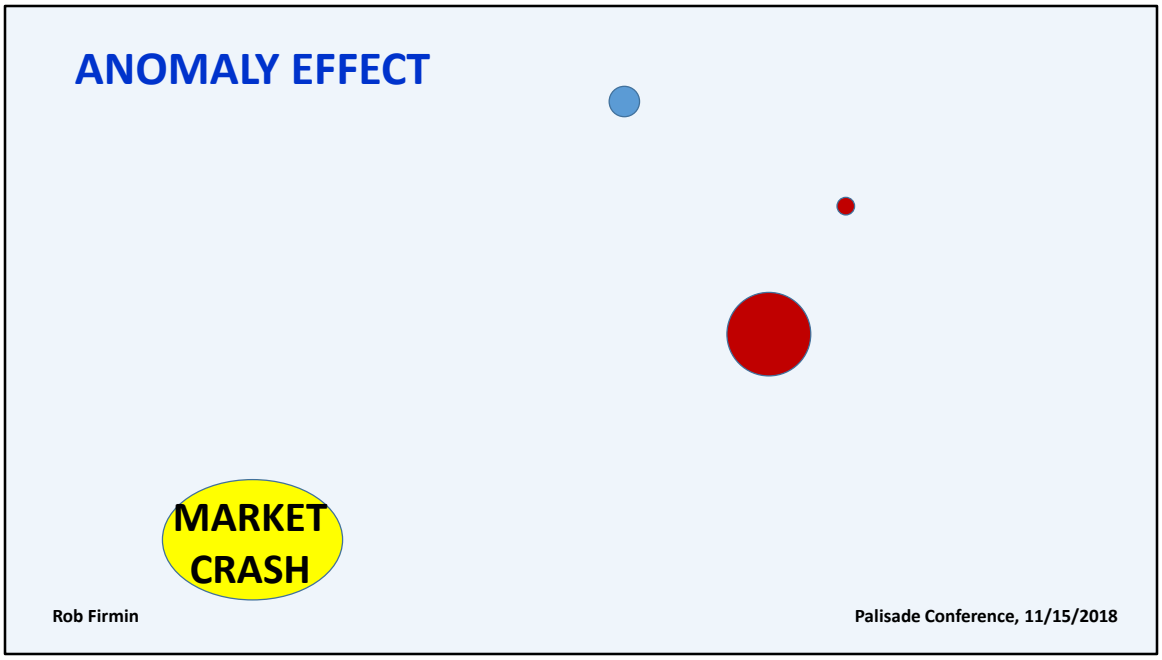
Let's go back to the motion metaphor.




**See this slide as an animation.**




**See this slide as an animation.**

The effect on other variables can persist or fade out. Illustration of the power of open-model time series as it identifies the crash as an anomaly and quantifies it. A strong anomaly like this is a type of intervention.

# ANOMALY EXAMPLE

# MARKET CRASH = TIME SERIES PULSE



Cannot know with certainty when the market will crash.

# TIME SERIES PULSE

# INSERT PULSE COEFFICIENT(S) IN WHAT-IF SCENARIOS

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But can use the quantitative effects from the model to what-if test the market crashing again next year, or the year after, for example.

# DETAILS

# TRUE TIME SERIES MODELING— NOT JUST REGRESSION

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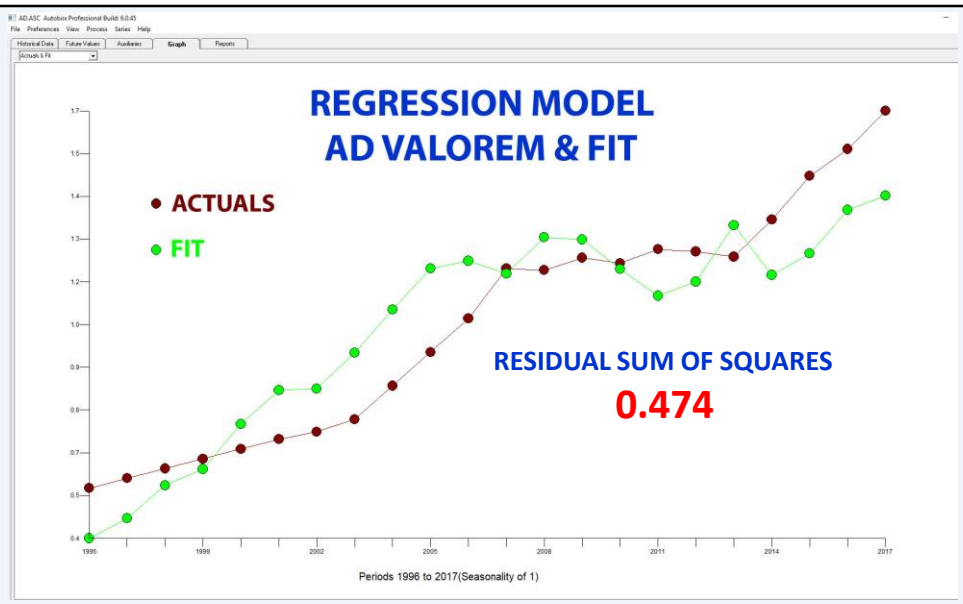
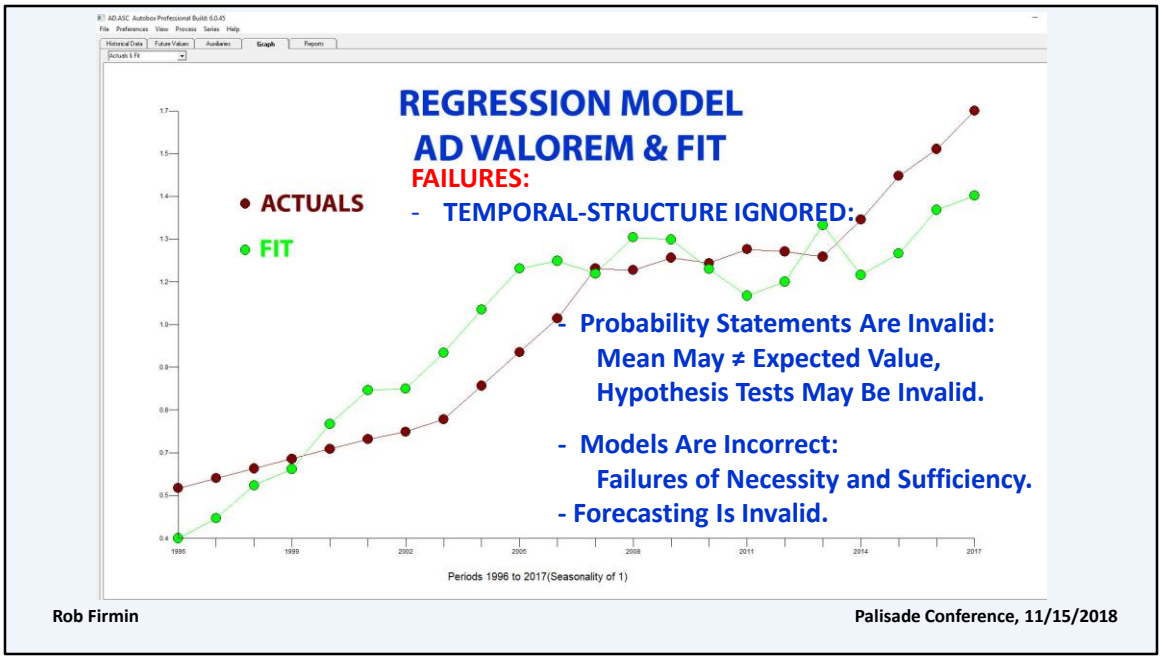
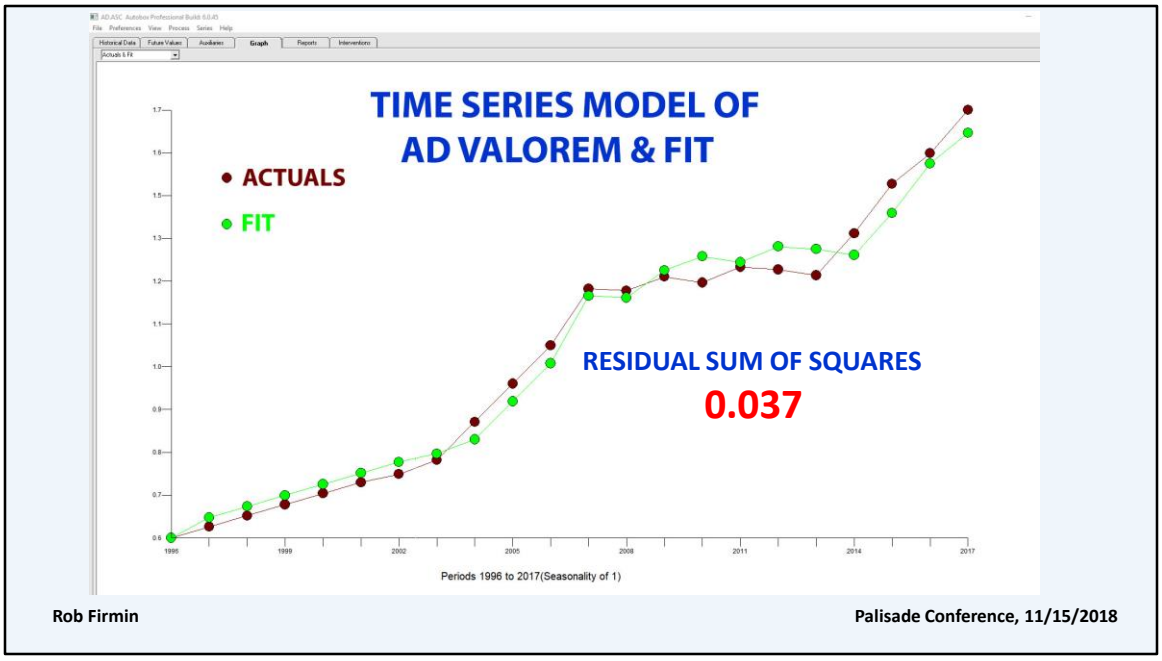
There are many forecasting methods. The one discussed here is substantially extended and refined ARMAX modeling, including identification of latent structure—not just endogenous structure. The next three slides are a demonstration of how common regression fails in time series modeling—why it is dangerous when applied to this field.


REGRESSION MODEL
AD VALOREM & FIT
ACTUALS
FIT
RESIDUAL SUM OF SQUARES
0.474
Periods 1996 to 2017(Seasonality of 1)




Invalid forecasting models are like high blood pressure—dangerous to the health of the enterprise but without symptoms—until it is too late.




This is the valid time series model. See the difference? These models are called ARMAX (Autoregressive–Moving-Average model with eXogenous inputs). ARMAX is not just regression on steroids, it is ARIMA on steroids. It corrects some of the assumptions of ARIMA and adds the capability to validly and explicitly model time series effects that ARIMA homogenizes. It is substantially more flexible in its ability to capture virtually all time series characteristics while satisfying necessity and sufficiency.

# TIME SERIES MODELING

- VARIABLES KNOWN & UNKNOWN
- PULSES
- DETERMINISTIC TREND DETECTION
- INTERVENTIONS
- LEVEL SHIFTS
- SEASONALITY OF ANY TYPE

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The list on this slide and the next includes aspects of models captured by proper extended-capability ARMAX time series modeling.

# TIME SERIES MODELING

- CAUSAL VARIABLE FORECAST INTEGRATION
- X & Y VARIABLE UNCERTAINTY PROPAGATION
- SIMULATED CONFIDENCE INTERVALS
- TIME & CALENDAR PECULIARITIES
- ANTICIPATORY LEAD EFFECTS
- STATISTICAL VALIDITY

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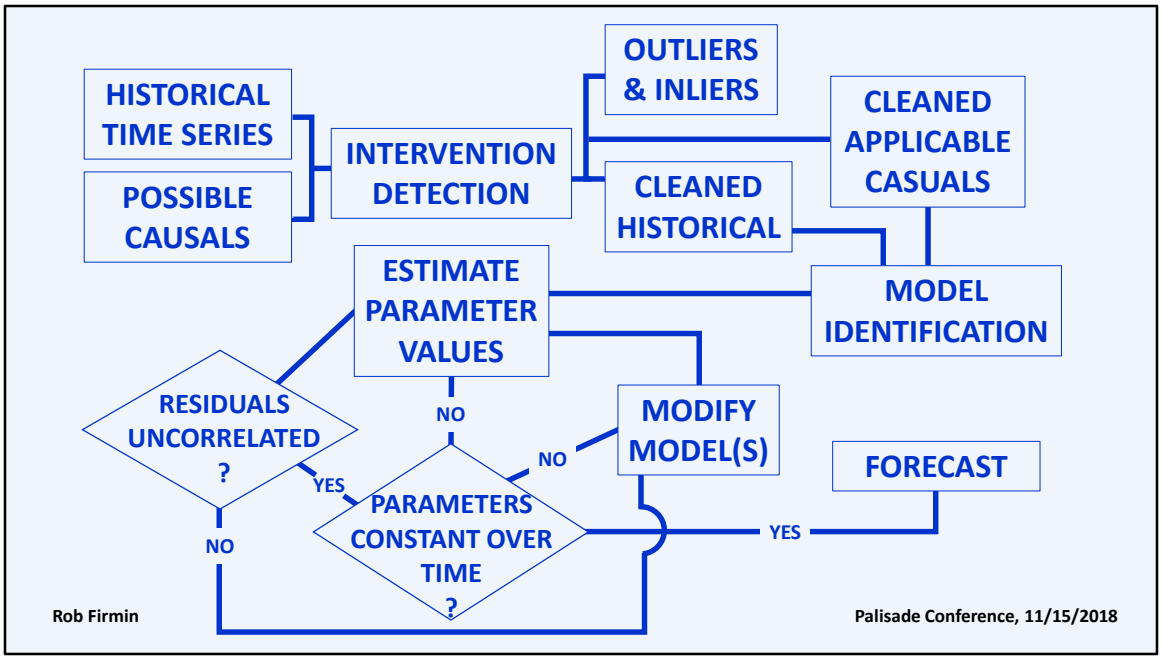
All time dependent. A comprehensive ARMAX modeling system incorporates all of the listed capabilities, plus others. It is sufficiently flexible to permit users to begin with a theory about the data and proceed with ARMAX modeling from it, to discover whether the theory is sufficient.




A SUPERFICIAL FLOW CHART ON HOW OPEN-MODEL TIMES SERIES MODELS ARE BUILT. EVERY STEP CONTAINS ONE OR MORE STATISTICAL TESTS, E.G., CHOW (MODEL DYNAMICS CHANGE) AND TSAY (VARIANCE CHANGE).

# TRUE TIME SERIES

# MANY STEPS
# MANY ITERATIONS

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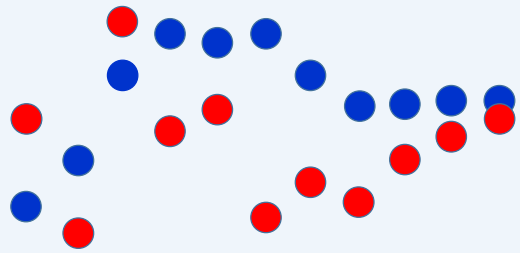
Each iteration engages multiple statistical diagnostic tests to determine the adequacy of the model. It may require many iterations to arrive at the best solution that satisfies the statistical criteria for a model that includes everything it needs and excludes what is superfluous—the correct temporal structure.

## SIMPLE HYPOTHETICAL EXAMPLE



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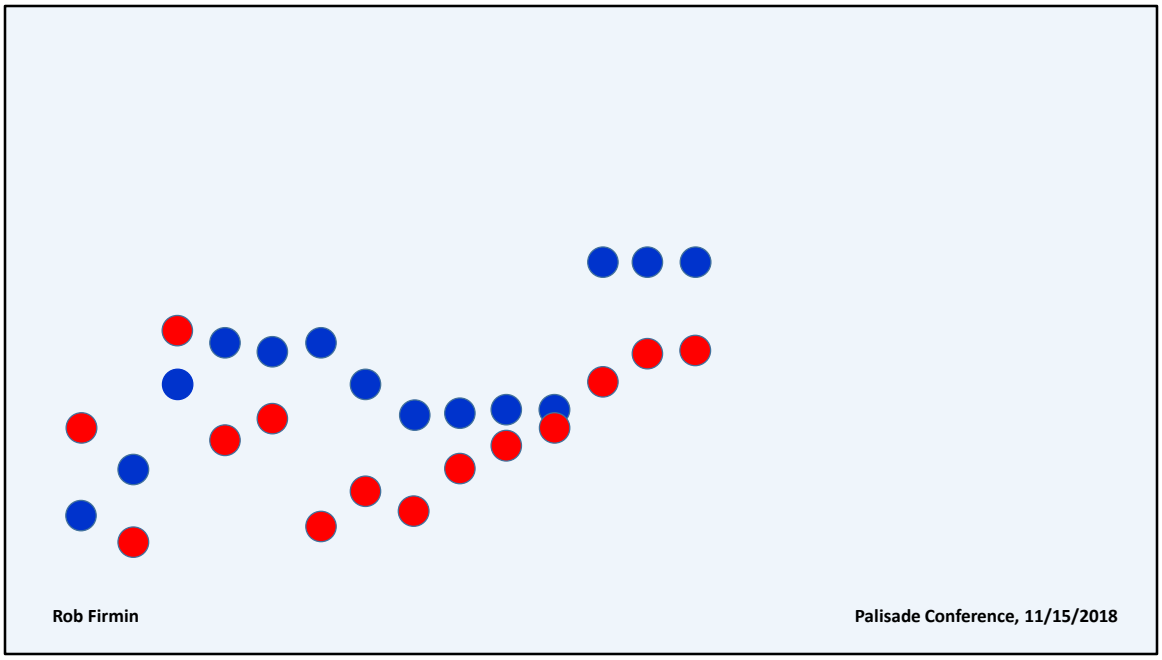
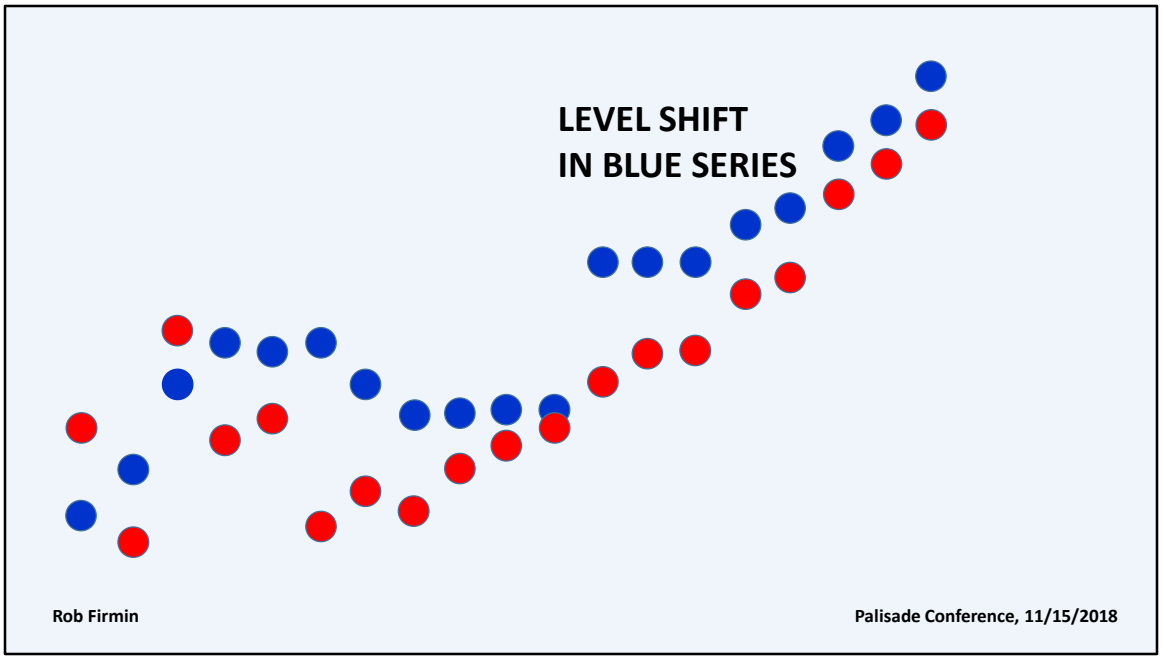
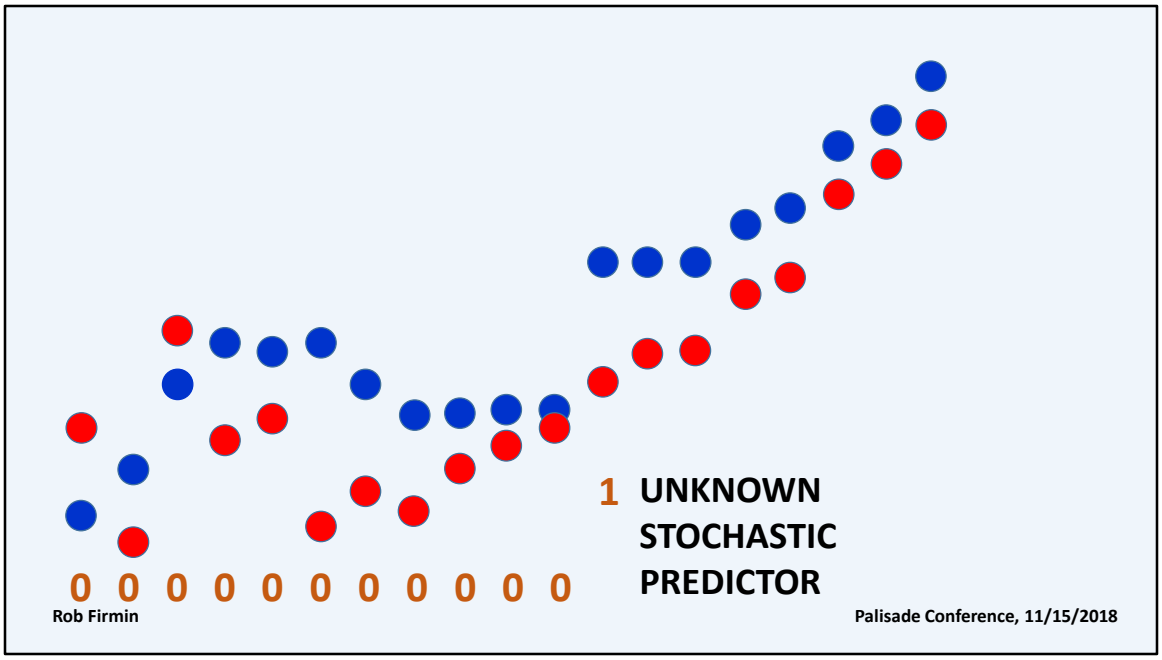
Example of two hypothetical time series. Not much happening—not much of a relationship.



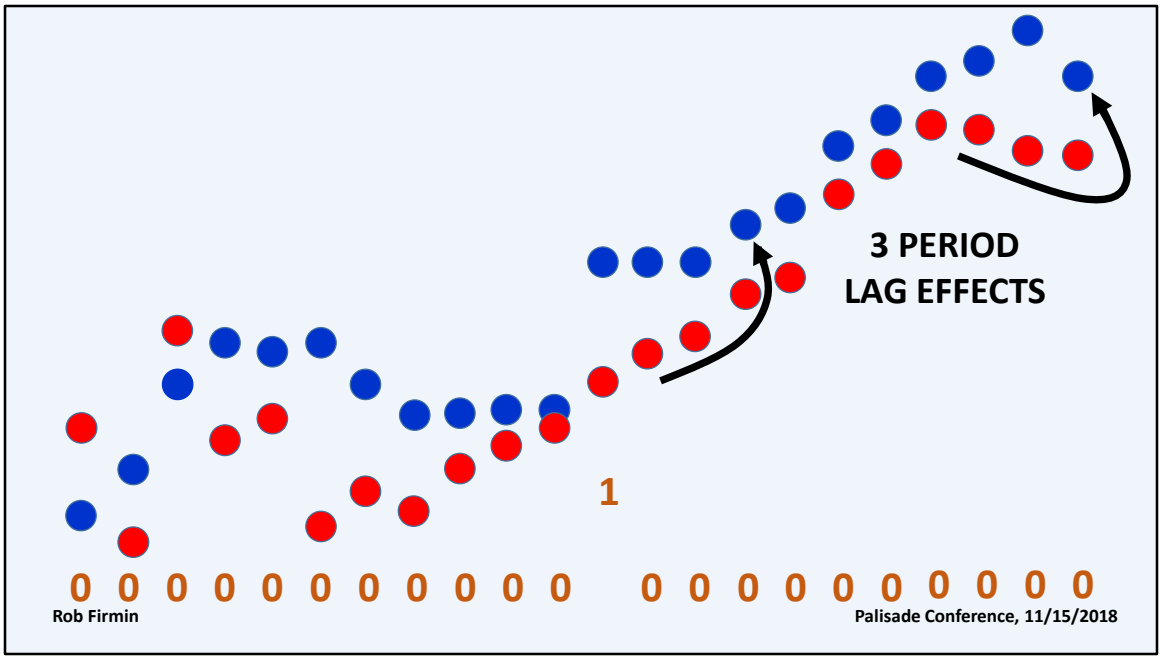

But as time proceeded the blue series responded to a more ordered movement in the red series, AND, something is causing the blue series to shift upward.




These illustrations show steps separate from the necessary modeling of how much the blue series' past behavior persists—these changes can be captured and incorporated into a proper time series model.

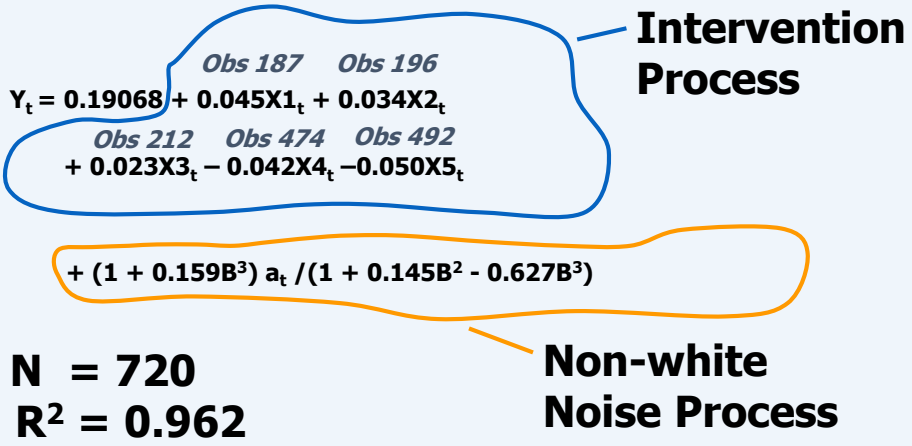



The model attributes the level shift to a variable not included in the data being analyzed. So it created it. Experts in the subject matter under study may be able to realize what it is, (e.g., earthquake, wildfire, election, a new product introduction), and possibly use it in what-if scenarios.




Modeling has identified three major parts to the temporal structure of how these two series relate. The early periods' relationship is weak or non-existent. The level shift is significant. The rest of the time periods exhibit a separate joint temporal structure that is dominated by a 3-period lag effect from the red series to the blue. Consequently, the series is described by two models: the first describes the early part of the series as a virtually non-existent relationship; the second describes an AR transfer function plus a level-shift intervention caused by an unknown stochastic predictor.

# INTERVENTION EQUATION EXAMPLE




**N = 720**

**$R^2$ = 0.962**

Process control example. Final model is ARMAX that includes interventions. Appropriate intervention modeling allowed the expert time series system called Autobox to find not only representative AR and MA parameter estimates, but what we called anomalies earlier in the presentation—without resorting to ad hoc methods. The variables X1 through X5 are simulated level shift variables. The sequential observation numbers (sequential seconds) in yellow denote the place at which each level shift begins. The level shifts have steps. Note that the data are not differenced. Differencing is not always called for. This is an explanatory model that can provide not only the best forecast, but the best diagnostic model.

# ARMAX EQUATIONS IN GENERAL

$$y_t = \frac{\omega_t(L)}{\delta_t(L)} X_{t-b} + \frac{w_t(L)}{d_t(L)} I_{t-\tau} + \frac{\Theta_t(L)\theta_t(L)}{\nabla_t \nabla_t^s \Phi_t(L)\phi_t(L)} e_t,$$

*where*

$y_t$ = *dependent series*

$\omega_t(L)$ = *lagged or led polynomial of* $\omega_t$

$\theta_t(L)$ = *nonseasonal moving average polynomial*

$\Theta_t(L)$ = *seasonal moving average polynomial*

$\nabla_t$ = *first difference*

$\nabla_t^s$ = *seasonal difference*

$\phi_t(L)$ = *autoregressive polynomial*

$\Phi_t(L)$ = *seasonal autoregressive polynomial*

$X_{t-b}$ = *time varying parameters (prewhitened and differenced if nec.)* $_{b=\text{time lag}}$

$I_{t-\tau}$ = *computer based automatic intervention detection and modeling* $_{\tau=\text{time lag}}$

*(outliers, seasonal pulses, local trends, level shifts, etc.)*

$e_t$ = *disturbance*



These are terms considered in ARMAX modeling. It does not show the processes employed to derive their values for final models.

# TIME SERIES EXPERT SYSTEM

# FULLY AUTOMATED STEPS AUTOBOX FORECASTING SYSTEMS

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Autobox is the only system that automatically determines the best ARMAX model from the data presented to it. It offers the ability to modify terms or test theories of how the model should work. But the automatic system is excellent and fast. Among its unique aspects, it incorporates uncertainty of its independent transfer function variables into models and forecasts, and the only system that detects deterministic trends, as seen in the list in slides 42 and 43. Autobox can include Delphi-type variables (with pre-knowledge of an X variable's uncertainty)—an Autobox user can specify a cumulative function of an X (independent or causal) variable, e.g., an @RISK-fitted distribution), i.e., a Delphi-type variable.

# INTEGRATING AUTOBOX EQUATIONS INTO @RISK

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Autobox model equations and results are integrated into @RISK manually at this time. Autobox outputs tons of data about each model, including its properly simulated confidence limit distributions for each forecast time period. These values can be fed into @RISK where distributions are fitted and thereby integrated into @RISK simulations. The Autobox model equation becomes just another @RISK formula in the @RISK Excel model.
NOW BACK TO EXPLAINING TO POLICY MAKERS

# EXPLAINING UNCERTAINTY

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to policy makers

# POINT-ESTIMATE MODELS

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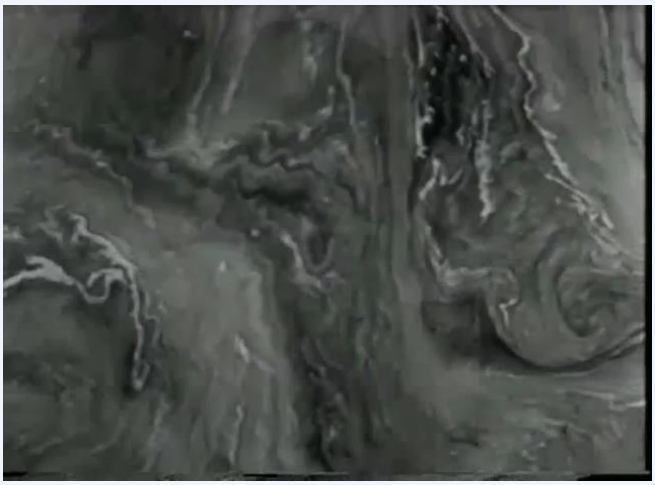
Point-estimate models, models that use and forecast a single datum per period, are analogous to a clock mechanism. They are deterministic—the gears' teeth and their ratios—the relationships between variables and their single-point certainty in each time period—do not change.

# PROBABILITY MODELS



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**See this slide as an animation, and stop after 4 seconds.** Probability models incorporate uncertainty, analogous to thick clouds pushing against each other. But the superficial randomness may be obscuring strong underlying motion-memory within each series, as well as strong relationships between them. Researchers and decision makers want to know the NATURE of the underlying phenomena—they want a model that tells them how the series work, so that they can understand what is important and thereby get a better idea of what to expect and what to do about it. ARMAX models can provide incredible fits, which is important, but what is most distinguishing is the existence of a relatively comprehensive and comprehensible model.

# POLICY MAKERS UNDERSTAND STRESS TEST

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As with stress tests for large banks. They provide information on what can happen and the ranges of possible consequences.

# EXAMPLE:
# CONDITIONS SCENARIOS

| | WILDFIRE | HOUSING | POLICE HQ COST |
|---|---|---|---|
| HOUSING | x | | |
| POLICE HQ | x | x | |
| CalPERS | x | x | x |

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Stress tests need to combine possible background conditions with plans for potential initiatives.

# EXAMPLE:
# POLICY STRESS TESTS

| | # OFFICERS | PAY OFF DEBT |
|---|---|---|
| PAY OFF DEBT | x | |
| BUILD HQ | x | x |
| RENT HQ | x | x |



This is an example of possible policy combinations.

# INTEGRATE MODELING INTO BUDGET CYCLE

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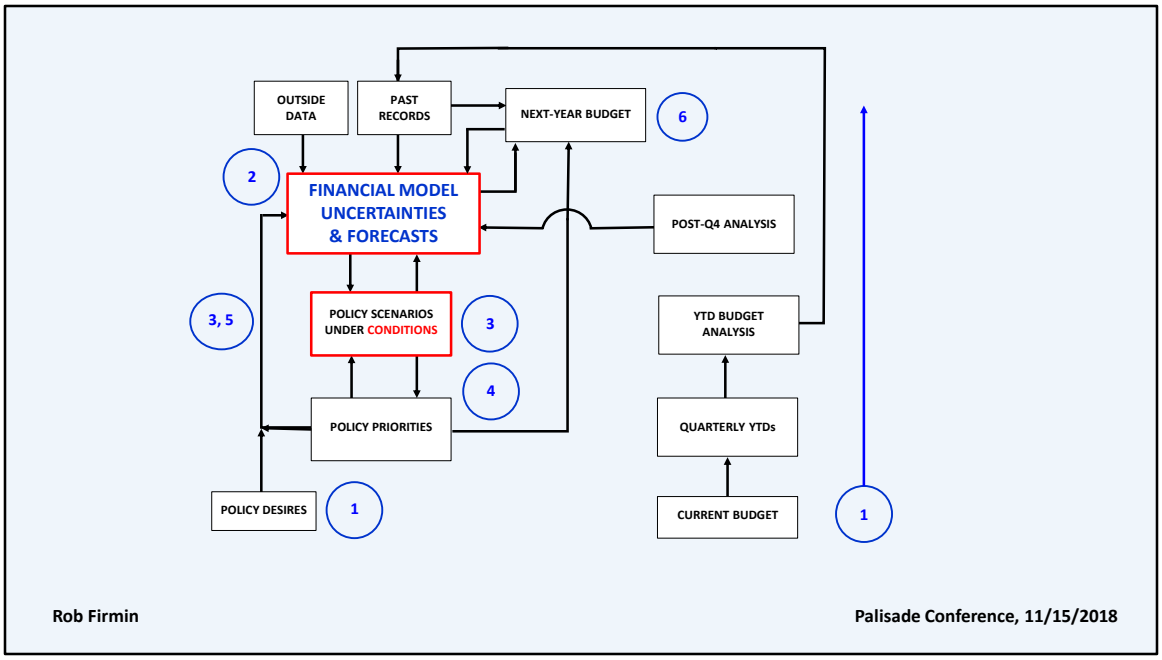
To get policy makers to actually use modeling it is critical to bolt it into the decision-making cycle as a scheduled activity. Model results do not make decisions, but interact with decision makers to stress-test alternative policies, ultimately helping them decide what to pursue and what to delay or forget.




Example of an initiative stress-testing budgeting system. Time series modeling and forecasting, integrated into a larger uncertainty financial model, is a mandatory and iterative step in the annual budgeting process.

# FORECAST BENCHMARKING

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Time-series modeled forecasts can be used to establish a benchmark to estimate what will happen if the dynamics of the past continue to evolve forward into the future. Policy initiative forecasts are then modeled to understand how they may alter the future relative to the benchmarked future.

# FORECAST BENCHMARKING

# TIME SERIES INTEGRATED IN @RISK PROBABILITY MODEL

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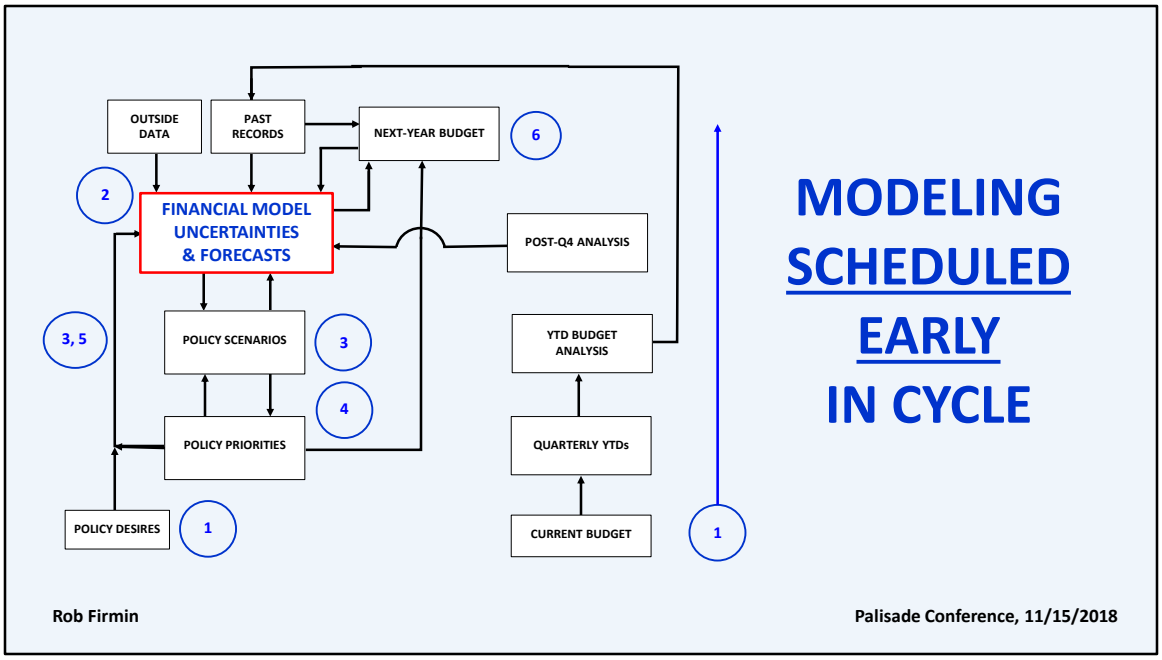
Time series integrated into probability models inform a powerfully rational planning system.




Cannot over-emphasize importance of including modeling in the budget and strategy schedules.

# YOU CAN GAIN POLICY MAKERS' CONFIDENCE IN MODELING

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OR ANY OTHER AUDIENCE

# GET WITH THE FLOW!

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