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Media Mix Modeling vs. ANCOVA

An Analytical Debate

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What is the best way to measure incremental sales, or “lift”, generated from marketing investment dollars?

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Measuring ROI From Promotional Spend

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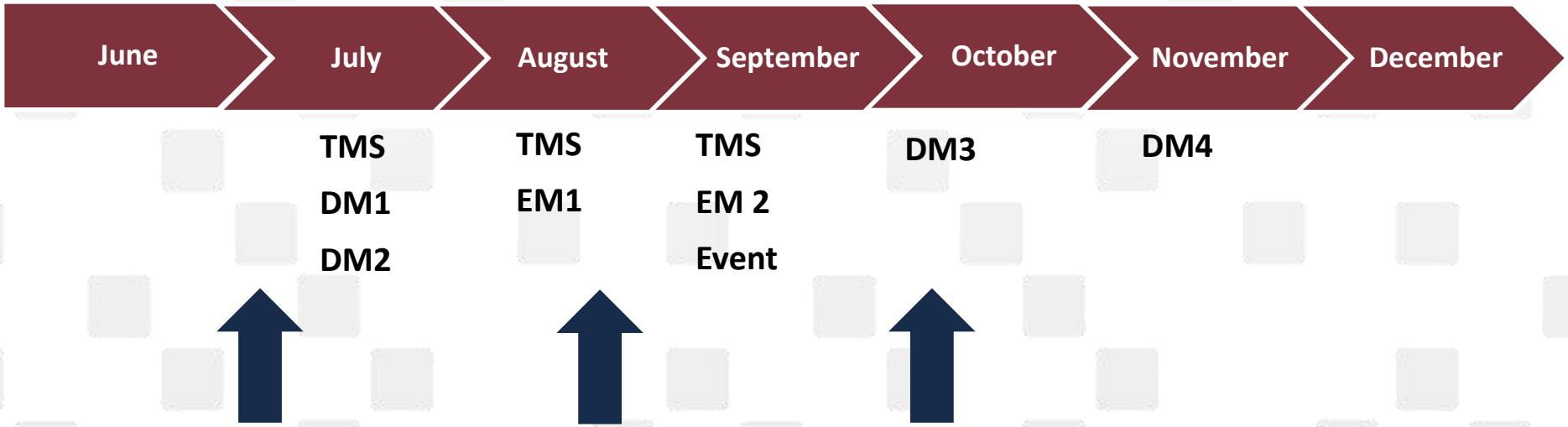
Where possible to implement, an experimental design that uses a randomly selected holdout group provides the most statistical power and reliability in marketing measurement

Sample Direct Marketing Campaign Plan: 2012



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Use Randomization to Increase Statistical Power

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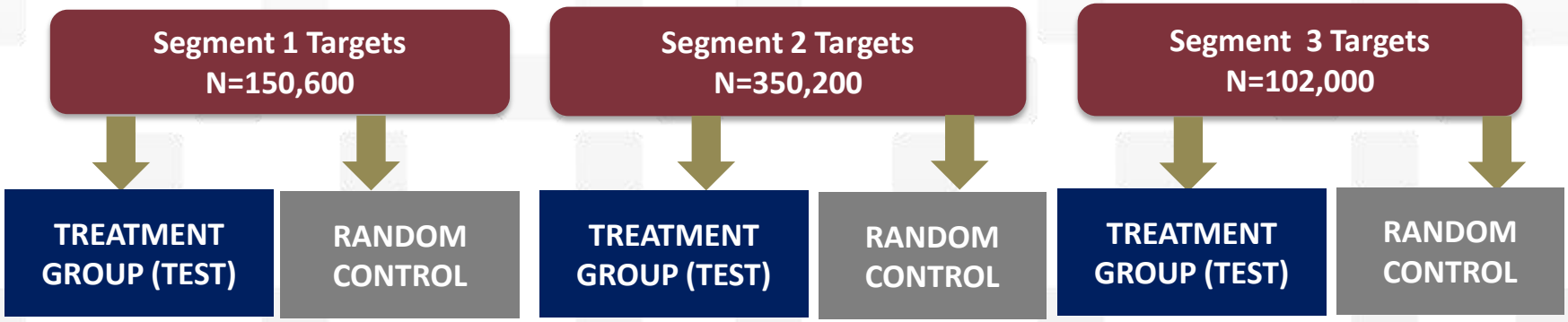
- Holdout sample should be selected from the lowest level of the experimental design and each treatment cell should have a corresponding randomly selected holdout group



NOTE: Control group can be much smaller than treatment group. Use sample size calculator to determine minimum possible sample size for control group

Sample Size Calculator

$$SS = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)
p = percentage picking a choice, expressed as decimal (.5 used for sample size needed)
c = confidence interval, expressed as decimal (e.g., .04 = ±4)

Option to apply finite population correction adjustment

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Verify Pre-Campaign Holdout Validity

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PRE PERIOD | CAMPAIGN RUNS | POST PERIOD

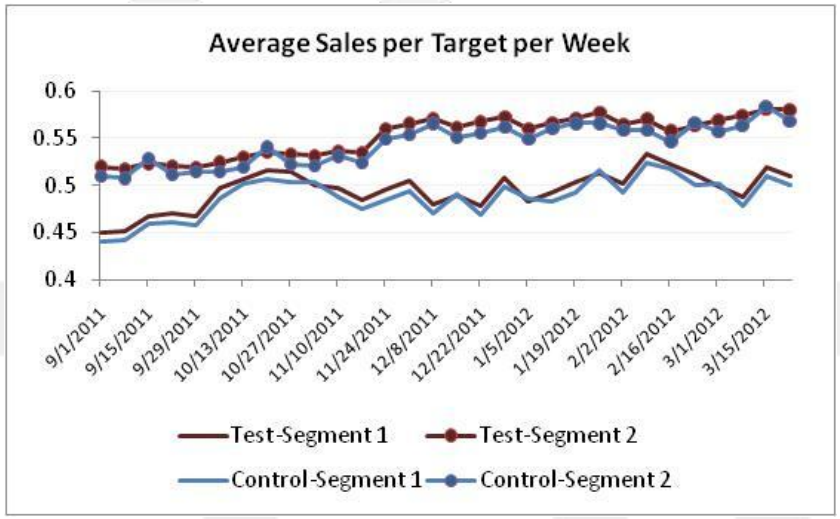
- Random selection of the control group from the target group should guarantee that the test and control groups are equivalent on key metrics prior to the campaign start, but…
- Statistical testing of the difference between pre-period test and control groups on key metrics is an important validation step and adds to confidence in the post-period measurement

P-Values for the Difference Between Test and Control Group Mean Values on Key Metrics in Pre-Period

Sample Metrics	Group1	Group2	Group3
Avg. Sales$	.45	.52	.35
Media Impressions	.82	.84	.61
Other Promotional Spend	.25	.38	.27
Competitor Spend	.31	.45	.24
Demographics	.28	.19	.24

p >.15 is non-significant

Pre-Period Trends: Test and Control Groups



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Measure Pre-Post Launch Change

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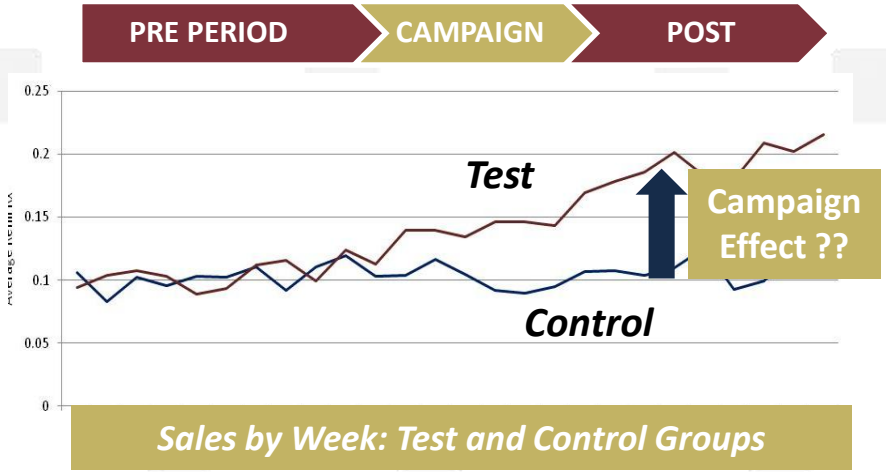
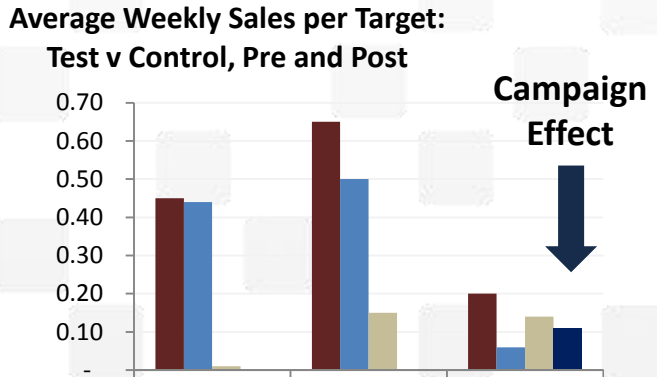
- If the test group and control group are statistically equivalent prior to the campaign launch, then the difference in sales between the groups after the campaign represents the incremental sales contribution of the campaign
- ANCOVA (Analysis of Covariance) test will measure the significance of the difference and also control for other potential factors that could differentially impact test and control groups during the campaign period



Sales by Week: Test and Control Groups



	Pre-Period	Post-Period	Growth From Pre to Post
Test	0.45	0.65	0.20
Control	0.44	0.50	0.06
Test-Control	0.01	0.15	0.14
ANCOVA Adjusted			0.11

ANCOVA Adjusted difference is after controlling for covariates and, if significant (p-value less than .15), is the measure of true incremental sales from the campaign

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Summary: ANCOVA for Marketing Measurement

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Benefits

- Extremely reliable results
- Conservative test
- Control for other factors that may impact volume growth of target relative to holdout
- Able to scale to calculate overall ROI from marketing program
- Expect replicable results if same conditions and weights apply in repeated treatment

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There is another option…

Media Mix Modeling can overcome many limitations of ANCOVA-based analysis

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Limitations of ANCOVA

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- Feasibility of holdout group
- Opportunity cost of being out of market with incremental media
- Selection of test period length is subjective
- Difficult to measure mass & digital media
- No guidance on cross-tactic decisions
- Does not provide insight into future budget allocation decisions
- Does not explain “base” factor contributions

As we will see, Media Mix Modeling will overcome all of these limitations…

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How is Media Mix Modeling Different?

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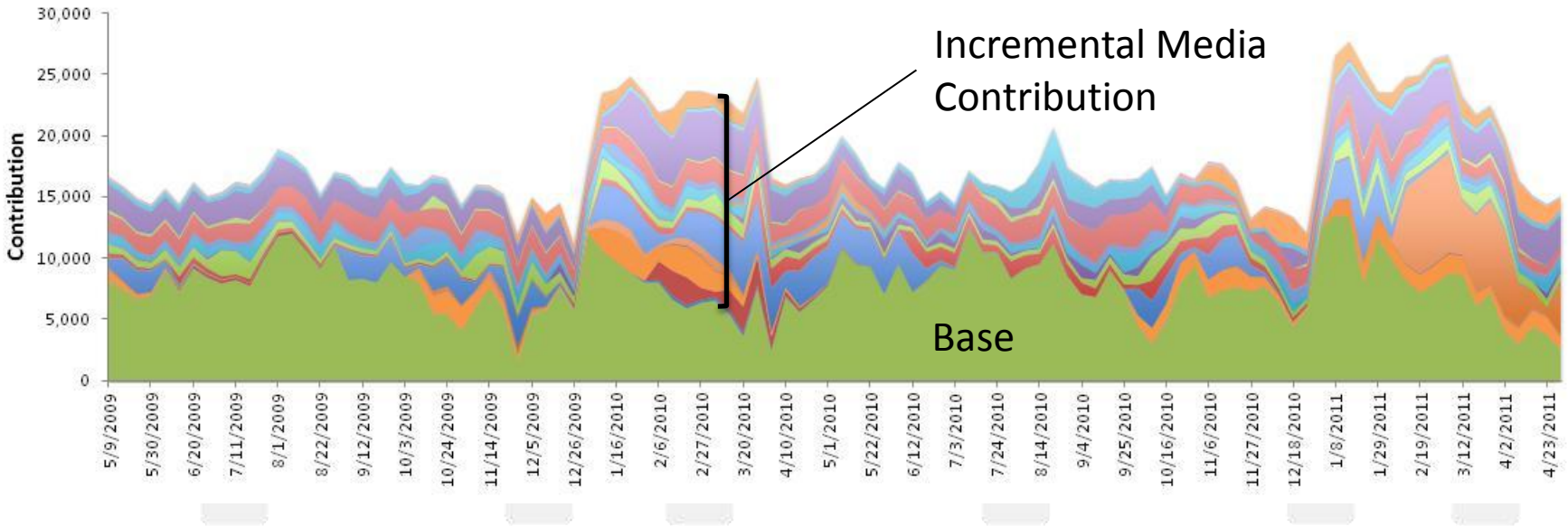
Media Mix Models can be used to understand the ***incremental***, layered effect of ***cross-tactic*** marketing ***over time***…



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What are the Requirements and Process?

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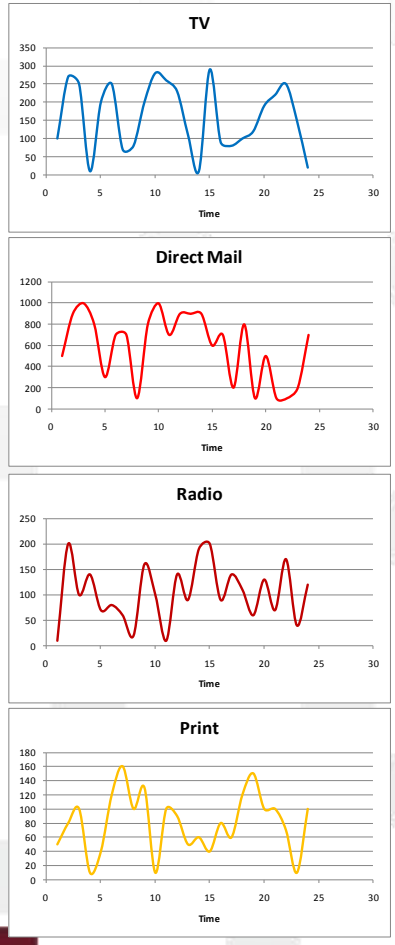
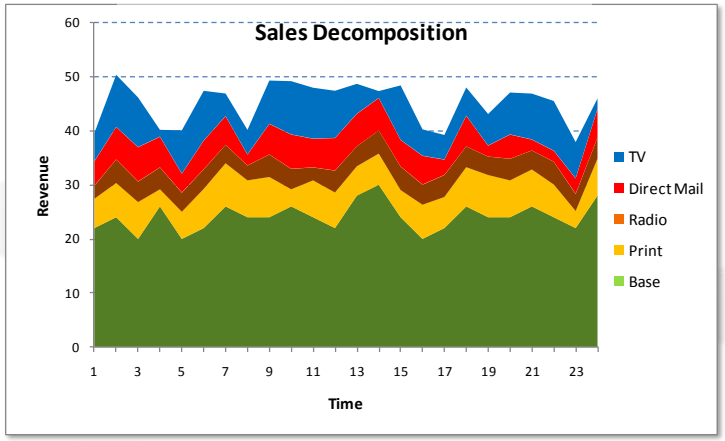
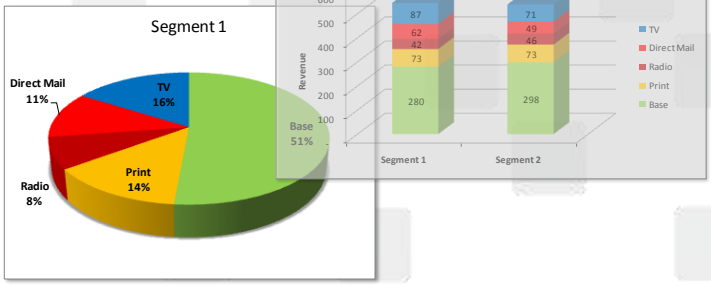
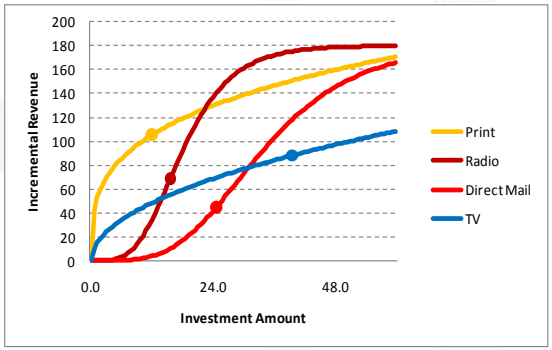
Input Data → **Statistical Models** → **Response Curves & Optimization**

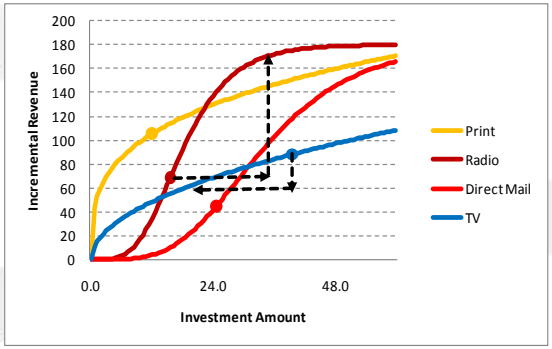


$$y_t = \alpha + \sum_{i=1}^{p} \beta_i x_{it}^{p_i} + \varepsilon_t$$









Investment

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How Does Media Mix Modeling Work?

Functional forms of model equations…

$$y_t = \alpha_0 + \sum_{l=1}^{L} \beta_l X_{lt}$$

$$y = \alpha_0 + \beta_1 x_1 + \beta_2 x_1^2$$

$$y = \alpha_0 + \beta_1 x_1^{\rho}$$

$$y = \alpha_0 + x_1^{\beta_1} + \ldots + x_L^{\beta_k}$$

$$y = \alpha_0 x_1^{\beta_1} x_2^{\beta_2} \ldots x_L^{\beta_k}$$

$$y = \exp(\alpha_0 - \frac{\beta_1}{x_1})$$

Estimation of equations…

$$\hat{\alpha}_0 = \bar{y}_i + \hat{\beta}_1 \bar{x}_i$$

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

$$\hat{u}_i = y_i - \hat{y}_i = y_i - \hat{\alpha}_0 - \hat{\beta}_1 x_i$$

$$\sum_{i=1}^{n} \hat{u}_i^2 = \sum_{i=1}^{n} (y_i - \hat{\alpha}_0 - \hat{\beta}_1 x_i)^2$$

Functional Forms of Equations

- Functional form of a relationship between response and explanatory variables is determined by factors such as diminishing/increasing returns to scale, (a)symmetry in response, etc.
- Some of the most frequently used functional forms are:

Functional Form	Representation	Return to Scale
Linear	$y_t = \alpha_0 + \sum_{l=1}^{L} \beta_l X_{lt}$	**Constant**
Quadratic	$y = \alpha_0 + \beta_1 x_1 + \beta_2 x_1^2$	**Diminishing**
Power additive	$y = \alpha_0 + \beta_1 x_1^{\rho}$	**Diminishing**
Multiplicative (log-log)	$y = \alpha_0 x_1^{\beta_1} x_2^{\beta_2} \ldots x_L^{\beta_k}$	**Diminishing**
Log-Reciprocal	$y = \exp(\alpha_0 - \frac{\beta_1}{x_1})$	**S-Shaped**

Estimation of Equations

- Example equation

$$y_i = \alpha_0 + \beta_1 x_i + u_i$$

Population equation indicating relationship between x and y; estimated using sample of data representing the population

- Estimation of the 'betas'

$$\hat{\alpha}_0 = \bar{y}_i + \hat{\beta}_1 \bar{x}_i$$

Intercept equals the sample average of y plus the sample estimate of x

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

Sample covariance between x and y divided by the sample variance of x

- Residual

$$\hat{u}_i = y_i - \hat{y}_i = y_i - \hat{\alpha}_0 - \hat{\beta}_1 x_i$$

Difference between actual and predicted, estimate of the unknown error in the population equation

- Sum of Squared Residuals

$$\sum_{i=1}^{n} \hat{u}_i^2 = \sum_{i=1}^{n} (y_i - \hat{\alpha}_0 - \hat{\beta}_1 x_i)^2$$

Ordinary Least Squares estimates minimize the sum of squared residuals

Application of Parameter Estimates

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- How do we calculate contribution for each variable in the model?
  - Multiply coefficient from model ("beta") by weekly model inputs (impressions)
  - Sum weekly values to get total contribution attributable to each media
- Model Coefficient ("Beta") for Display: 0.0000486431

Week	Display Impressions	Contribution
5/30/2009	1,972,606	96
6/6/2009	2,226,734	108
6/13/2009	2,483,358	121
…		
5/7/2011	5,550,921	270
5/14/2011	7,016,425	341
5/21/2011	4,937,705	240

Sum contribution across weeks to get total incremental sales due to Display… **53,415**

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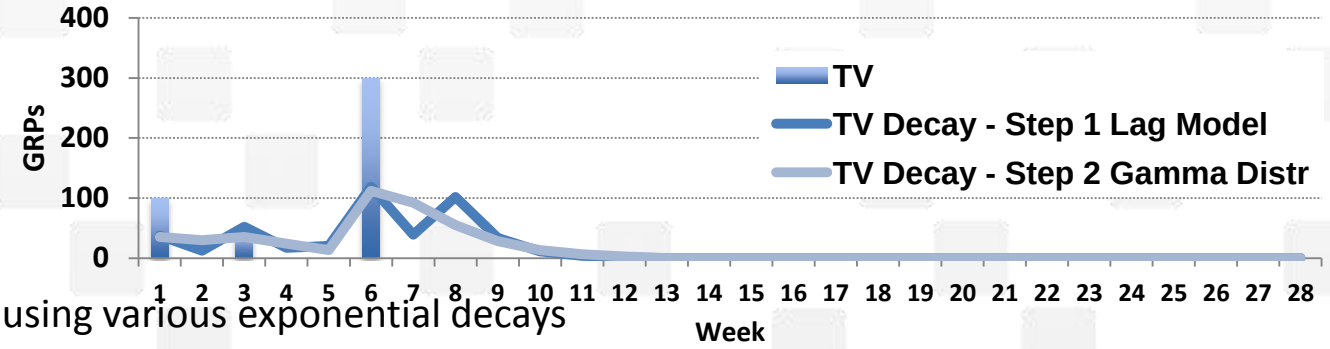
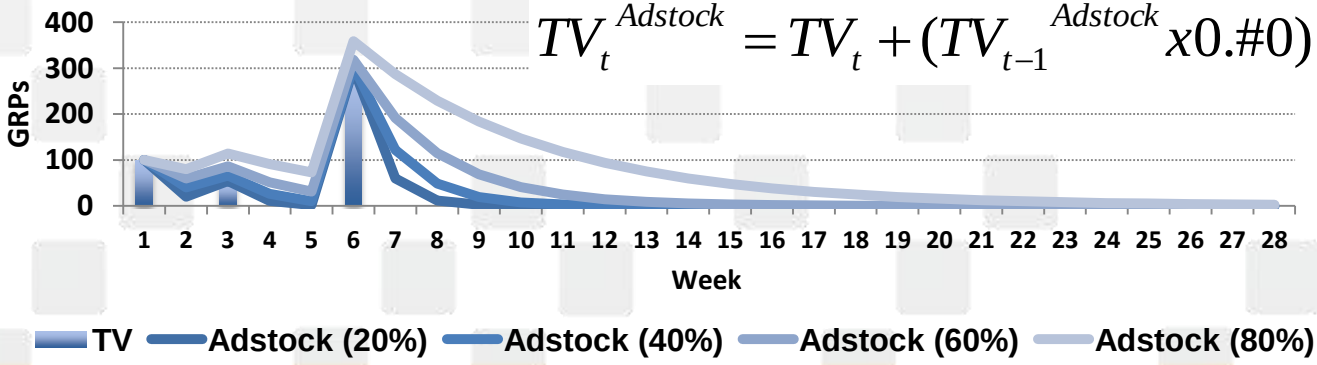
Measurement of time-varying impacts

- "Adstock" refers to the effect of advertising extending several periods after the original exposure
- Estimate using Distributed Lag Model
  1. Estimate model with lagged effects for all media terms – coefficients represent % decay at each lag
  2. Smooth with estimation of gamma distribution to the lagged effect coefficients



- Estimate using various exponential decays

$$TV_t^{Adstock} = TV_t + (TV_{t-1}^{Adstock} x 0.\#0)$$



Toolset of econometric methodologies

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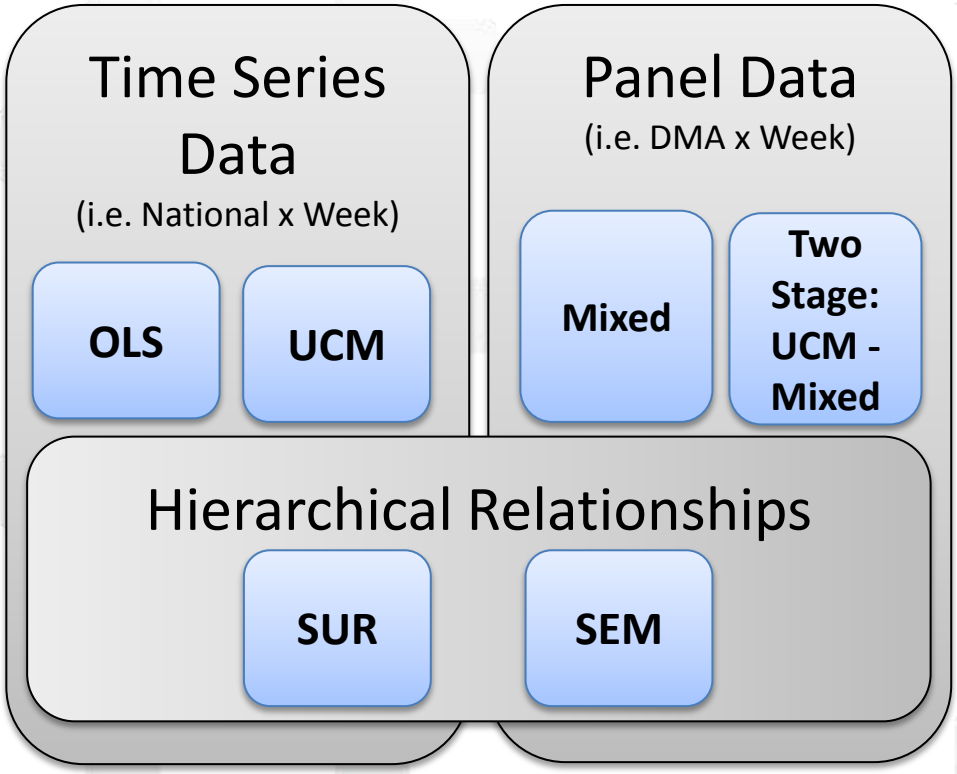
Methodologies used in MMM Analyses

- Ordinary Least Squares (OLS)
- Mixed (Bayesian Shrinkage, Random Coefficients)
- Unobserved Components Models (UCM)
- Two Stage: UCM-Mixed
- Seemingly Unrelated Regression (SUR)
- Structural Equation Modeling (SEM)

Methodology Selection



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Case Study Comparisons

What does each approach offer in these instances?

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Case Study 1: Direct Campaign

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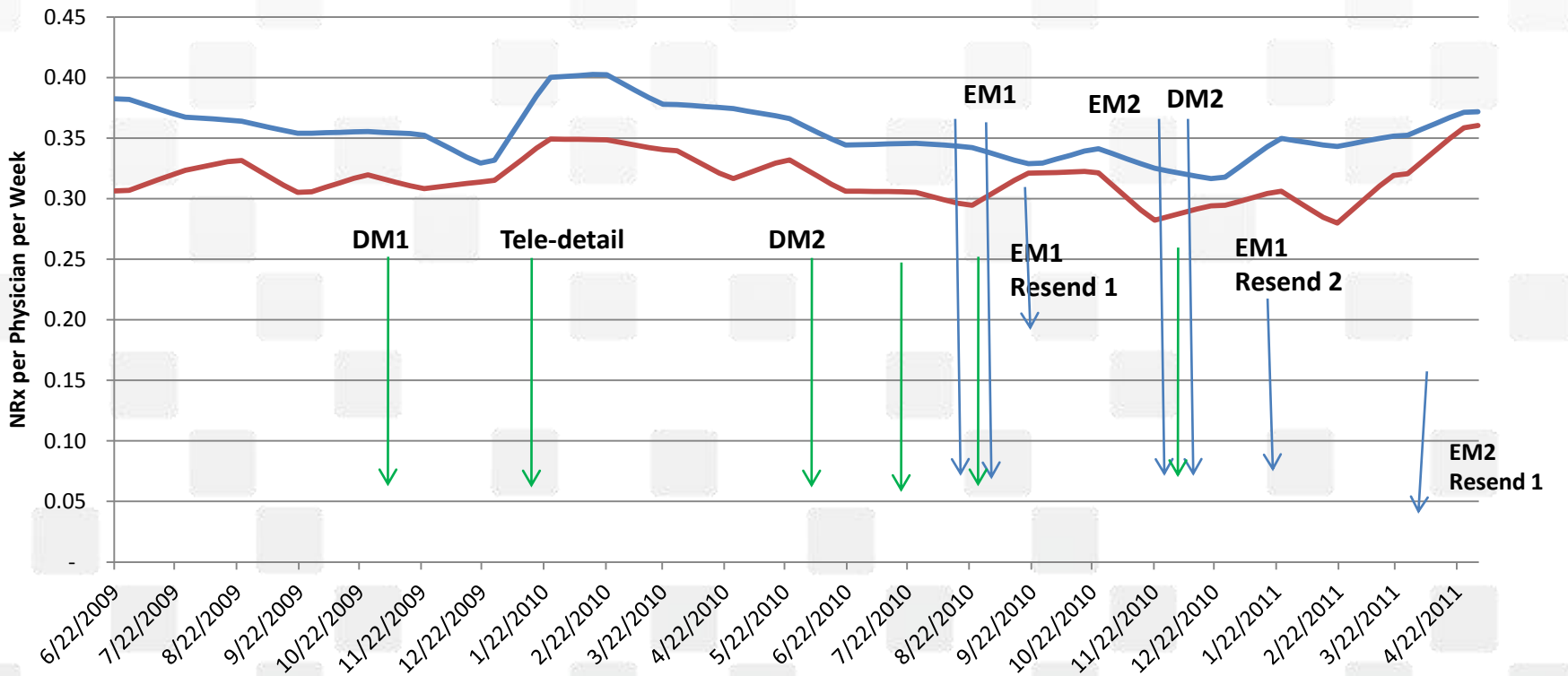
- Typical multi-channel campaign to physicians with mix of tactics deployed in rapid succession across long timeframe
- Capitalizes on use of “universal control group” of non-marketed holdout



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Case Study 1: ANCOVA APPROACH

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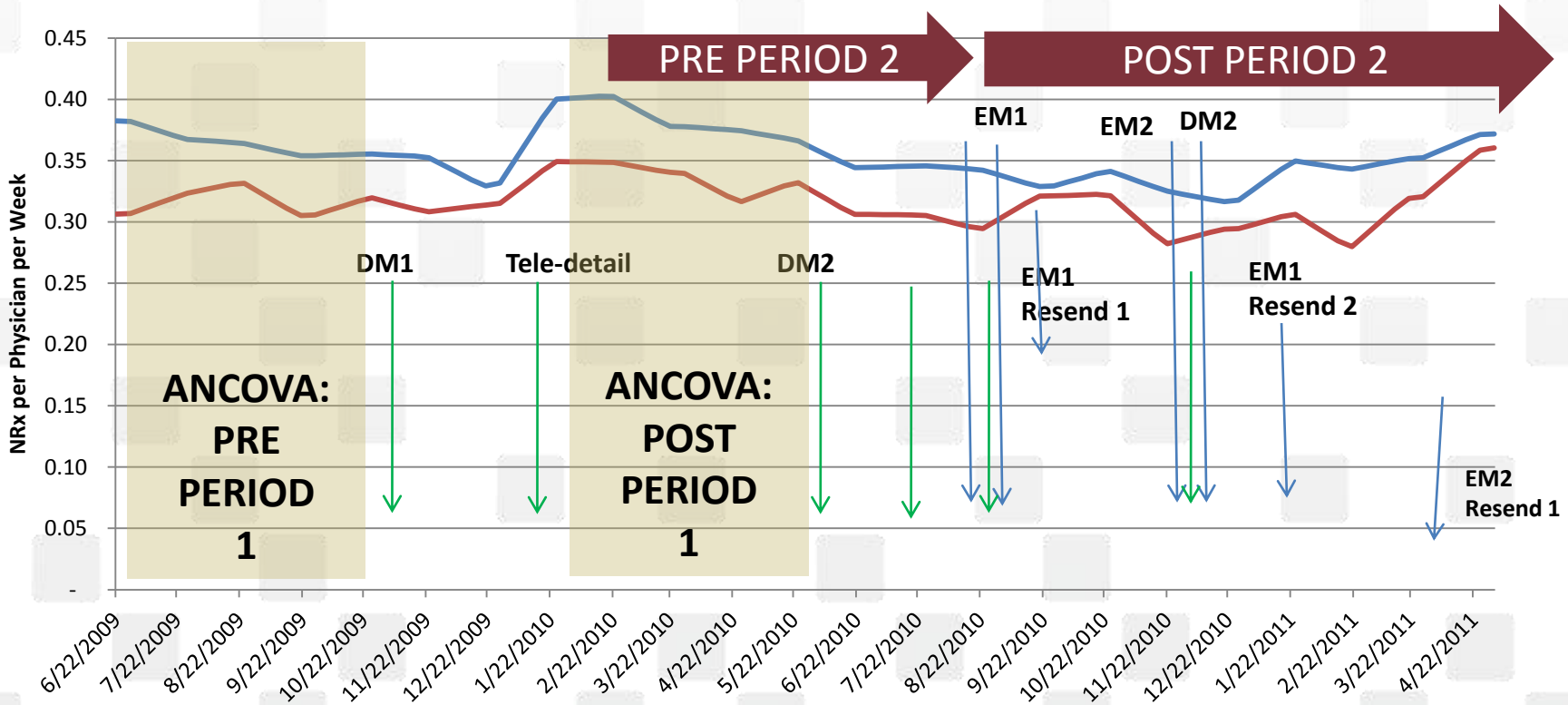
1. Define multiple pre-post periods
2. Conduct holdout-validity tests for each pre-period and each set of test/control groups
3. Measure ANCOVA-Adjusted change in volume using double difference



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Case Study 1: ANCOVA

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	Ancova 1: Time Period 1	Ancova 2: Time Period 2
	Change in Per Physician Prescription Volume from Pre1 to Post 1	**Change in Volume from Pre2 to Post2**
Test	+1.4	+2.5
Control	+0.4	-0.2
Difference	1.0	2.7
ANCOVA-Adjusted	**0.8**	**2.2**
Significance	*.05*	*p* <.001

- ANCOVA could provide solid measurement of overall campaign impact for two different time periods while controlling for other factors
- Per physician increase could be scaled to measure total impact and calculate overall ROI

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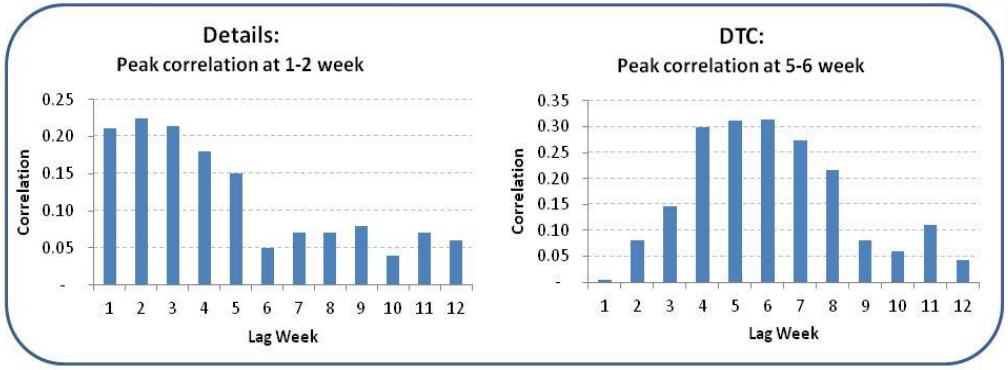
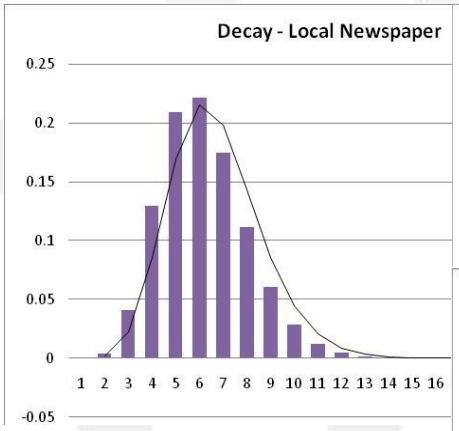
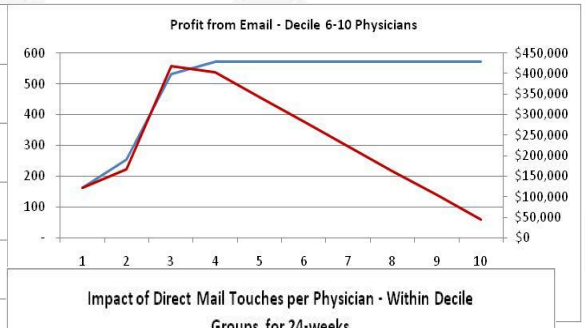
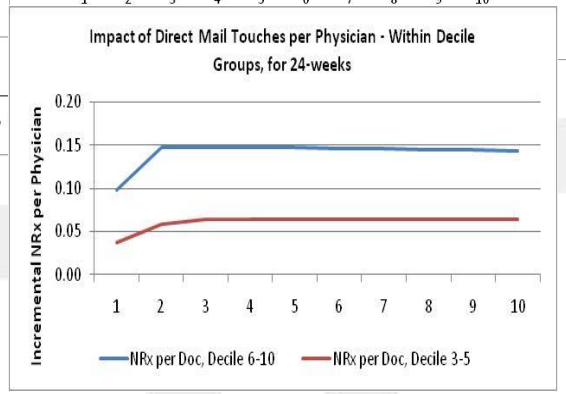
Case Study 1: Mixed Modeling Approach









1. Use correlogram approach fitted with gamma curves to calculate decay curves per channel
2. Transform input variables to account for decay
3. Build model at the physician-week level over 130 weeks of history and all physicians, whether targeted or not in campaign
4. Fit model using best functional form
5. Calculate response curves for each tactic
6. Input into planning tool for optimization

Case Study 1: Campaign Planning From MMO Output

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- MMO equation creates outputs that can be used in a scenario planning tool to test the impact of different investment levels by tactic and calculate expected ROI from varying budget levels

INPUTS

1

Initial Annual Budget	2009	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	$ 25,477,915	$ 28,025,707	$ 22,930,124	$ 25,477,915	$ 27,000,000	$ 32,000,000

Allocate

OR

Input by Media

2

Absolute Spend

	2009	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Details	$ 19,336,346	21,269,981	17,402,711	19,336,346	20,491,525	24,286,252
Samples	$ 3,147,789	3,462,568	2,833,010	3,147,789	3,335,842	3,953,591
Speaker Programs	$ 582,623	600,000	524,361	582,623	600,000	600,000
Voucher Redemptions	$ 644,625	709,087	580,163	644,625	683,136	809,642
WebMD	$ 875,000	962,500	787,500	875,000	927,274	1,098,991
Online Banner (Prof)	$ 203,560	223,916	183,204	203,560	215,721	250,000
Media 1	$ 158,987	170,000	143,088	158,987	168,485	170,000
Media 2	$ 163,549	179,904	147,194	163,549	173,320	200,000
Media 3	$ 207,634	220,000	186,871	207,634	220,000	220,000
Media 4	$ 140,797	150,000	126,717	140,797	149,208	150,000
Media 5	$ 17,005	18,705	15,305	17,005	18,021	21,358
Total Annual Budget	$ 25,477,915	27,966,662	22,930,124	25,477,915	26,982,532	31,759,834

Final Budget

Reset

Simulate Scenarios

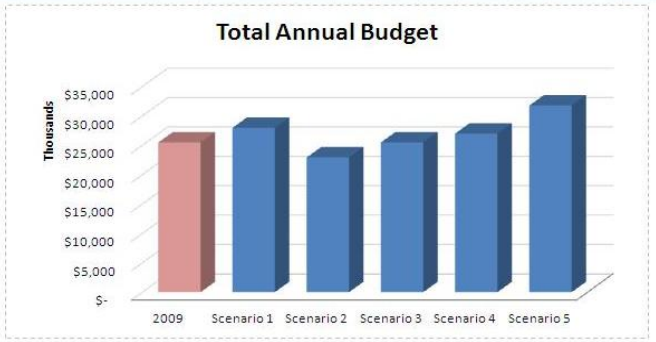
3

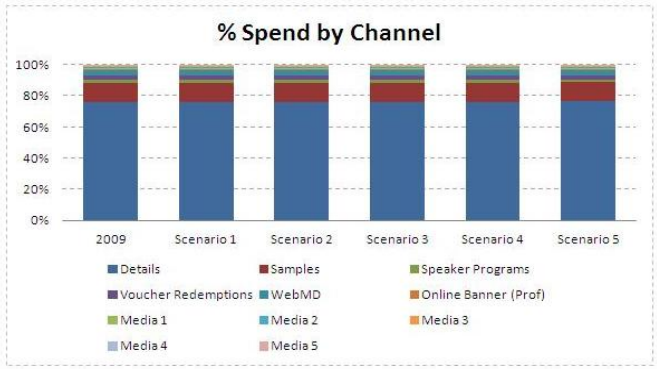
Help:

1. Enter Annual Budget for scenario 1 to scenario 5 and press "Allocate". This will allocate the budget to each channel in proportion to historical allocation (pink colored cells)

OR

2. Modify the budget for any channel (pink colored cells)
   Note: Final budget used for simulation is the budget in the red box (also shown in the charts)
3. Once finished entering the budgets, press "Simulate Scenarios" button to run simulation





… and ANCOVA confirmed lift estimates

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Case Study 2: Web Support Program

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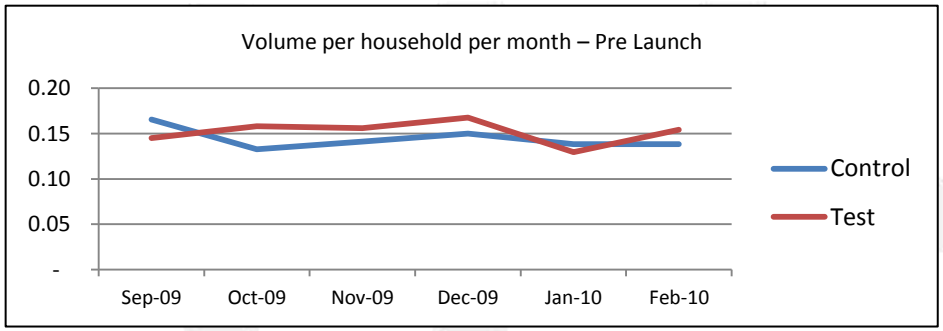
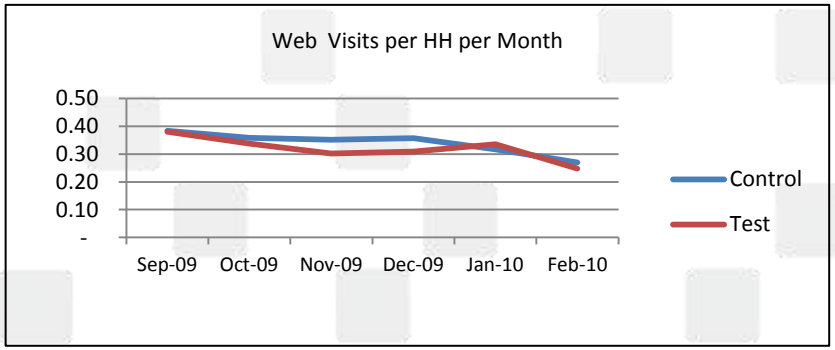
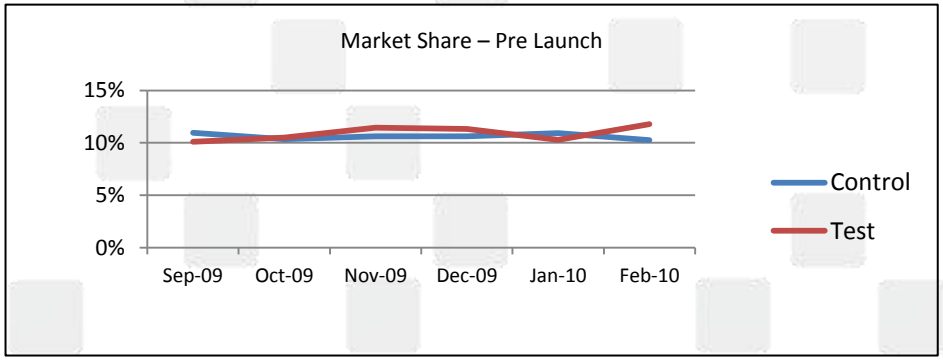
- Situation: Launched consumer support website where consumers register online for product support and information. Consumers only provide zip code in online support registration. Sales not able to be tied directly to consumers but only to geography (zip code)
- Key question: Does consumer support program drive future sales?

ANCOVA Approach:

1) Match consumer registered zip code to most likely purchase zip code
2) Identify control zip codes with no consumer registrations in proximity
3) Test "lift" after web program launches







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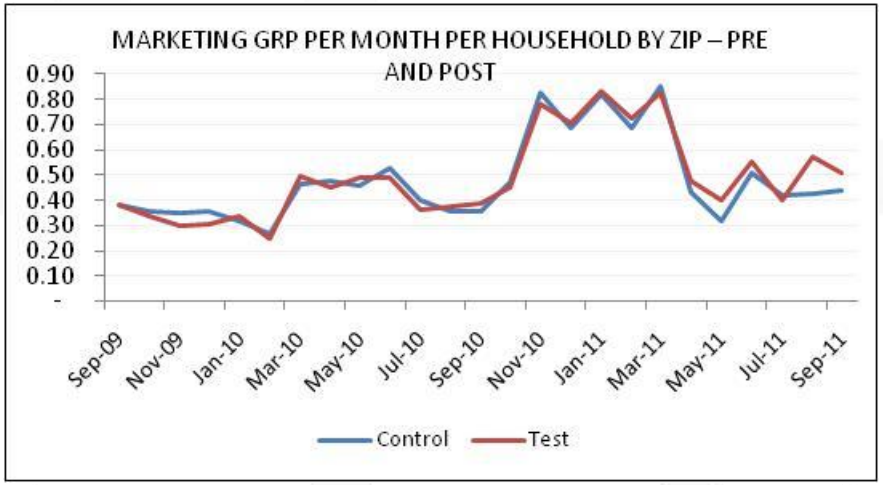
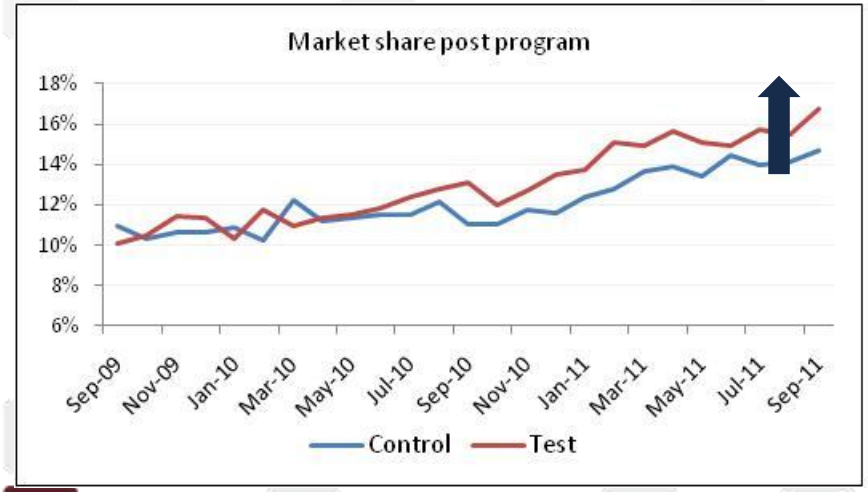
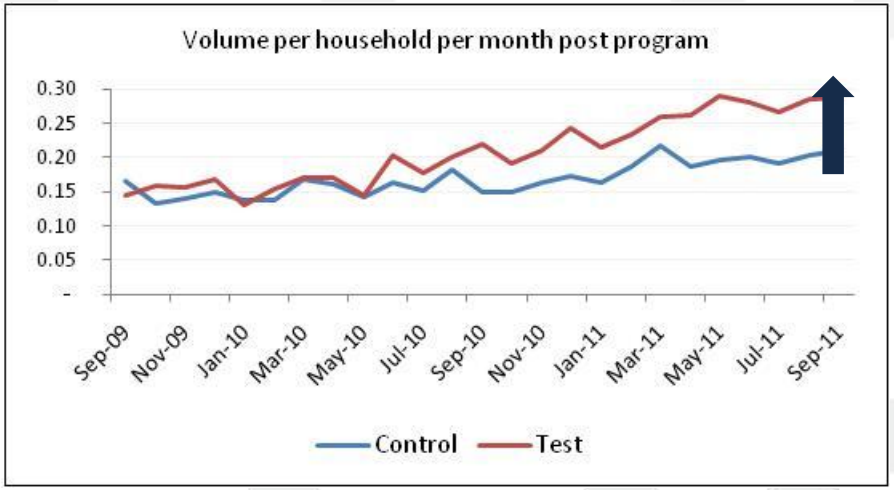
Case Study 2: Possible ANCOVA Output

ANCOVA may demonstrate a link between sales and web support program use

- Test pre-post period differences between zip codes with registrations and with no registrations
- Control for covariates that might influence test zip codes







Case Study 2: Mixed Model Approach

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1. Collect zip-level data on all programs in place, by week, over long time period
2. Calculate contribution of each of the tactics, including the web registrations
3. Compare relative contribution to sales and relative ROI levels of each tactic

Model Output: Quadratic Form

Effect	Estimate	StdErr	tValue	Probt
Intercept	0.126	0.009	13.433	0.000
log_trend	0.025	0.004	6.719	0.000
total_mkt_grp	0.411	0.012	35.333	0.000
sq_total_mkt_grp	(0.139)	0.005	-27.309	0.000
decay_register	5.037	0.755	6.672	0.000
sq_decay_register	(8.051)	2.934	-2.744	0.006
decay_activation1	7.056	0.550	12.820	0.000
sq_decay_activation1	(4.106)	1.586	-2.589	0.010
decay_activation2	0.603	0.077	7.823	0.000
sq_decay_activation2	0.052	0.040	1.297	0.194

Input	Model	ROI
Baseline	52%	
TV GRP	25%	2:1
Registrations	3%	4:1
Activation 1	6%	3:1
Activation 2	7%	6:1
Promotion 1	7%	1:1

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Case Study 3: Cross-Tactic Measurement

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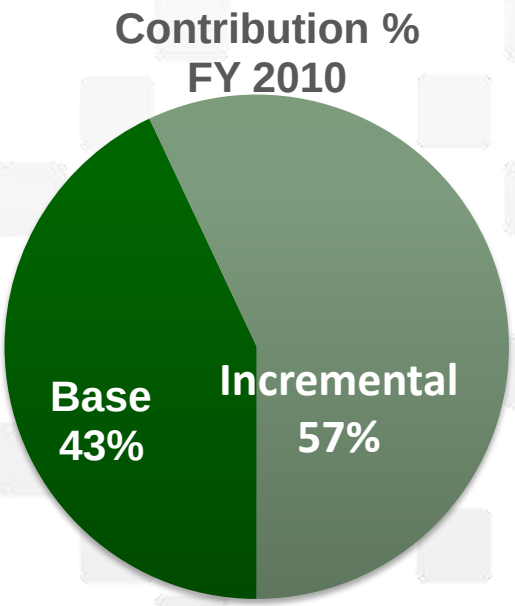
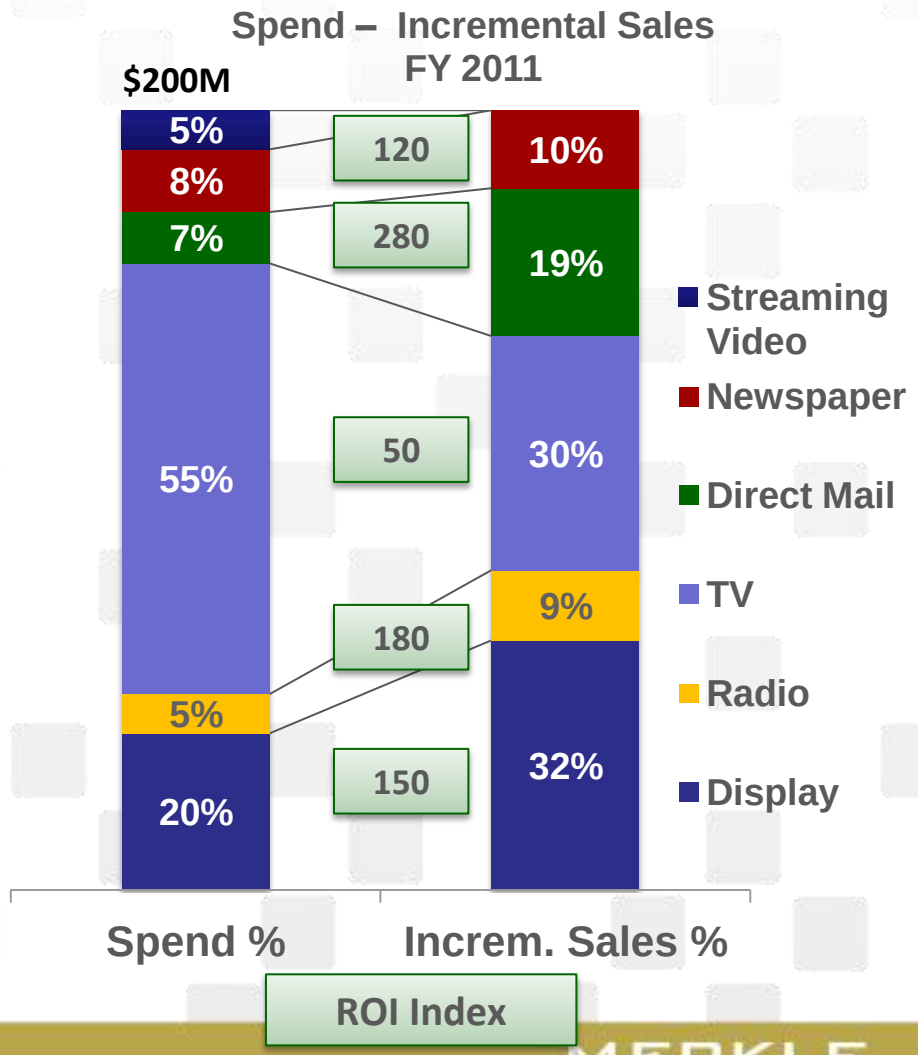
Situation: Large advertising spend – objective is to optimize spend by tactic and geography





Media mix modeling indicates incrementality of media along with indication of ROI across tactics…

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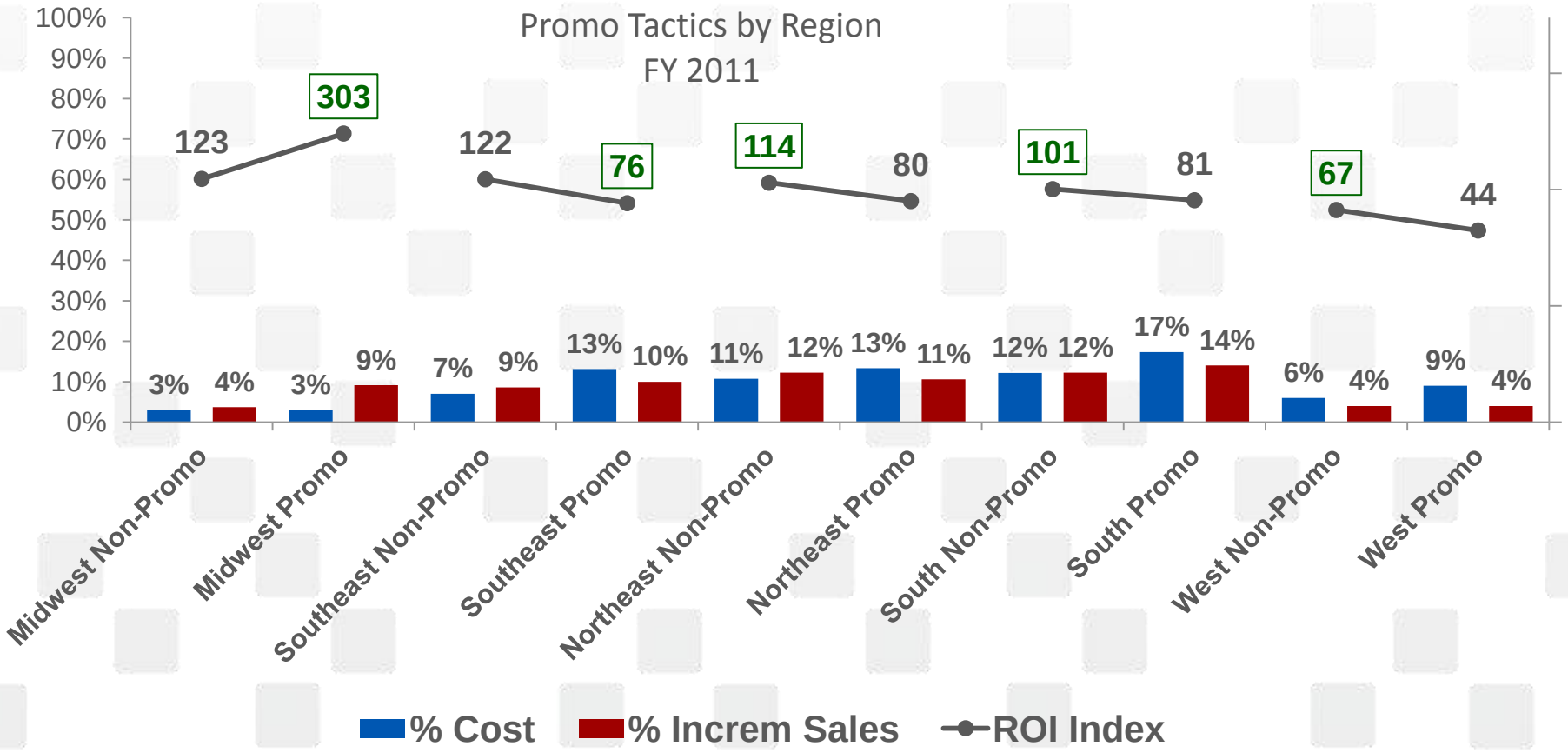
Case Study 3: MMM provides insights into promotional performance by region

ANALYTICS CRM EXCHANGE

Media mix modeling indicates promotional messaging is more effective in the Midwest than all other regions…



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A Best Practice Approach

.. Taking marketing measurement to the next level

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Comparison of Methods

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✓ = Winner on this Attribute	ANCOVA	Media Mix Modeling
Cost	✓ (Depends on # groups)	
Hidden Costs	Cost of withholding promotion from control	✓
Complexity of Execution	Statistics simpler, but test design more complex	✓
Data Requirements	✓	
Measurement Ability	✓	✓
Scenario Planning	Only to repeat exact	✓
Best for...		

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Best Practice Measurement Framework

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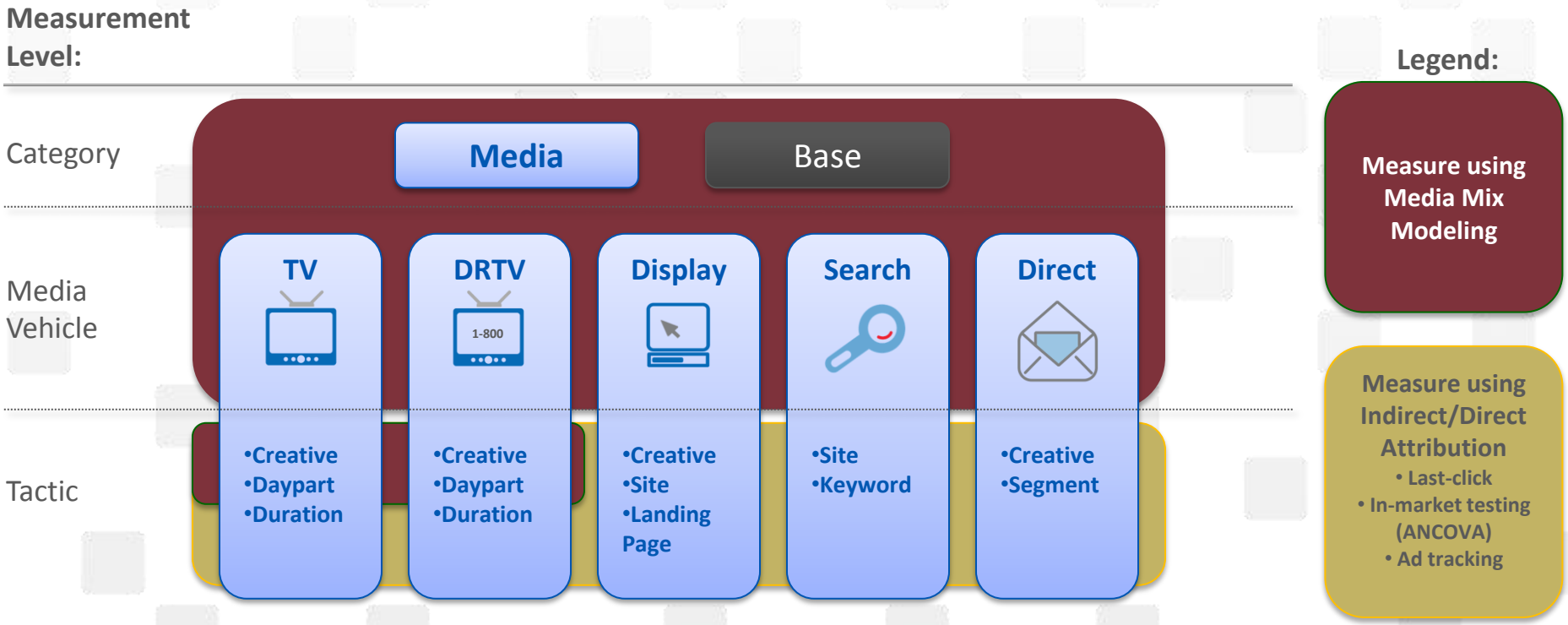
Media Mix Modeling gives best practice estimates of media impacts – both overall and at the vehicle level. The methodology is also extensible to the tactic level, and can be applied in cases where indirect or direct attribution is not feasible. Indirect/Direct Attribution is best employed in relative analyses within a media vehicle, at levels of granularity not possible via traditional mix modeling (i.e. search keywords).



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