

## Abstract

- There's a trend towards alternative, safer chemicals
- California's Green Chemistry Initiative and European Union's REACH Program introduced guidelines for chemical safety, hazard assessment
- Firms are encouraged or required to move towards greener chemicals
- We want to understand how manufacturers make tradeoffs in design criteria in chemical substitution decisions
- Our research focuses on using a survey based methodology to elicit tradeoff weights for decision factors and respective drivers

## Background

California's Green Chemistry Initiative (2008) led to the creation of the Safer Consumer Products Program (2013) to reduce toxic chemicals in consumer products

EU's REACH – 2007. Guidelines on risk assessment, and registration and authorization of use of chemicals

Alternatives Analysis (AA) – the process of identifying, comparing, selecting a safer alternative

Many organizations have developed frameworks to help organizations seek alternatives.

## Examples of Chemical Substitution

Replacement of EDTA with IDS as a chelating agent among pharmaceutical firms

Replacement of BPA in polycarbonate plastics



## Approach

- Motivation for research: drivers for substitution not extensively studied in literature
- We used an online survey to elicit information from chemical companies who have done a substitution decision in the last few years
- We asked them to explain what type of decision (new design or re-design) as well as specify if it was a product or chemical
- We sought their responses to 6 factors that contributed to their decision (ranking from 1-10)
- In addition, we also asked them to comment on individual drivers (33) that contribute to each factor We also collect demographic information such as company size and level of the organization

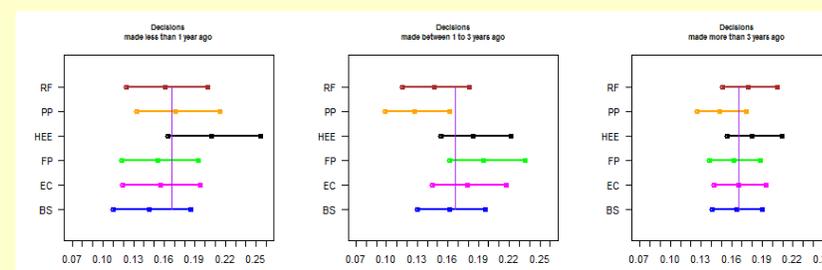
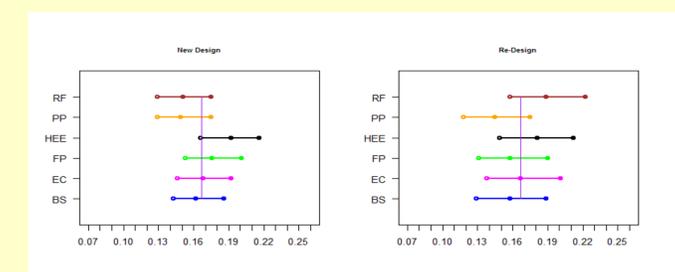
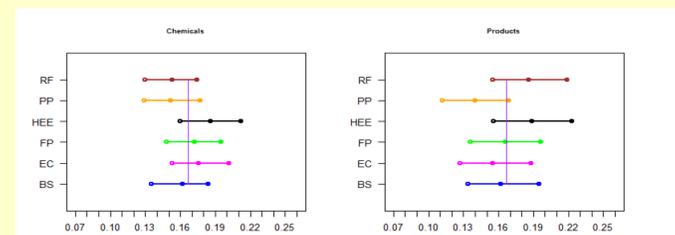
## Methods and Analysis

- **Research Question**
    - What are the tradeoff weights for design criteria in chemical substitution decisions
  - **Hypothesis:**
    - Tradeoff weights will differ based on company size, type of industry (chemical vs. product) and time of decision
- Analysis Approach:
- Use Bayesian Dirichlet Multinomial Modeling to determine whether tradeoff weights were significantly different from equal weighting
  - First, use scaled weights:
 
$$k_i = \frac{S_i}{\sum_{i=1}^{n_f} S_i}$$
  - Let  $\Theta_i$  = tradeoff weights for each category, with vector of weights given by  $\Theta$
  - Let  $f_i$  refer to each factor  $i$  to  $n$
  - Let  $\zeta_j$  be the sum of scores each company gave to the decision factor:
  - $\zeta_j(f_i) = \sum_{i=1}^m S_{ij}(f_i)$  where  $m$  is the number of companies and  $j$  refers to the  $j$ th company.
  - Assume multinomial sampling distribution as the likelihood distribution for the observed sum scores  $\zeta_j$  in each of the six categories, and that the sum scores are proportional to the tradeoff weights  $\Theta_i$  for each category
$$\Pr(\zeta | \Theta) \propto \prod_{i=1}^{n_f} \theta_i^{\zeta_i}$$
  - The tradeoff weights, have a conjugate Dirichlet prior. If we assume an informationless prior distribution, the posterior distribution for the tradeoff weights is also a Dirichlet distribution.
  - We use the posterior distribution to obtain credible intervals

## Results

Pooled Tradeoff Weights						
Overall (n=33)	BS	EC	FP	HEE	PP	RF
Median	0.161	0.168	0.169	0.187	0.148	0.165
90% CI	(0.146,0.176)	(0.154,0.184)	(0.154,0.187)	(0.172,0.203)	(0.133,0.164)	(0.150,0.181)
95% CI	(0.144,0.178)	(0.151,0.188)	(0.152,0.190)	(0.169,0.207)	(0.130,0.168)	(0.147,0.184)

- When looking at pooled tradeoff weights:
  - Both Health and Environmental and Public Perception are significantly different at a 0.10 level of significance.
  - Shows that respondents do not think all factors have equal weight
- Looking at categories:
  - Chemical vs Product: Two categories not significantly different, but Public Perception is significant at 0.10 level (lower for Product)
  - New Design or Re-Design:
    - Health and Environmental more significant at 0.10 level (higher for New Design)



## Discussion

- Companies place emphasis on all six factors in decision making, HEE stands out
  - 64% of respondents said they conduct a formal AA. Most use in house tools, a few use standard tools
  - Those who don't use AA:
    - Barriers include: Time, Cost, Limited Internal Experience, Resistance to Change
- For more information (including more analysis, including principal component analysis on decision drivers):
  - Rao, V., Francis, R.A., Tanir, J.Y. "Analyzing Chemical Substitution Decisions Among Chemical and Product Manufacturers." *Clean Technologies and Environmental Policy*, Vol. 21, No. 2, pp 395-411.
- **Acknowledgements**

The authors would like to thank the following organizations for their work in distributing the survey

  - American Chemical Society
  - Green Chemistry Institute
  - American Chemistry Council
  - Green Chemistry and Commerce Council
  - Health and Environmental Sciences Institute
  - Japanese Chemical Industry Association
  - Toxics Use Reduction Institute