# Minimalism and Model-Building: An assured model of the exchanges among consumers, retailers, and manufacturers

David Midgley, INSEAD
Robert E. Marks, UNSW
Dinesh Kunchamwar, Barclays Capital
Daniel Klapper, University of Frankfurt

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# Agenda

- **purposes:**
  ***assurance* = verification and validation**
- **issues in ABM**
- **assuring ABMs**
- **minimalism, or beyond parsimony**
- ***Supermarket ABM 2.0***
- **verification**
- **validation**

# Simulation and Sufficiency

**Simulations might attempt, inter alia:**

- **to *explain* a phenomenon;**
- **to *predict* the outcome of a phenomenon; or**
- **to *explore* a phenomenon, to play, in order to understand the interactions of elements of the structure that produce the phenomenon.**

**Simulation derives sufficient conditions for the emergence of a phenomenon.**

**Ironically, sufficient conditions are necessary (but not sufficient) for explanation.**

# Consider historical market data:

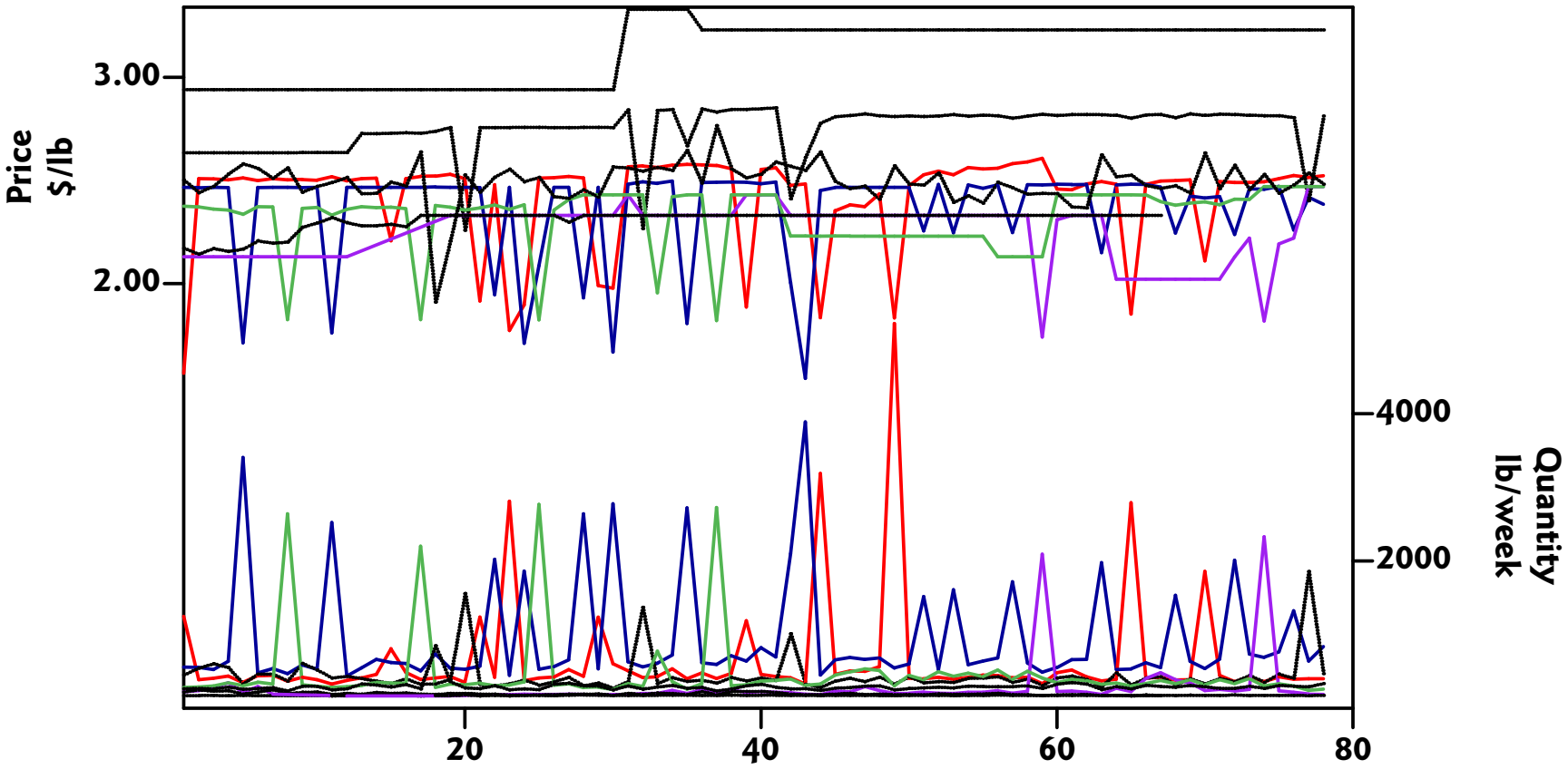


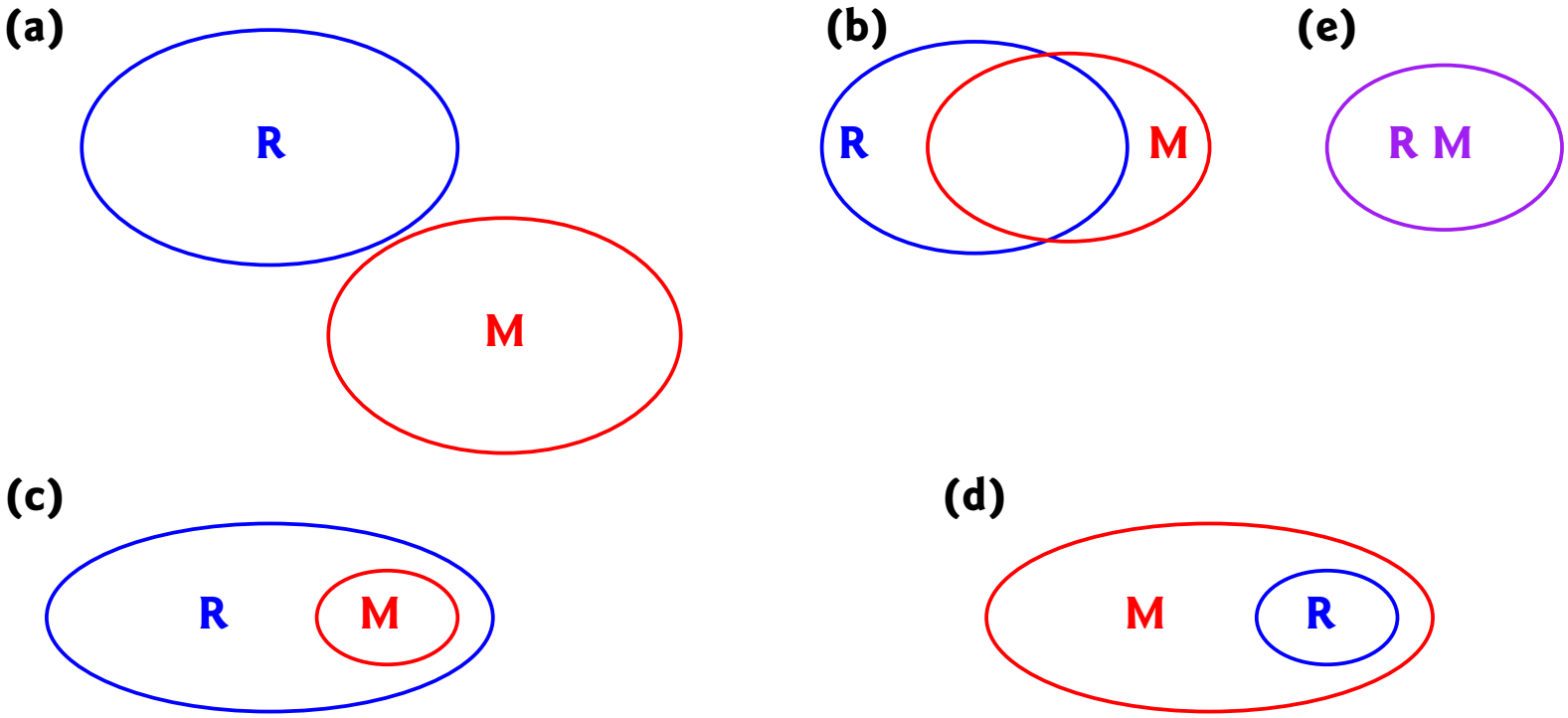

Figure 1: Weekly Prices and Sales (Source: Midgley et al. 1997)
(Coloured lines: Folgers, Maxwell House, Hills Bros, CFON)

# Simulations with Agent-Based Models

**We have been pursuing a research programme of simulation of oligopolistic market behaviour, first, of a ground coffee market, and, today, of a market in laundry detergent.**

**We are searching for simple sufficient conditions to produce observed behaviour, which requires model *assurance*: verification and validation.**

**With a metric in performance space, we can derive a graphical description of five possibilities for validation: model behaviour *M* and real-world phenomenon *R*.**




**Validity Relationships for prediction (after Haefner (2005).**

**M = model behaviour**
**R = historical reality**

**(a) the model is (pretty) useless**
**(b) the model is both incomplete and inaccurate**
**(c) the model is accurate but incomplete**
**(d) the model is complete but inaccurate**
**(e) the model is complete and accurate (in your dreams!)**

# Issues in ABM

- **ABMs have several benefits,**

**but they are computer *simulations*.**

**∴ to liberate their potential, three key issues must be addressed:**

- **— Does the software implement the desired model?**
- **— Is the system always well behaved?**
- **— Can the models be empirically validated?**

- **Recently, we proposed a procedure to address these issues, called model *assurance*.**
  **see Midgley, Marks, Kunchamwar (2007)**

# Minimalism

**Parsimony:**

- **Other things equal, the simplest solution tends to be the best one (from *Wikipedia*: "Occam's razor", and see Einstein too)**

**Minimalism:**

- **What is the simplest solution that explains 80% of the observed phenomenon?**

**Why?**

- **Current science tends to have many subtleties and nuances, pushing explanation from 80% to 90%,**

**but Incorporating these into ABMs results in models that are very difficult to assure,**

**so It is better to start minimalist and then to add complications later, one-by-one.**

## *Supermarket ABM 2.0*

**Three types of agent: Consumers (several subtypes), Retailers (two stores), and Manufacturers (eight brands).**

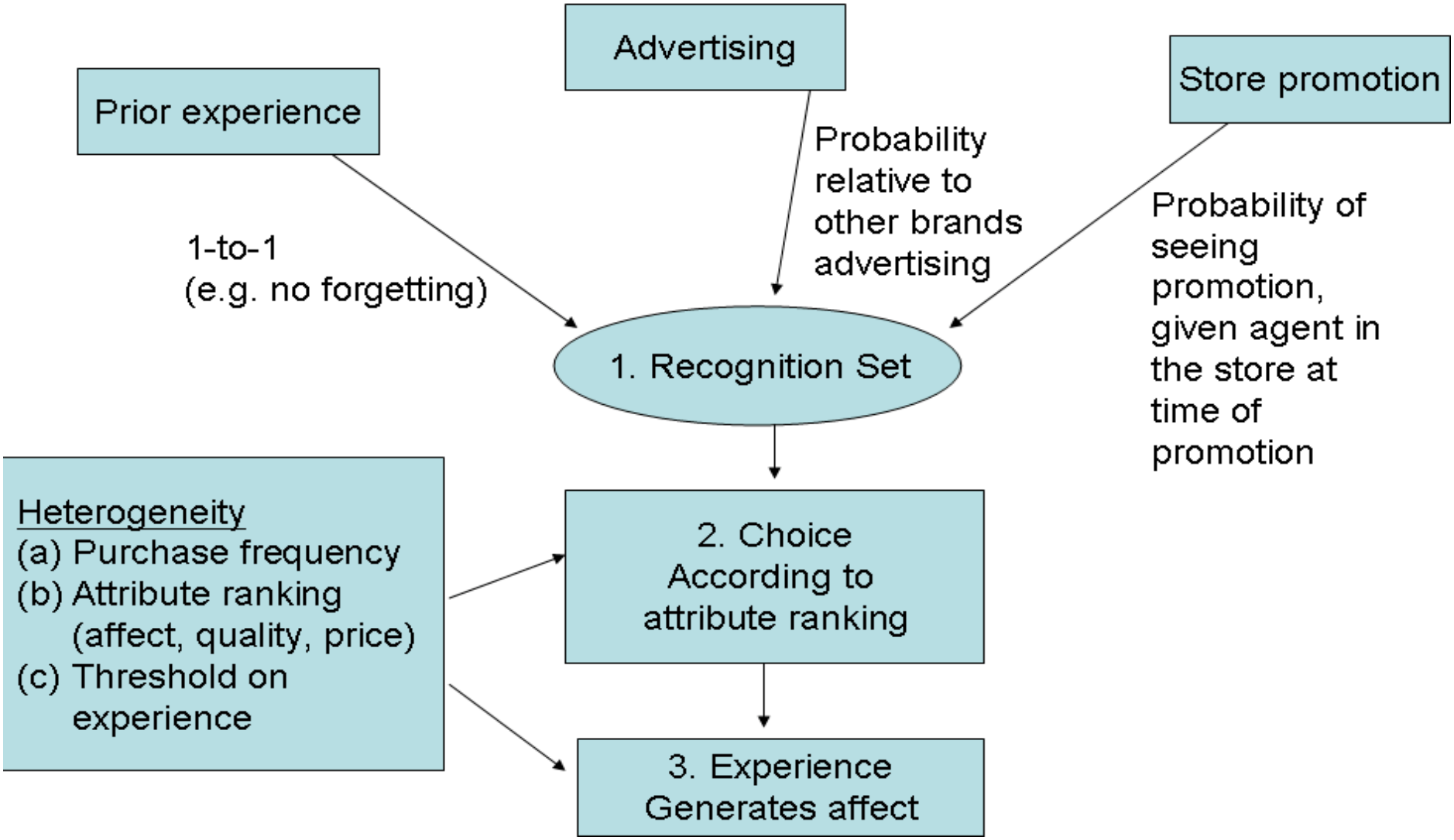
**The overriding philosophy is to keep the model simple by keeping the agents as simple as necessary, but no simpler.**

**Consumer agents vary by: purchase frequency, attribute (affect, quality, price) rankings, and threshold on experience.**
**Each drawn from one of four distributions.**

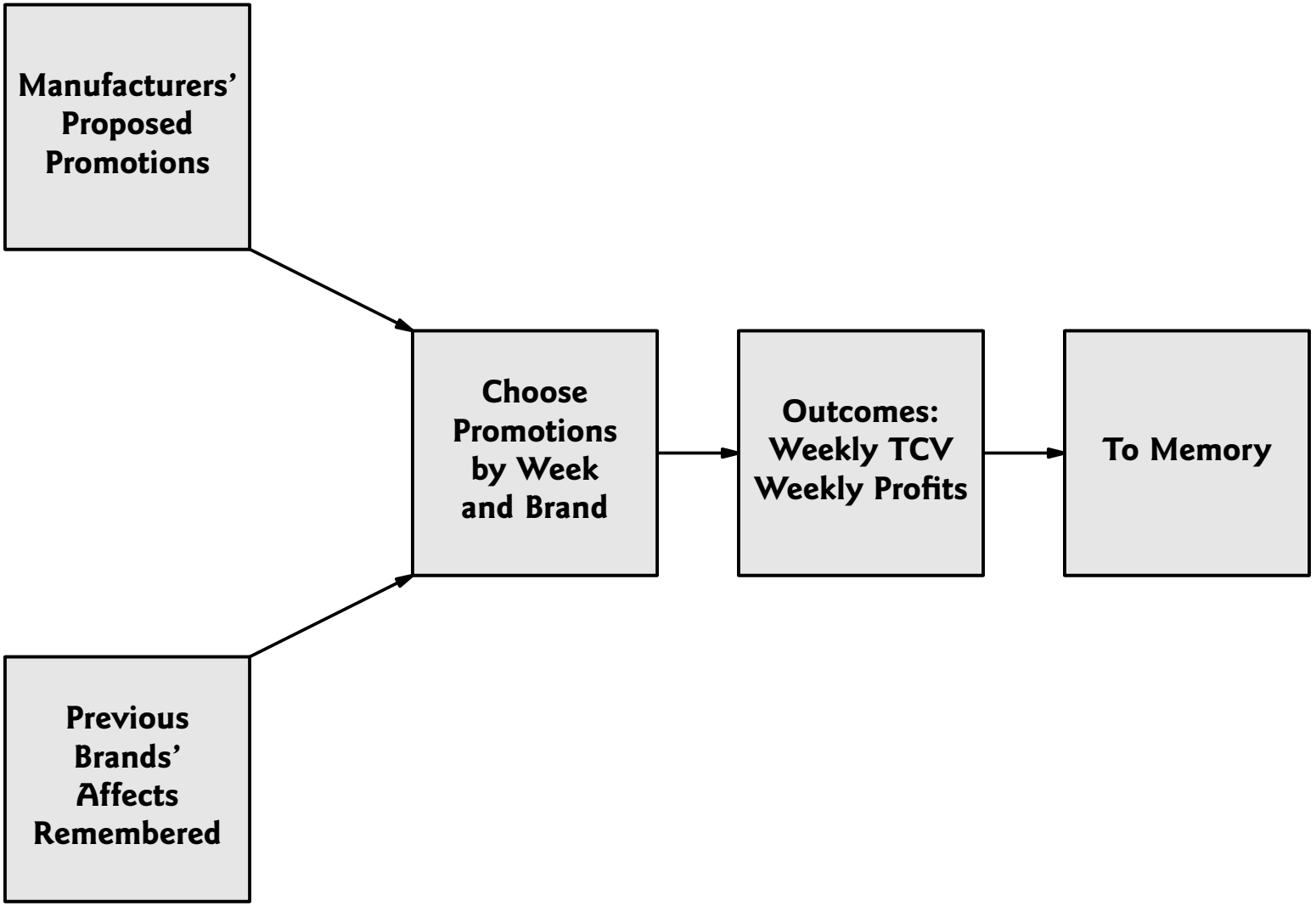
**Retailer agents have several assigned parameters, including number of consumers (exogenous).**

**Manufacturer agents have several parameters drawn from one of eight distributions.**

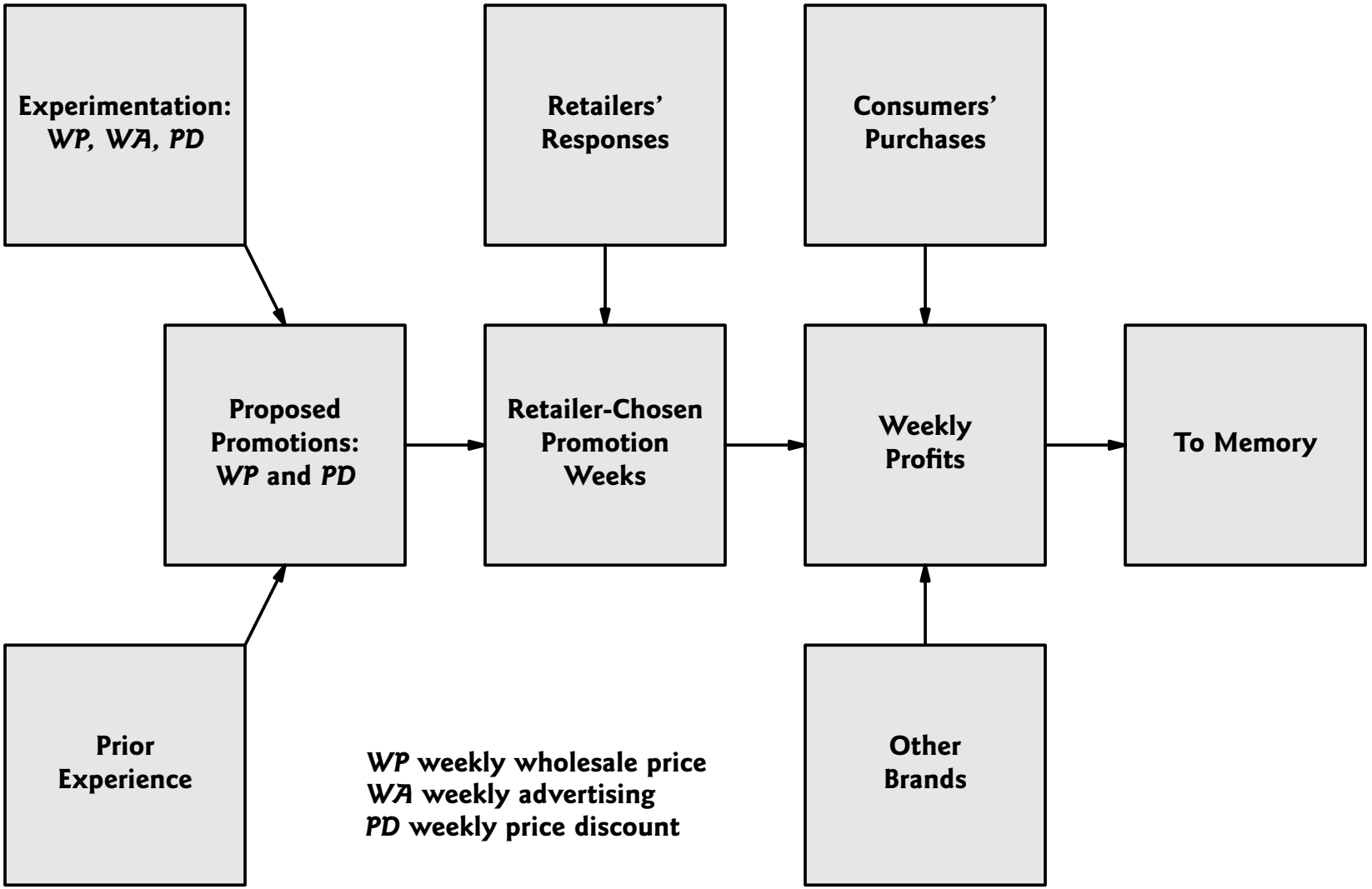
# Consumer agent



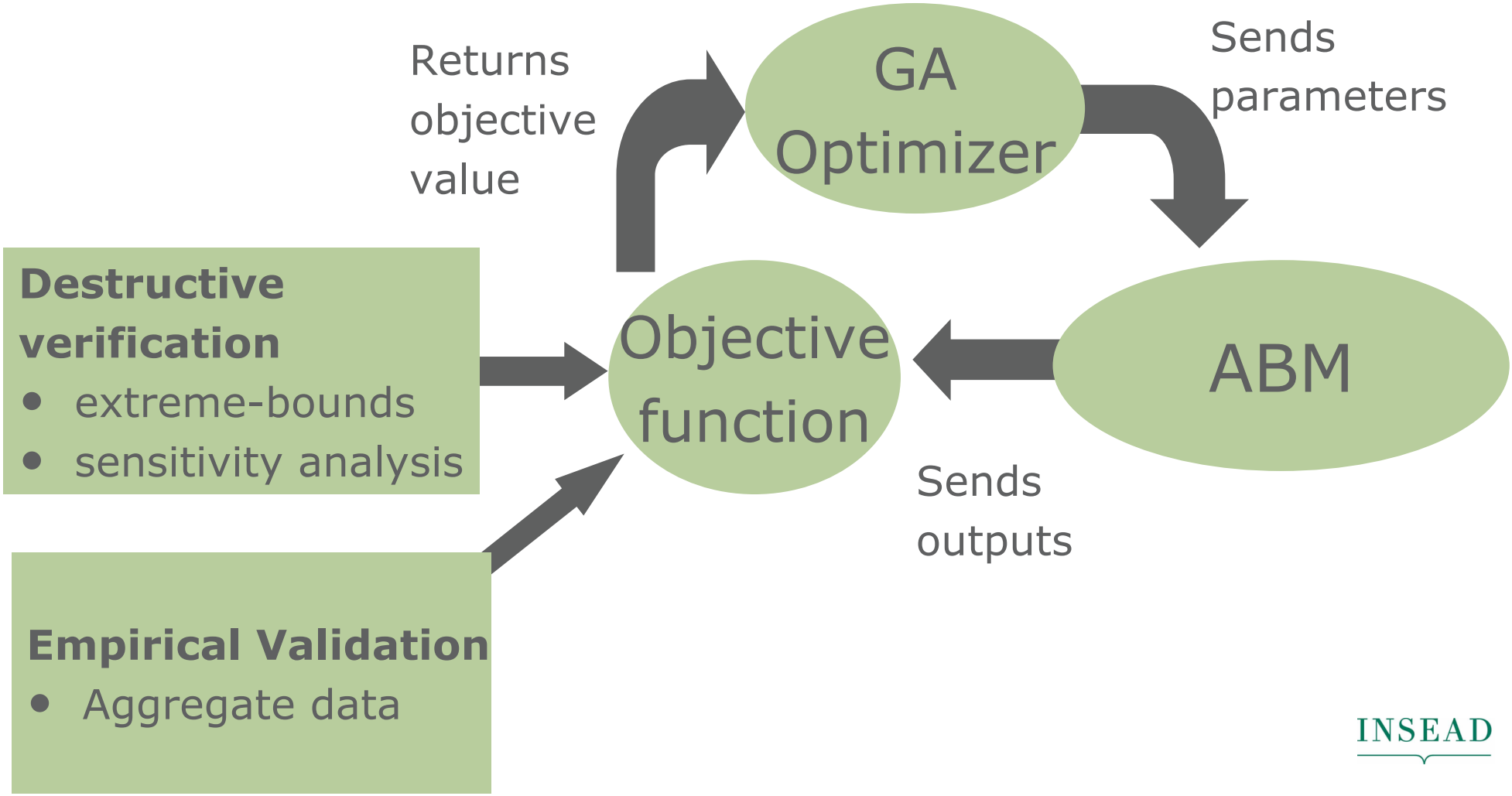
# Retailers


Manufacturers' Proposed Promotions
Previous Brands' Affects Remembered
Choose Promotions by Week and Brand
Outcomes: Weekly TCV Weekly Profits
To Memory

# Manufacturers



# Work at the macro-level: Embed the ABM in an Automated Nonlinear Testing System

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# Verification

**Two steps:**

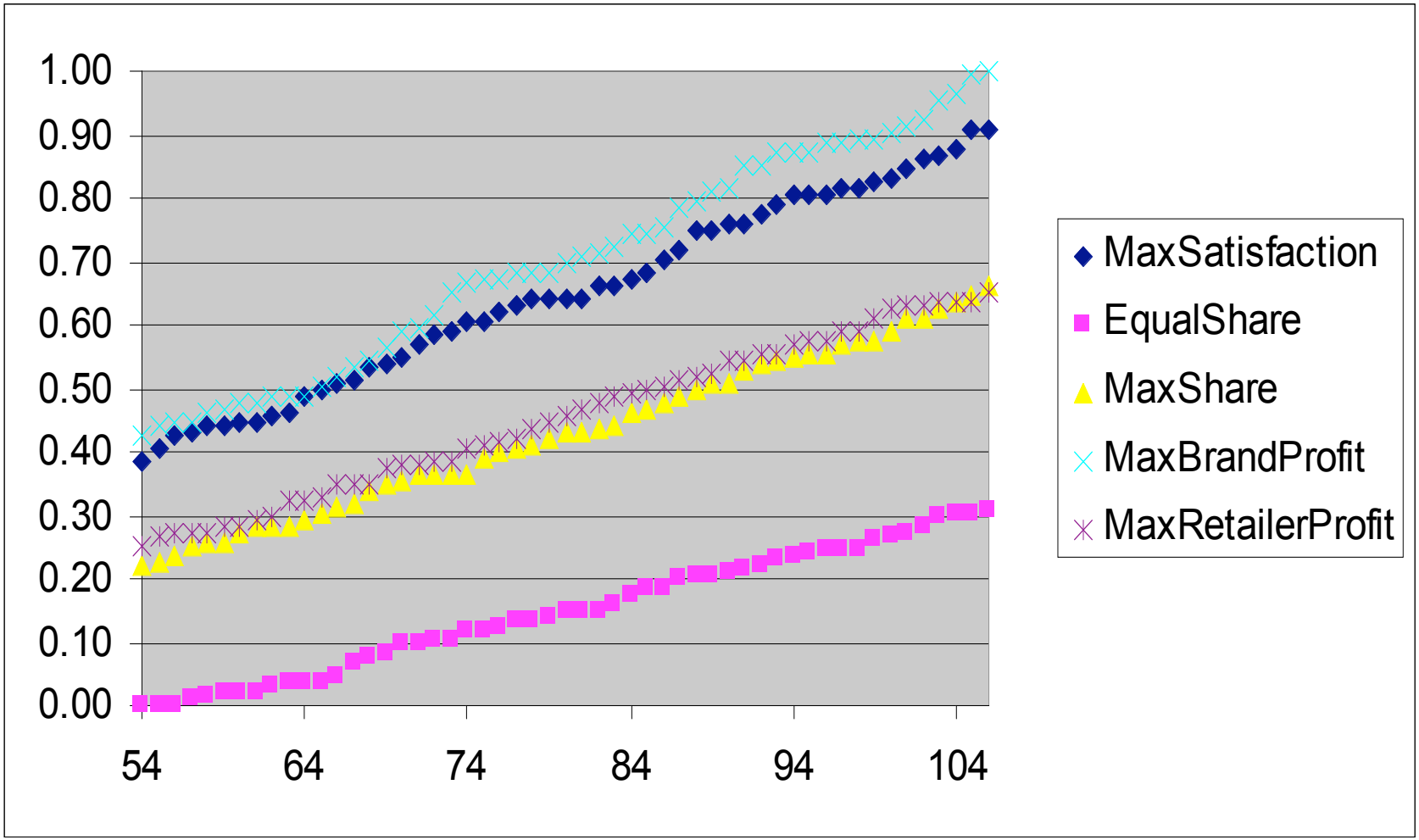
1. **Code checked against specification by two independent judges (PhD students in computer science).**
   - **Good news: some redundant and unused code, some interpretation issues, but relatively minor.**
   - **Bad news: time consuming.**

# 2. Destructive Testing

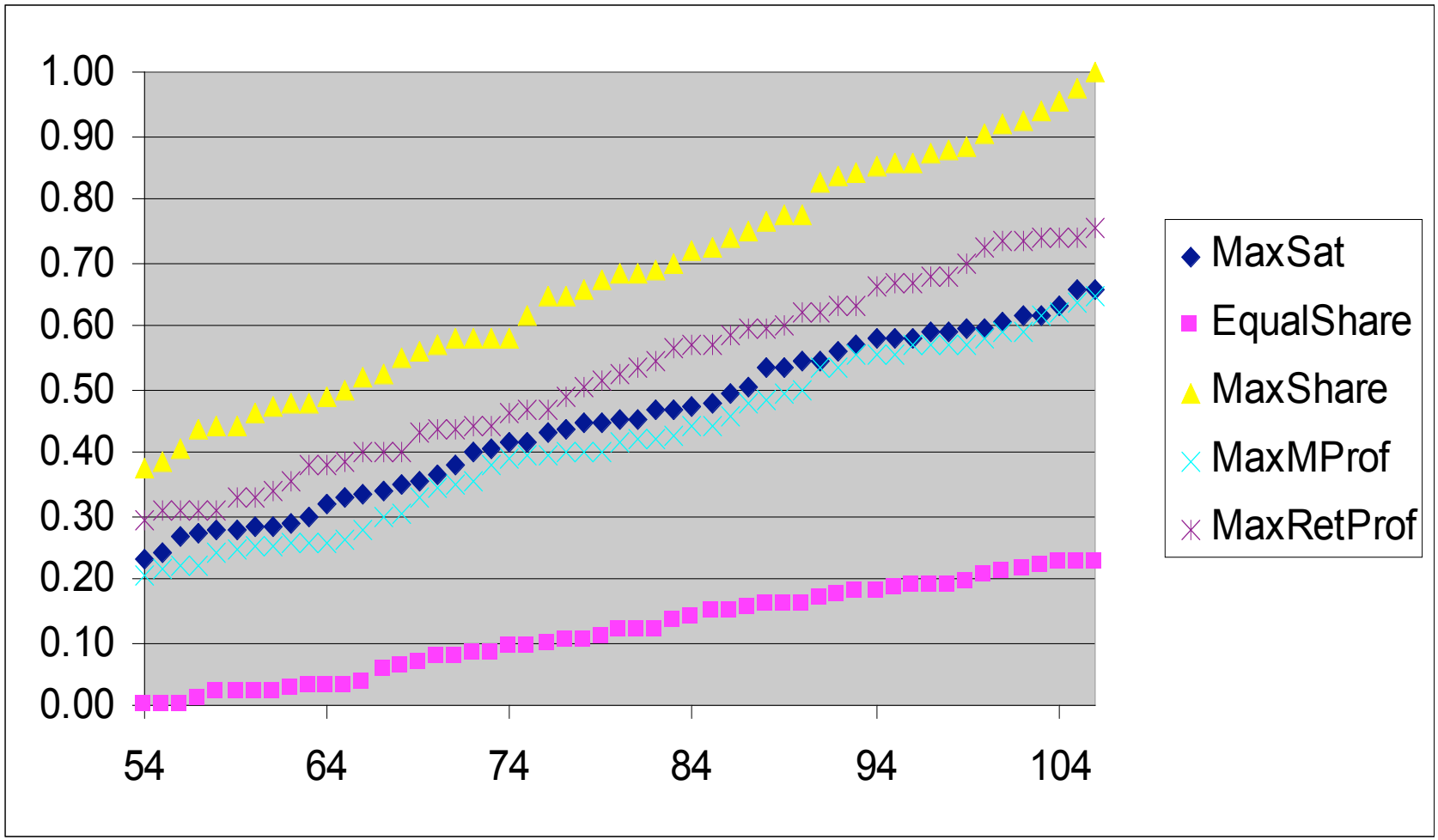
**Using Miller's 1997 ANT system:**

- **5 extreme objectives tested for (consumer satisfaction, equal market shares, manufacturer profit, monopoly, retailer volume)**
- **Consumer agents already micro-optimized (to reduce the number of parameters and hence the degrees of freedom)**
- **GA used to optimize remaining parameters.**
- **Good news: difficult to drive the model to extremes.**
- **Bad news: noisy optimization, hard to get convergence.**

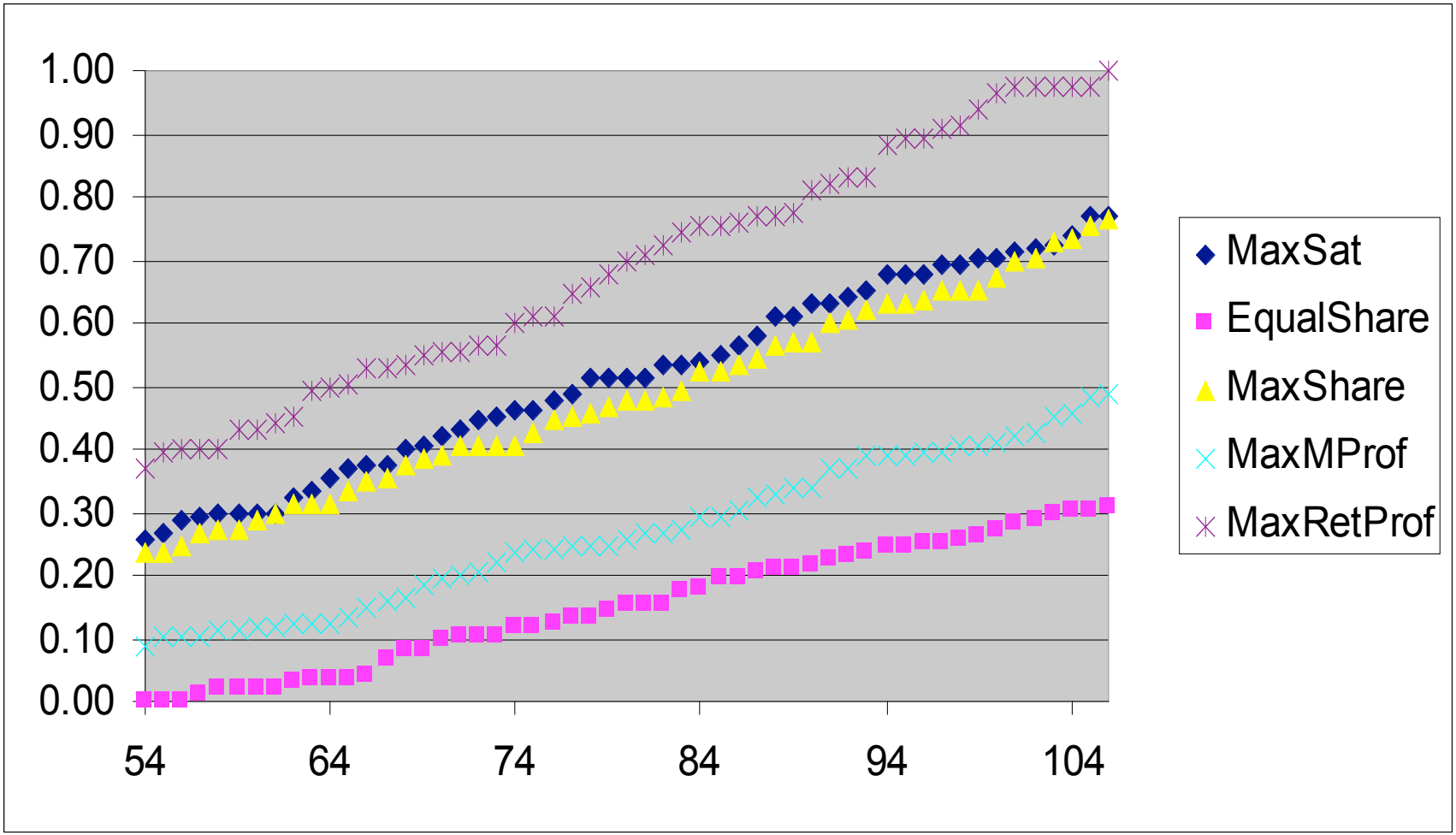
# Consumer satisfaction for the leading brand under 5 criteria



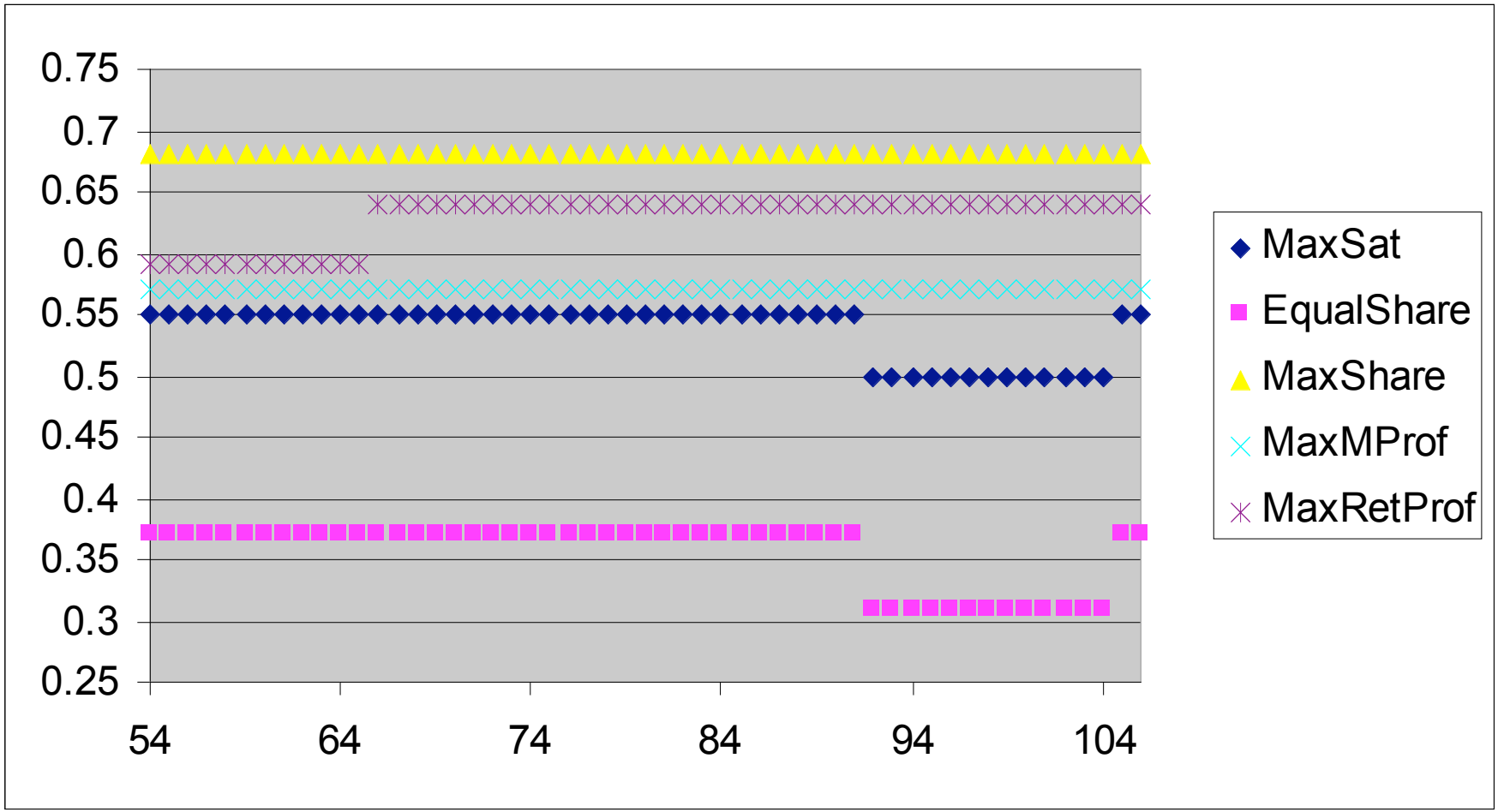
# Profits for the leading brand under 5 criteria



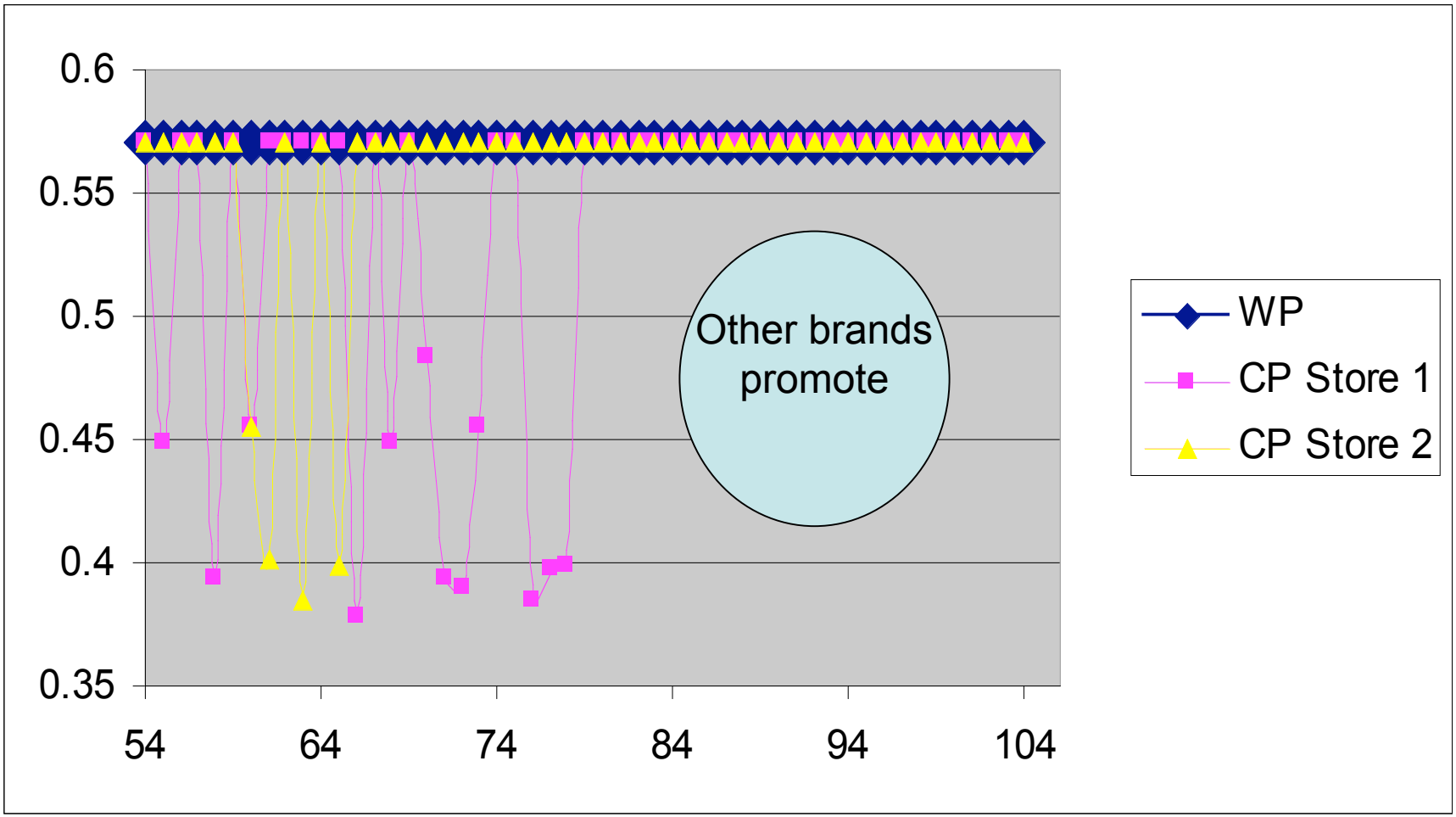
# Profits for the leading retailer under 5 criteria



# Wholesale price for leading brand under 5 criteria



# Consumer price in the two stores for leading brand under MaxMprof



# Observations and Insights from Destructive Testing?

**Modelling weaknesses revealed?**

1. **Rising Consumer Satisfaction with post-burn-in ticks 54–100, while prices level and purchases are constrained. Why?**
   - **No satiation or even dimishing marginal utility modelled.**
     **$\therefore$ Affect unlimited $\rightarrow$ postive feedback.**
     **$\therefore$ Satisfaction unlimited.**
   - **No budget constraints on consumer agents.**

   **Fitting consumer behaviour to historical data: $\therefore$ constrained.**

## Insights continued

2. **Consumer Satisfaction from brand X is higher after GA optimization to max MaxBrandProfits than to max MaxConsumerSatisfaction.**

   **i.e. Perverse behaviour of model.**

- **Let's review after validation → better parameter and variable values.**
  **Is this behaviour of the model an artifact of unrealistic numbers into the model?**

# Validation

- Have panel data of a sample of households.
- And check-out scanner data for two stores and eight brands.
- Develop 4 stereotypical agent types for Consumers (deals with heterogeneity).
- Micro-calibrate these agents from the panel data and analysis.
- Fit the remaining parameters by minimizing differences (MSE) between 10 outputs from simulation and actual store data (store and brand revenues).
- Again using the GA to optimize.

# Issues in Assurance

- Increasing measures in destructive testing.
- Satisfaction highest with MaxBrandProfit, not MaxConsumerSatisfaction.
- Scaling between the model and the universe.
- GA convergence in validation (difficult).
- Can we somehow weight consumer agents so that we don't need 10,000, which may be impossible to optimize?
- Mapping real-world prices onto a simpler frame.
- Need for a additional "light buyer" agent

# References

[1] Haefner J.W. (2005), *Modeling Biological Systems: Principles and Applications,* New York: Springer, 2nd ed.

[2] Marks, R.E. (2007) Validating Simulation Models: A General Framework and Four Applied Examples. *Computational Economics.* 30(3): 265–290, October. http://www.agsm.edu.au/~bobm/papers/s1.pdf

[3] Midgley D.F., Marks R.E., and Kunchamwar D. (2007) The Building and Assurance of Agent-Based Models: An Example and Challenge to the Field, *Journal of Business Research,* Special Issue: Complexities in Markets, 60: 884–893.

http://www.agsm.edu.au/~bobm/papers/Midgley-Marks-Kunchamwar.pdf

[4] Miller J., Active nonlinear tests (ANTs) of complex simulations models. *Manage Sci* 1998, 44(6):820–30.