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

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December 2007

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:

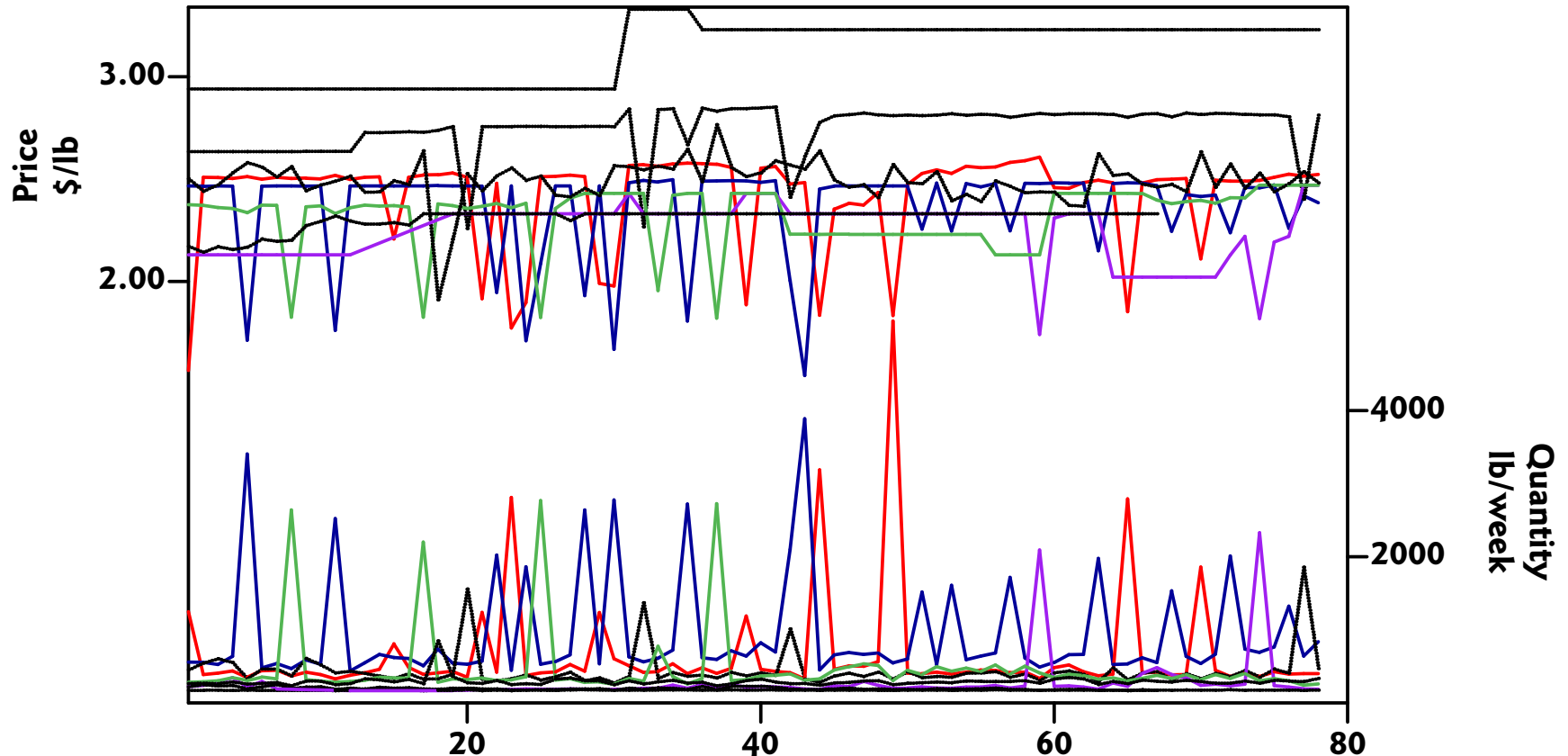


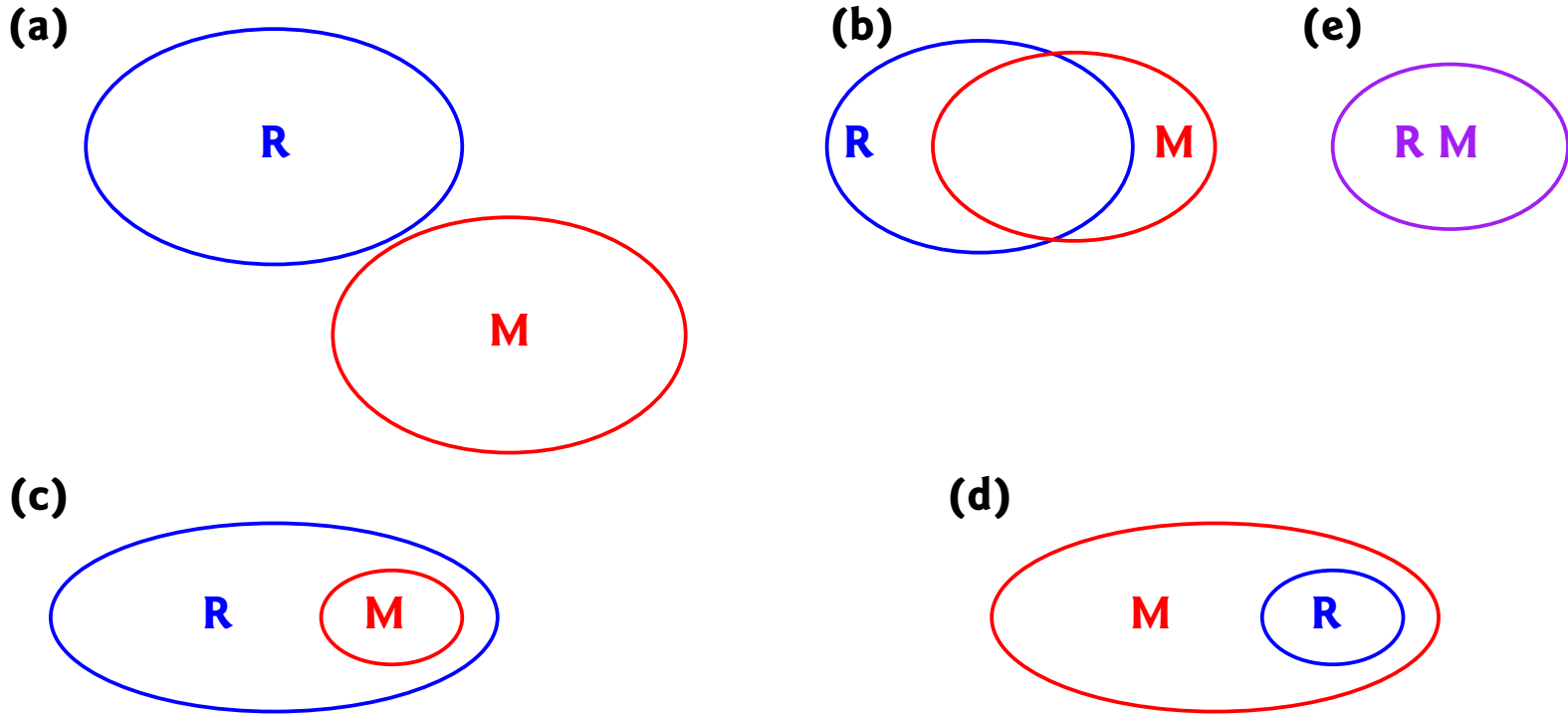
Figure 1: Weekly Prices and Sales (Source: Midgley et al. 1997)
(Coloured lines: **Folgers**, **Maxwell House**, **Hills Bros**, **CFON**)

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.

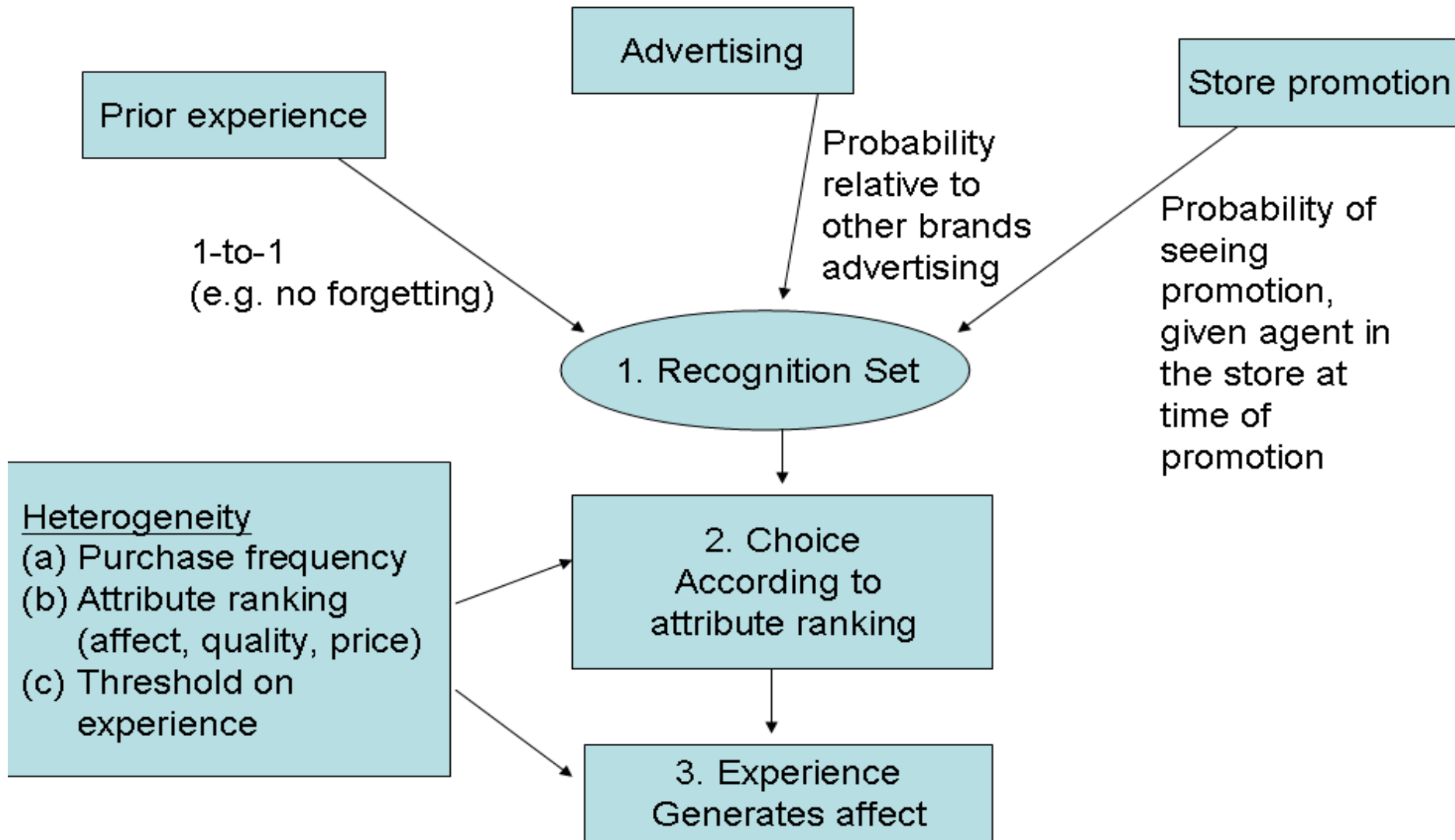
Consumer agents vary by: purchase frequency, attribute (affect, quality, price) rankings, and threshold on experience.

Each drawn from one of four distributions.

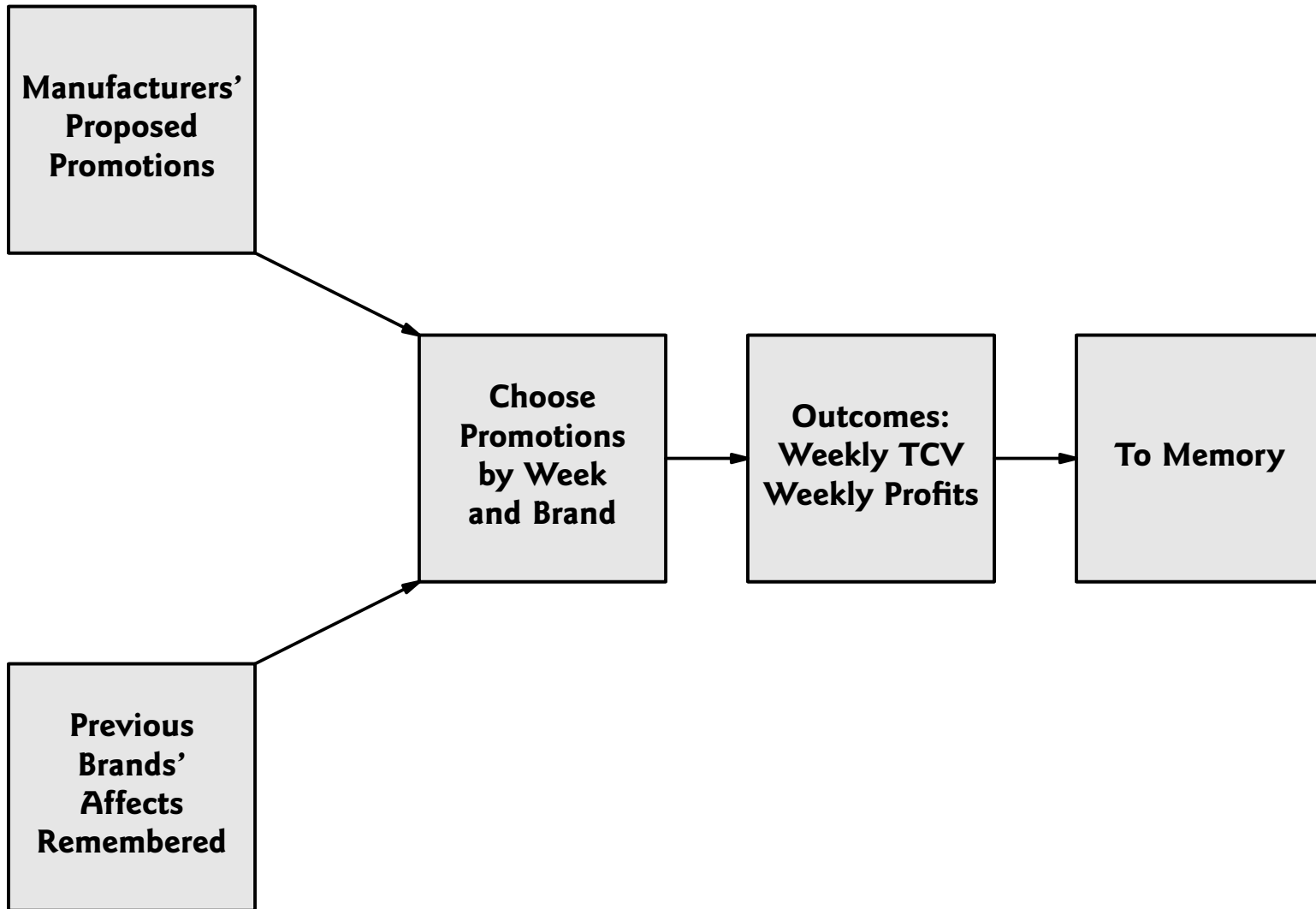
Retailer agents have several assigned parameters, including number of consumers (exogenous).

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

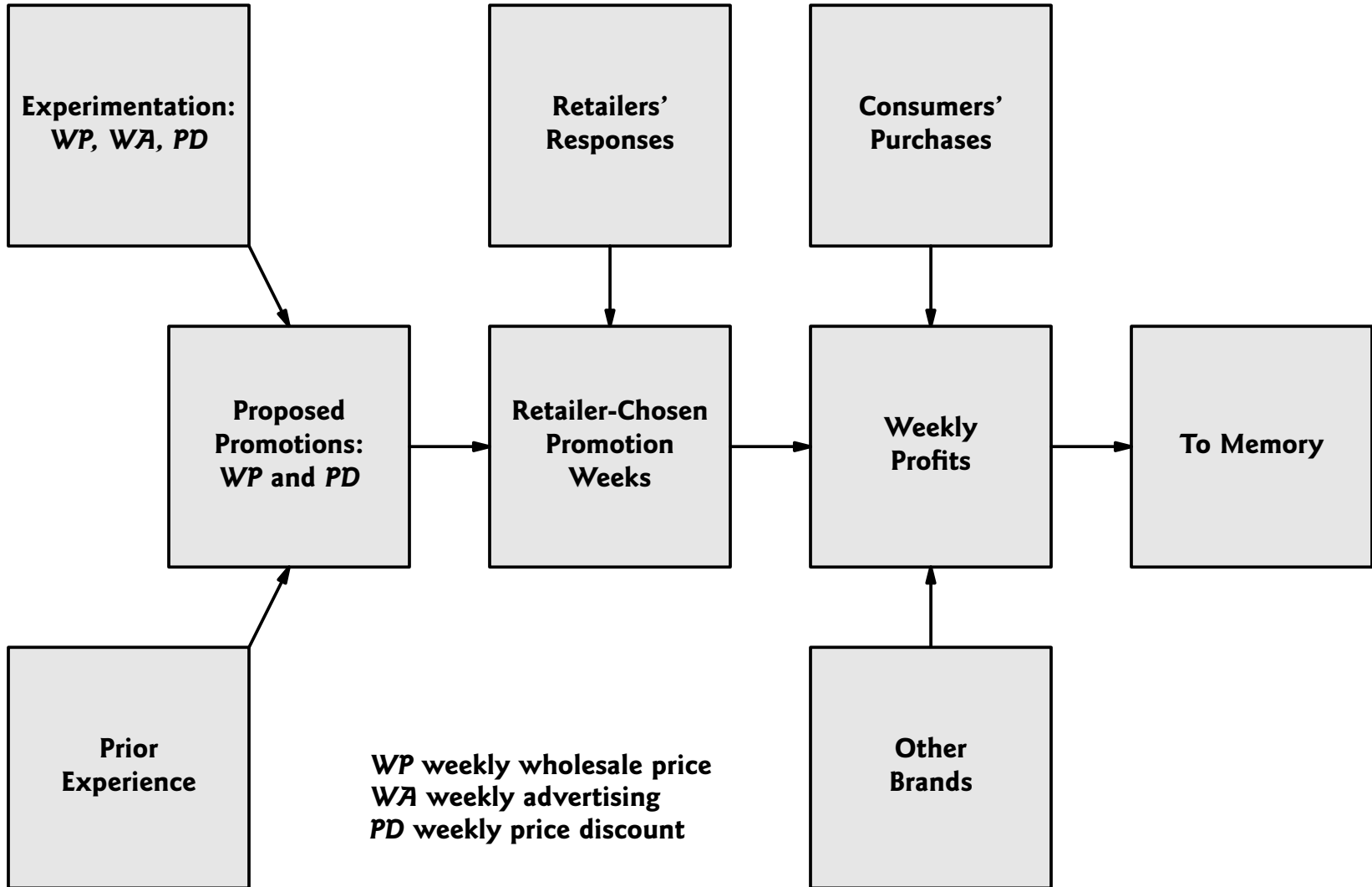
Consumer agent



Retailers



Manufacturers



Insert 3 : GA here

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.**

Insert 4 5 here Plots here

Observations and Insights from Destructive Testing?

Modelling weaknesses revealed?

- I. **Rising Consumer Satisfaction with post-burn-in ticks 54–100, while prices level and purchases are constrained. Why?**
 - **No satiation or even diminishing marginal utility modelled.**
 - ∴ Affect unlimited → positive feedback.**
 - ∴ Satisfaction unlimited.**
 - **No budget constraints on consumer agents.**

Fitting consumer behaviour to historical data: ∴ 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.**
- **G \bar{A} 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.**