Behavioural Finance

Lecture 01
Behaviour in Economics

Subject Content

- You lot!
  - Enrolments (145 as at time of writing) far exceed expectations
    - Made standard tutorial impossible
    - Instead
      - 2 hour lecture each week
      - 1 hour devoted to
        - General Discussion
        - Discussion of assigned readings each week

Subject Content

- From the (economist's) armchair to the (psychologist's) couch…
  - Most neoclassical economic theory "a priori":
    - "A rational person behaves as follows…"
    - "How do markets populated by rational traders behave?"
  - This subject inherently empirical
    - "How do actual people behave?"
    - "How do actual markets behave?"
- Putting economics in the couch
  - Just how "rational" is economics?

Subject Content

- Broad outline of topics to be covered:
  - Behaviour in Economics
  - What is "Rational" Behaviour in economic theory?
  - Reassessing conventional microeconomics
  - Reassessing conventional finance
  - Behavioural Finance proper
  - Power Laws and Fat Tails: Market manifestations of actual investor behaviour
  - Behavioural Macroeconomics
  - Endogenous money: the data
  - Dynamics of a credit-driven cyclical economy
  - Financial Instability
  - Endogenous Money
  - The Global Financial Crisis

Assessment

1. Weekly reviews of (at least) 2 readings (20% total)
   - 2 readings chosen at random for you on vUWS
   - Write detailed notes on these and save to vUWS site (as well as on own PC!)
   - Full marks (2 out of 2 for each of 10 weeks) given simply if obvious you have read readings
   - Do them well not because they are marked but because reading them is
     - Worthwhile in their own right
     - Good preparation for essay and final exam
2. Essay (20% total, due October 1st)
3. Final Exam (60% total)

Essay

- Focuses on core idea in this subject
  - **What economists call "rational" is not necessarily rational:**
    - *"What respectively are rational and irrational behaviour?*
    - *Consider ordinary language, psychology, computer science and economics-based usages of the terms.*
    - *Having refined your own definition, estimate the degree to which, in your opinion, the behaviour of stock market investors is driven by rational and irrational behaviours.*
    - *If possible, provide empirical support for your opinion."*
  - Set readings essential for essay

Behaviour in Economics

- "A priori" economic notions about behaviour
  - Micro
    - Consumers maximise utility subject to budget
    - Firms maximise profits subject to demand
    - Markets converge to supply=demand equilibrium
  - Macro
    - Agents in economy have "rational expectations"
    - Economy in "rational expectations equilibrium"
  - Finance
    - Investors maximise expected returns subject to investment opportunities
    - Asset market prices reflect correctly anticipated discounted future cash flows…

Behaviour in Economics

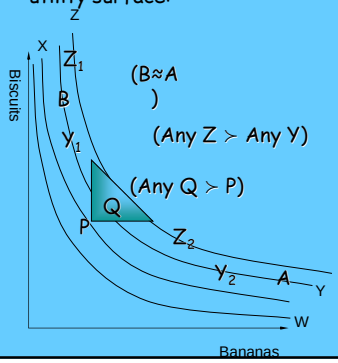
- Theorising about rationality in other disciplines very different
  - Analyse ***actual*** behaviour
  - Build theories of mind that replicate observed behaviour
  - No *a priori* tagging of observed behaviour as "rational" or "irrational"
- Empirical research generally finds economic *a priori* model does not fit actual behaviour
  - So most people are "irrational"?
  - Or is the economic definition of "rational" wrong?
- Re-capping standard economic theory—firstly, demand…

Neoclassical Micro—Utility Maximising Consumers

- Consumers assumed to be "rational utility maximisers"
  - "Rational" consumer assumed to obey these rules:
    - "Completeness"
      - Given any 2 bundles of commodities **A** & **B** , consumer can decide whether prefers **A** to **B** (**A≻B**), **B** to **A** (**B≻A**), or is indifferent between them (**B≈A**)
    - "Transitivity"
      - If (**A≻B**) and (**B≻C**) then (**A≻C**)
    - "Non-satiation"
      - More is preferred to less
    - "Convexity"
      - Marginal utility positive but falling as consumption of any good rises

Neoclassical Micro—Utility Maximising Consumers

- Upshot: consumer's preferences can be represented by a utility surface:



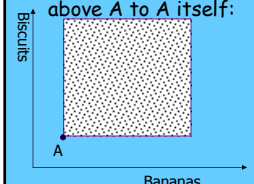
- "Indifference curves"
  - Each curve joins points that give consumer equal satisfaction
  - All points on higher curve give more satisfaction than any on lower
  - More is always better

Neoclassical Micro—Utility Maximising Consumers

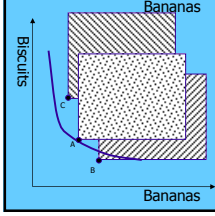
- Initial objections to (Samuelson 1938: "A Note on the Pure Theory of Consumer's Behaviour") theory
  - Indifference curves unobservable
  - Shouldn't base science on unobservable entities
  - Samuelson's solution: theory of "revealed preference" (Samuelson 1948 "Consumption Theory in Terms of Revealed Preference")
    - Indifference curves can be *inferred* from observed behaviour
      - Simplest instance: more is preferred to less so…

Neoclassical Micro—Utility Maximising Consumers

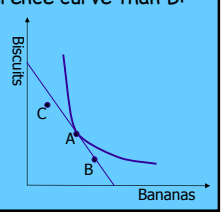
- Rational consumer **must** prefer any combination in box above A to A itself:



- More complicated:
  - If offered choice between A and B *when both are affordable* and chooses A, then A **must** lie on higher indifference curve than B:

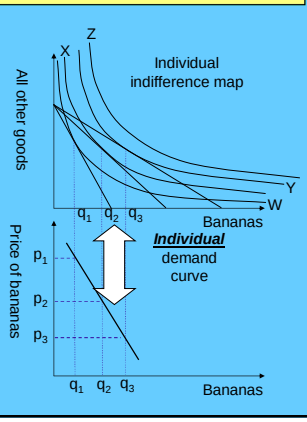


- Can infer indifference map from actual choices
- ***Not "non-observable" after all…***



Neoclassical Micro—Utility Maximising Consumers

- Next stage: deriving rational consumer's demand function from indifference map:
- The "Law of Demand":
  - Consumption of a good rises as its price falls
- One problem: some goods can be so undesirable that consumption **falls** as price **falls**
  - "Giffen Goods" (potatoes in Ireland during famine)



Neoclassical Micro—Utility Maximising Consumers

- Income effect from lower price
  - Can consume more of all commodities because fall in price of one while income constant means increase in real income
- Can overwhelm substitution effect
  - Buy more of a good as its price rises
- Solution: "Hicksian compensated demand curves"
  - IF consumer income was reduced to cancel out income effect THEN all such demand curves would be downward sloping:

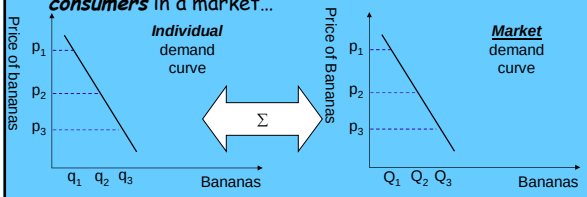
Neoclassical Micro—Utility Maximising Consumers

- Procedure to derive Hicksian compensated curve:
  - Consider initial budget line aa
  - Consumer chooses combination A on indifference curve X
- Now consider new relative price ab
  - Consumer chooses combination B on indifference curve Y
- Move new budget line back till tangential to original indifference curve X
  - Point of tangency is combination C
- Substitution effect only: consumer necessarily consumes more Bananas when price of bananas falls
  - "Law of Demand" restored

- *Yes I know…*
- But it does get interesting soon…

Neoclassical Micro—Utility Maximising Consumers

- Next step—aggregate from *single consumer* to ***all consumers*** in a market…



- Quick marks bonus:
  - **5 marks to *anyone* who can find *any* discussion of this aggregation issue in *any* undergraduate microeconomics textbook; AND**
  - **5 marks to first 5 people to document where 5 undergraduate text should discuss this and don't**

That's the theory…

- How does it stack up in reality?
  - Samuelson's "Revealed Preference" argues indifference curves can be inferred from behaviour
  - Sippel (1997) tried to test this
    - Very careful experimental design
    - Numerous previous experiments "sloppy" in some way
      - E.g. Household expenditure surveys [Koo (1963), Mossin (1972) and Mattei (1994)] subject to change in preferences over time
      - Study of inmates in a psychiatric hospital… to see if they were rational??? [Battalio (1973)]
        - Even of rats (too see is they were human???)
  - In contrast, Sippel:

Testing Revealed Preference

- Used university students as subjects
- Presented with
  - A budget constraint
  - A set of 8 commodities from which to choose:

Good	Max. Amount (if all budget spent on one good)
Video clips	30-60 minutes
Computer games	27.5-60 minutes
Magazines	30-60 minutes
Coca cola	400ml-2 litres
Orange juice	400ml-2 litres
Coffee	600ml-2 litres
Candy	400gms-2 kilos
Pretzels, peanuts	600gm-2 kilos

Testing Revealed Preference

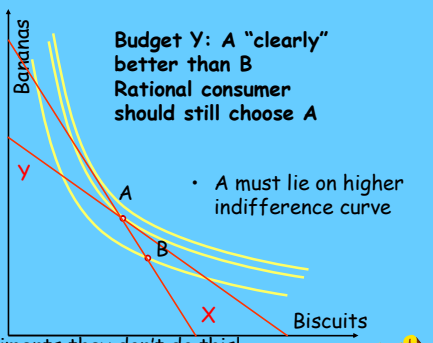
- Unlimited time to choose preferred bundle
- Test repeated ten times with different relative prices, budget constraints
- One of preferred bundles from each of tests chosen at random for student to consume in one hour after test
- Clearly were expressing preferences between bundles:
  - "There can be no doubt that the subjects tried to select a combination of goods that came as close as possible to what they really liked to consume given the respective budget constraints.
  - They spent a considerable amount of time on their decisions (typically 30—40 minutes) and repeatedly corrected entries on some of their order sheets when they reconsidered previous choices."

Testing Revealed Preference

- Key propositions being tested:
  - "Weak Axiom of Revealed Preference" *WARP*
    - If $A \succcurlyeq B$ then never $B \succcurlyeq A$
    - If consumer chooses bundle A once when B also affordable, then consumer will always choose A instead of B, regardless of relative prices
  - "Strong Axiom of Revealed Preference" *SARP*
    - If $A \succcurlyeq B$ & $B \succcurlyeq C$ then never $C \succcurlyeq A$
      - Formal definition of a utility maximiser
  - "Generalised Axiom of Revealed Preference" *GARP*
    - If $A \succcurlyeq B$ & $B \succcurlyeq C$ then $p_C * A \geqq p_C * C$
      - If $A \succcurlyeq B$ & $B \succcurlyeq C$ then A more expensive than set C at prices when C declined in favour of B

Testing Revealed Preference

- X Initial budget line
- Consumer chooses A when A & B both affordable
- Rational consumer "should" always prefer A to B
- But in experiments they don't do this! Sometimes, they choose B instead of A



Testing Revealed Preference

- Results first experiment (12 subjects)
  - 11 of 12 subjects violated SARP & WARP
  - 5 out of 12 violated weaker test GARP
- Results second experiment (30 subjects)
  - 22 of 30 subjects violated SARP & WARP
  - 19 of 30 violated weaker test GARP

Exp. 1 & 2	Consistent %	Inconsistent %	Number of violations per person (max possible 45)						
			1-2	3-4	5-6	7-8	9-10	11-20	> 20
SARP	8.3	91.7	7	3	-	-	-	-	1
GARP	58.3	41.7	3	1	-	-	-	1	-
SARP	26.7	73.3	7	4	-	1	4	3	3
GARP	36.7	63.3	8	1	2	3	1	1	3

Testing Revealed Preference

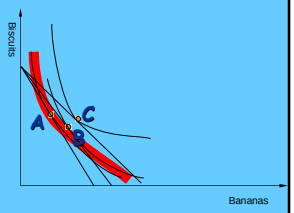
- Sippel's interpretation of results
  - In general "not too favourable to the neoclassical theory of consumer behaviour…" (p. 1438); but
    - Low number of inconsistencies (median 2 out of 45—but average higher)
    - Subjects did try to "select a combination of goods that came as close as possible to what they really liked to consume given their respective budget constraints" (1439)
    - "They spent a considerable amount of time on their decisions (typically 30-40 minutes)"
  - How serious are violations of axioms?…

Testing Revealed Preference

- Use waste of income from inconsistent choice as guide to how significant were deviations from "rationality":
  - Afriat index: ratio ($p_B * A$ / $p_B * B$) when (from previous experimental round) $A \succcurlyeq B$
  - Where consumer chooses A when B affordable, use formula "$A \succcurlyeq B$ if $(e * p_A * A) \geqq (p_A * B)$"
    - Consumer deemed to prefer A over B if A (say) 11% more expensive than B & consumer still chooses A (here e=0.9)
    - Like having "thicker indifference curves"

Testing Revealed Preference

- With thicker indifference curves, more combinations are shown as "indifferent":
- e=1: $C \succ B \succ A$
- e=.95: $C \succ B$ & A but $B \approx A$
- Choosing A or B appears "rational" for e=.95 but not for e=1



- The "good" news: number of apparent violations of GARP dropped significantly for e<1
- The "bad" news: even "throwing a dart"—*totally random choice*—appeared rational for e<0.95!
- For e=.9, random choice appeared *more* rational than what human subjects did!

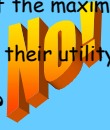
Testing Revealed Preference

	% Experimental subjects violating GARP		% of times randomly chosen set violated GARP	
e	Exp 1	Exp 2	Exp 1	Exp 2
1	41.7	63.3	61.3	97.3
.99	25	26.7	46.8	65.2
.95	8.3	10	16.8	12.8
.90	8.3	3.3	1.5	9.4

Lower level of violations for random choice!

Testing Revealed Preference

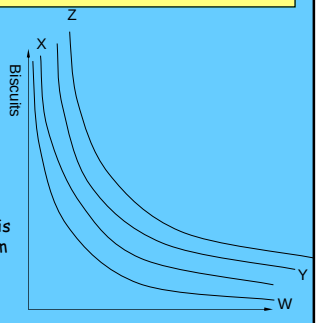
- Several other careful attempts to interpret results
- But overall judgment:
  - "We conclude that the evidence for the utility maximisation hypothesis is at best mixed.
  - While there are subjects who do appear to be optimising, the majority of them do not…
  - we … call the universality of the maximising principle into question." (1442)
- So if people aren't maximising their utility, what are they doing?
  - Are they being "irrational"?



- It's the neoclassical definition of rational behaviour that is irrational!
- Let's check basic assumptions of model:

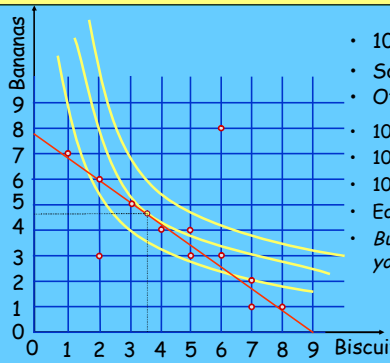
Reconsidering Revealed Preference

- "Rational" consumer assumed to obey these rules:
  - Completeness, Transitivity, Non-satiation & Convexity
- Consider "Completeness":
  - Given any 2 bundles of commodities **A** & **B** , consumer can decide whether prefers **A** to **B** (**A≻B**), **B** to **A** (**B≻A**), or is indifferent between them (**B≈A**)
  - Looks easy enough on 2-dimensional graph:



- Each bundle contains just two items
  - (1,4): 1 biscuit, 4 bananas
  - (4,1): 4 biscuits, 1 banana
  - Say 100 different combinations to consider:

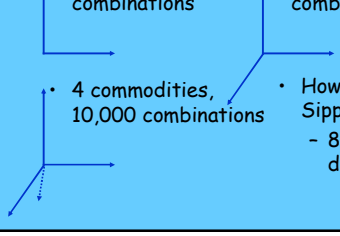
Computational complexity & rationality



- 100 combinations
- Some you ignore
- Others you can't…
- 10 pairs
- 10 budget sums
- 10 utility comparisons
- Easy!
- *But what about when you add another good?*

Computational complexity & rationality

- How to represent additional good on indifference map?
  - *Have to add an additional axis*
- **Every additional commodity adds another dimension.**
  - With no more than 10 units of each:



- 2 commodities, 100 combinations
- 3 commodities, 1,000 combinations
- 4 commodities, 10,000 combinations

- How many combinations in Sippel's experiment?
  - 8 commodities so 8 dimensions…

Reconsidering Revealed Preference

- Even if discretise choice and consider 5 combinations per good (0, 15, 30, 45, 60 minutes of video etc.)
- There are 5^8 combinations to consider:
  - 390,625 different combinations!
    - Combo 1: 15 min video, 30 min game, 45 min magazine, 500g cola, 250 g orange juice, 500g coffee, 1kg Haribo, 200 g snacks
    - Combo 2: 30 min video, 45 min game, 0 min magazine, 1 litre cola, 500 g orange juice, 0 coffee, 500g Haribo, 500 g snacks
    - Which do you prefer?...
      - Impossible to differentiate finely—instead tend to consider one or two items you like and ignore rest

Reconsidering Revealed Preference

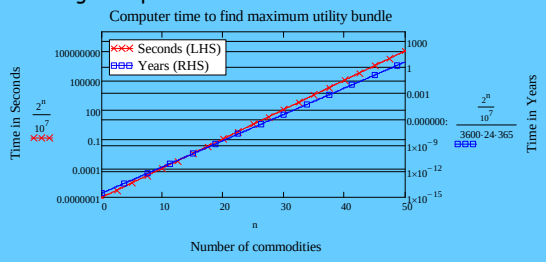
- Is this irrational?
  - According to revealed preference/utility theory, yes
  - In real life, no!
    - Reality is bewildering array of choices
    - Difficulty is not choosing best option, but making satisfactory choice in finite time
- Consider simple shopping trip:
  - (say) 100 items you could buy at supermarket
  - Buy either 0 or 1 units of each
  - How many different combinations to compare?
    - 2^{100}=1,267,650,600,228,229,401,496,703,205,376!
    - That's one million trillion trillion different combinations

Reconsidering Revealed Preference

- Revealed preference/Indifference curves a "toy" model
  - Looks good on paper
  - ***Can't possibly scale to reality***
  - Consumption an "exponential complexity" problem:
    - Number of combinations scales exponentially as additional commodities considered
    - To buy or not to buy decision a 2^n problem:
      - 2 choices, zero or one unit
      - n combinations for n commodities...
      - Put revealed preference function in computer
      - Program it to find highest utility combination...
      - If calculating utility of a bundle takes 10^{-7} sec.:

Reconsidering Revealed Preference

- Working out optimal bundle would take...



- Neoclassically "rational" computer would take ***3.5 years*** to choose utility maximising bundle in 50 commodity corner store...

Reconsidering Revealed Preference

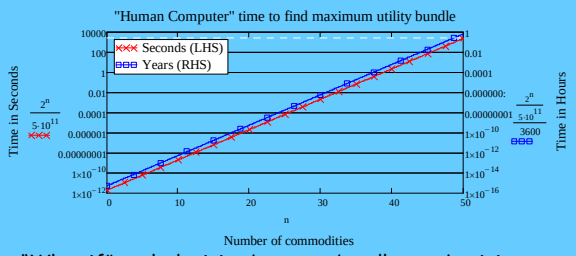
- What about a human "computer"?
  - More to brain than neurones (discussed later), but
  - Brain has 10^{11} neurones
    - 100,000,000,000 (or 100 billion)
    - Each neuron connects to 1,000 others
    - Signalling between neurons basic operation in thinking, learning, deciding, acting
  - Signals transmitted by voltage spikes
    - Neuron takes 1 millisecond (10^{-3}) to generate a spike
    - Like computer transferring one bit of data from one register to another
      - Actual decision by computer (in 10-7 example above) might take 100 such steps
    - Likewise, many neuron signals needed to make basic action

Reconsidering Revealed Preference

- 50-100 milliseconds shortest time for actual perception ("That's a tube of toothpaste")
- 100 such perceptions would take at least 5 seconds
- So IF brain acted as massively parallel HCRP ("Human Computer Revealed Preference") machine
  - which it doesn't
- AND if every decision took 5 seconds
- THEN "Human Computer" would operate at 5×10^{-11} seconds per RP decision
- So a HCRP would take...

Reconsidering Revealed Preference

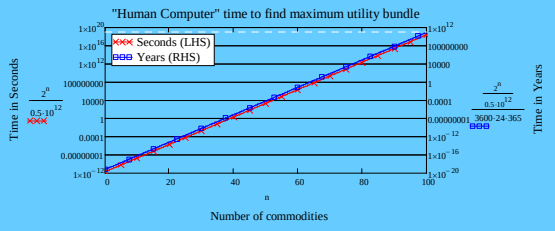
- 2252 seconds to shop in a 50 commodity corner store!



- "What if" each decision between bundles took minimum human perception time (50 ms=$5x10^{-2}$) in massively parallel processing (10^{11} neurons), regardless of number of commodities in a bundle?

RP versus EP: EP wins every time…

- Decision speed then $0.5x10^{-12}$:



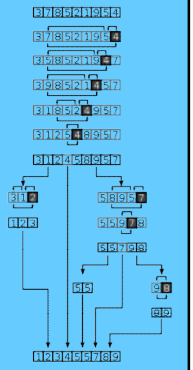
- "To buy or not to buy" (0 or 1 of each commodity) RP shopping trip in 100-commodity store would take…
  - 80,000,000,000 years…
  - 6 times estimated age of universe (13.7 billion years)

RP versus EP: EP wins every time…

- Ranking bundles of goods with n commodities an "exponential problem"
  - Number of comparisons scales exponentially with number of commodities
    - Comparisons = $(1+\text{UnitsBought})^{\text{NumberCommodities}}$
    - In our example—buy or not buy one item in 50 commodity shop:
      - Comparisons = 2^{50}=1,125,899,906,842,624
        - (10 million billion different potential bundles)
- Such problems inherently ***non-computable***:
  - Simply impossible for any program on any computer to find highest utility combination in finite time
  - "Consider all options" Computing (and by inference deductive thinking) restricted to "polynomial problem"

RP versus EP: EP wins every time…

- ***Definitive*** (optimum) programs must run in polynomial time
  - e.g., "bubble sort algorithm": sort list of n numbers:
    - Select last ("pivot")
    - Choose next to last ("pre-pivot") and another ("rand") at random
    - If either larger than pivot
      - Swap larger with pivot
      - Move smaller to where larger was
    - Repeat till all before pivot smaller than it
    - Partition list into two and repeat



RP versus EP: EP wins every time…

- Worst case: (List starts in reverse order)
  - algorithm takes n^2 steps where n is length of list:
    - n=10: 100 steps
    - n=1,000: 1,000,000 steps
    - n=1,000,000: 1,000,000,000,000 steps
      - Still a lot, but do-able in finite time…
- Average case: (List starts in purely random order)
  - Takes n x log(n) steps
    - n=10: 10 steps
    - n=1,000: 3,000 steps
    - n=1,000,000: 6,000,000 steps
- Best case: list already sorted, just n steps…
- 34 steps in previous example
  - between 10^2=100 and 10 x log(10)=10

RP versus EP: EP wins every time…

- Simply isn't possible to "be rational" as economists define it:

Algorithmic Complexity	*Example*	*Input size & Number of Operations*			
Class		10	20	50	100
n	Add up n numbers	10	20	50	100
n^2	Sort n numbers	100	400	2500	10000
2^n	Utility n bundles (0-1 items)	1024	1048576	1.13E+15	1.27E+30
4^n	Utility n bundles (0-3 items)	1048576	1.09951E+12	1.27E+30	1.61E+60

- At a billion comparisons a second, a "Revealed Preference" shopping trip would take longer than the Age of Universe ***times*** the Age of the Universe:

Fractions of age of Universe to complete	*Example*	*Input size*			
Class		10	20	50	**100**
n	Add up n numbers	2.31E-26	4.63E-26	1.16E-25	2.31E-25
n^2	Sort n numbers	2.31E-25	9.26E-25	5.79E-24	2.31E-23
2^n	Utility n bundles (0-1 items)	2.37E-24	2.43E-21	2.61E-12	2934.082981
4^n	**Utility n bundles (0-3 items)**	2.43E-21	2.54E-15	2934.082981	**3.72E+33**

- Bottom line: Neoclassical theory of rational behaviour falls over at first step
  - "Completeness" axiom computationally impossible…

Theory vs Reality

- "Completeness"
  - Given any 2 bundles of commodities **A** & **B** , consumer can decide whether prefers **A** to **B** (**A≻B**), **B** to **A** (**B≻A**), or is indifferent between them (**B≈A**)
- "Transitivity"
- "Non-satiation"
- "Convexity"
  - All breached in practice because depend upon Completeness to work!
- But people still succeed to shop
- So they do different ***rational*** things to shop in finite time:
- Reality
  - Capacity to compare fails even with 8 goods in bundle
  - Computational overload means can't compare available bundles in finite time
- "Satisfice"
  - Choose satisfactory bundle
- "Prioritise"
  - Concern most desirable item in bundle and ignore others
- "Habit"
  - Buy as always with some change
- "Categorise"
  - Purchase within categories
  - Drastically reduces dimensionality of choice

Theory vs Reality

- Even attempting to utility-maximise is irrational in a world with more than 20 commodities
- Computational complexity overwhelms optimising
  - "If the brain is performing computation, it should obey the laws of computational theory.
  - These results come from two areas, *computability* and *complexity*, and can be paraphrased as follows:
    1. You cannot compute nearly all the things you want to compute. [Godel/Turing proof that most things can't be proven—not discussed here]
    2. The things you can compute are too expensive to compute. [as shown]" (Ballard 2000, p. 6)
- i.e., exact (optimal) answers to anything complex are impossible to achieve; and even shopping is complex!

Goodbye Revealed Preference

- Can't characterise that behaviour using "indifference curves" and "budget lines"
  - Normal behaviour must violate Revealed Preference model because Revealed Preference behaviour is computationally impossible.
  - True "rational behaviour" for real-world consumers is
    - Making a satisfactory consumption decision in finite time
- Next:
  - Even if revealed preference did work…
  - Market demand curves can't be downward-sloping…