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# CONSUMER DECISION RULES FOR AGENT-BASED MODELS

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## *Introduction*

Individual decision-making about consumption has been the subject of many theories and approaches. In this paper, we are interested to propose some steps to include consumer decision making and behaviour in formal models, trying to do this in a more realistic way than the neoclassical theory.

Agent-based models will become the dominant

modelling technique in economics. They have several substantial and formal advantages over neoclassical diagrams "starting with curves", e.g. over demand curve and supply curve.

Instead of the narrow limits of comparative statics between equilibrium points, agent-based models allow to build and manage dynamic environments with both low and high levels of complexity.

In fact, agent-based models allow for high heterogeneity in the micro-agents (consumers, firms, banks....). No representative consumer or representative firm has to carry out the burden of representing different agents of the same class. Consumers aren't requested to share the same preferences or, as in some neoclassical model, the same income. This is a crucial issue for the realism of the model.

Computer simulation as they are, agent-based models are constituted by several **building blocks.** In particular, the modeller has to specify the inner structure of agents, their decision rules, and the relationships among agents.

Firms and consumers: these are the typical agents in basic economic models. Following the empirical evidence that real people are not as hyper-rational as the neoclassical theory assumes, evolutionary agent-based models consider consumers to be bounded rational, i.e. following easy decision-making rules which use only pieces of available information without requiring too much mathematical calculus.

By adopting this point of view, these models comply with the overwhelming empirical evidence of real agents' behaviours. When you buy a beer, you don't think too much. If you can't drink beer, you simply avoid doing it.

This paper proposes some easy rules for modelling the most common decision of **consumers**: to **buy**. This can be particularly useful if you intend to build your own model, but also to better understand this methodology.

We shall do something more than a mere description: we are giving in your hands a model in which these rules have been implemented to let you make experiments, since you can download "Race to

market" for free from the Economics Web Institute.

We further explore six crucial issues in purchasing, while connecting to marketing science and proposing a Golden rule for ABS modellers.

In short, we provide her a sketched introduction to a **new standpoint in demand theory**.

In so doing, we are introducing you to a rich strand of research that exhibits already a good number of agent-based models of consumers [1].

### *1. To buy or not to buy: this is the question*

The basic choice of a consumer is to decide whether to buy the good or not, once he feels a need and he knows (or simply believes) that a certain good could satisfy it (or he has being induced to shift the satisfaction of a need to the purchase of this "distractive" product). We assume that the good is available and within physical and psychological reach: it may be on the shelf of the supermarket and the consumer just needs to grasp it by extending the arm. More in general, it is implicitly assumed that the good passes certain quality tests and does not include some very strong negative aspects which need to be evaluated.

The easiest decision-making rule in this case is to fix a maximum acceptable price (often called "reserve price"). If the actual price of the good is higher than that, the consumer will not buy it because he can't afford it or because he evaluates that it is not worth the expense.

If, instead, the actual price is lower than the reserve price, the consumer buys one unit of it. Why only one?

Let's imagine that you like books and, while searching in a bookshop, you find one that is particularly interesting. Fix your reserve price and give a look on the back cover to the actual price. Sometimes, it is too much. Hopefully, instead, you can afford it. How many copies will you buy in this case? One, of course!

Check in a bookshop what people purchase and you will see the relative weight of alternative situations (e.g. you purchase two to make a gift to a friend).

And you'll not buy an irrational quantity of the good

simply because in this way you exhaust your budget constraint - as the mainstream model of consumer choice would dictate. The budget exhaustion rule, which would leave an empty wallet each time you exit a shop, is very comfortable for mathematical technicalities but it is at odd with real decision making of consumers. Consumers systematically leave shops with some residual money in their wallets. And they run to a cash machine if this exceptionally would not be the case.

This choice between zero and one holds in particular for non-grocery goods. As for grocery, see this model in which the consumer can choose different sizes (thus discrete weights and quantities).

That simple rule gives a direct answer to the question. The quantity bought is zero or one. Individual elasticity to price is zero except when the price jumps across the line of the maximum acceptable price.

Market elasticity to price - when we consider all consumers operating on the market - will depend on the distribution of the reserve prices of each one of them.

The overall quantity sold will depend on price, since a few consumers changes their quantity from zero to one (if the price falls) or from one to zero (if the price increases). Most consumers continue to do the same as before.

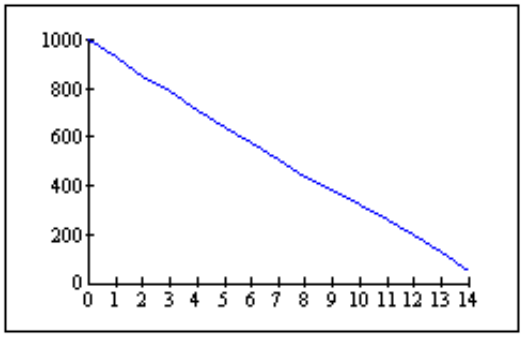
In this way, one replicates the standard result of **a falling demand at higher price** using **much less than the many heavy hypotheses** of neoclassical models.

The **consumer is not requested to be perfectly rational** nor to have **indifference curve among infinite combinations** of two goods.

As far as the aggregated demand curves arising from different distributions of reserve prices are concerned, we'd like now to present you some results and a suggestive interpretation.

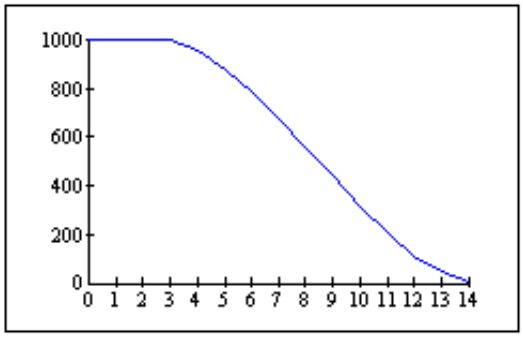
In particular we shall link the shape of the demand curve to the distribution of reserve price in the consumers' population. Then we shall refer reserve prices to income, so that **we shall derive the shape of the demand curve from income distribution**.

**A linear demand curve arises from a uniform distribution of reserve prices between two boundaries (min & max)**, be it a stochastic or deterministic uniform distribution. A diagram showing this case with the demanded quantity on the Y axis and the price on the X axis is the following:

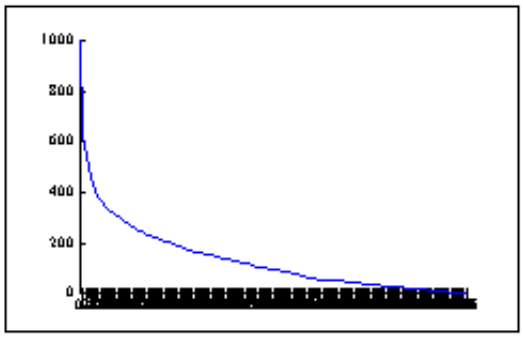



Routinely estimated in empirical research, linear demand curves can thus be generated in this setting very easily. Please note that, by contrast, neoclassical models with standard well-behaved (e.g. Cobb-Douglas) individual preferences **aren't able generate a linear demand curve so directly**, as you can directly experiment with this software.

Furthermore, in our setting, a **concave demand curve** arises from a distribution of reserve price with a **wide number of consumers having a similar middle reserve price**, only few "rich" and few "poor".




By contrast, a **convex demand curve** arises from **a polarised distribution of reserve price**s with most consumers having low reserve prices, few are "rich", and only slightly more are in the middle.




**Three kinds of society give rise to three shapes of consumers' demand.**

Indeed, it is particularly interesting to re-interpret the reserve price as an income indicator, arguing a positive correlation between income and reserve price. Higher reserve prices would thus be indicative of rich people, whereas the poor would express lower reserve prices. This interpretation is plausible and can be formally demonstrated in two cases.

If existed only one good to buy, the entire income would go there and the higher income would immediately result in higher reserve price.

If people equally shared their budget for different class of goods (say; 20% to food, 25% to home expenditure,...) then higher income would mean higher reserve price on each class. If, by contrast, a poor would allocate a higher reserve price for a certain good (and actual expenditure would follow), he would be forced to reduce the reserve price (and actual purchases) on at least another market.

See here for our model with no reserve prices but monthly overall ceilings, where we demonstrate that the purchases of the rich and the poor continue to reflect their income levels. See here for our model of insurance purchase based on a reserve price taking into account the probability of damage, its severity, risk-attitudes (including risk-aversion) and erratic components. You will be able to explore income-related issues in the insurance market, including the higher rate of un-insured people in the segment of the poor.

In empirical terms, it is a well known stylised fact that, although the rich save more than the poor and the budget shares for consumption goods aren't the same between rich and poor, the rich has indeed an actual expenditure higher than the poor for every category of fulfilled needs (see here for data).

By doing this passage from reserve prices to income, we argue that **income distribution is the determinant of demand curve shape**.

It's interesting to note that **neoclassical demand curves** generated by Cobb-Douglas indifference curves of many consumers **are convex**, corresponding - in our context - to **a polarised society with many poor, a weak middle class, and a handful of rich**.

By contrast, we expect that where a wide dominant middle class exists, the demand curve will be concave.

Let's now see how the total consumption is distributed in the population. In the neoclassical model with well-behaved properties, all consumers buy at least some quantity of the good. In our approach, given any price chosen by the seller, the consumers that can afford it will buy one unit each. The others will be **excluded** from consuming **a needed good** and remain **unsatisfied**.

The **total quantity bought** will be equal to **the number of consumers satisfied** whereas **the value of consumption** will be the **quantity times the price**.

**In the neoclassical model, an increase in price of a normal good reduces the quantity bought by each normal consumer**, whereas in our model **it reduces the number of consumers**, each buying exactly the same quantity as before: one unit.

**An increase of income** for **people already buying the good** will have **no impact** on the quantity sold, as instead it would be the case if this increase is concentrated on poorer people: people just below the income that generates a reserve price equal to the actual price, to the extend that the increase in income turns out to be sufficient for overwhelming the threshold.

In another perspective, when considering many markets based on the same principles, **the value of macroeconomic consumption will depend on income distribution** as well as on the **total income**.

The strength of the **Keynesian multiplier** will depend on who receives the increase of income. You can also compare the rich and the poor in their consumption results with this software, commented here.

How many important consequences arise from such an easy first step!

What we said assumed that the choice was actually in the mind and in front of the consumer. A default value of "zero" purchase can be assumed when the consumer does not make an actual choice, but simply pass near goods on the shelf (and even more if he does not enter in the shop!). It's much easier to puchase nothing than something. And to get the opportunity to choose is already an achivement in itself, due to a number of previous efforts and choices (e.g. to exit the house and go to a shopping venue).

### *2. Which one to buy: this is the second question*

An explicit comparative evaluation of pros and cons in purchasing goods that fulfill the same need (substitute goods), requires product differentiation within a category of goods, what widens the decisions that a consumer has to take. He has to choose which good to buy - among those he can afford and that could fulfil his needs.

This kind of situation happens in our model "Race to market", as described in the relative paper.

In this model, the good is vertically differentiated according two features: its performance and how easy it is to use [2].

There are just two goods, so the issue of how many to compare is straightforward, however similar rules could be used when there are more substitute goods on the shelves.

A first rule of choice is to **decide a minimum level for each feature** to be reached by a good in order to be acceptable. The consumer evaluate the affordable goods for each feature and attribute them a relative "score", in its subjective judgement - based or not on objective characteristics. This subjective judgement could be influenced by advertising and be biased (for instance, because of the country of product origin). Then, he compares the score with minimal thresholds. An "insufficient" good - even in one respect only - is rejected.

If there is only one good which satisfies both the price and quality constraints, that will be chosen.

If there is none, the consumer will buy nothing.

What if there are more than one acceptable goods? We need a further selection rule.

In "Race to market" we chose a palette of three alternative kinds of consumers, applying **three alternative rules** for purchase decision. Basically, they differ because of the relative role of price and quality.

**Rule 1:** If - at this stage of the decision-making process - only price is important, the consumer buys **the cheapest good** that survives to minimal quality requirements.

Please note that each consumer is free to set quality requirements, so that this rule is just for choosing inside a selected group of goods. If the consumer sets its requirements quite high, this would produce a purchase of a high-quality good.

**Rule 2:** If - at this stage - only quality is important, the consumer buys **the best good he can afford**. Given the reserve price, he will buy the good whose "overall quality" is the highest and each feature has a "sufficient" score.

To apply this rule, one has to build a measure of "overall quality", as we shall see in a moment.

**Rule 3:** A third group of consumers tries to balance price and quality, then they will choose the **best value - for - money product**.

Once computed a measure of "overall quality", it can be simply divided by the price, so to order goods in terms of value-for-money.

Let's see a numerical example. Consider a consumer facing **two affordable goods that passed all the tests of quality minimal requirements** with the following price and overall quality:

| Good | Price | Overall quality measure |
|---|---|---|
| A | 10 | 20 |
| B | 12 | 30 |

If he uses the first rule, he will choose A because it is the cheapest. If the second one, he will choose B, because it has the best quality. If he relies on the third one (value-for-money), he will choose B again, because 30/12(=2.5) is more than 20/10(=2).

Now, it's time to build a measure of "overall quality". A fairly general approach is to use a linear combination of the scores in each feature, weighted according the relative importances for the consumer of the feature itself [3].

Overall quality = score-in-feature1 x importance-of-feature1 + score-in-feature2 x -of-feature2

For instance in the preceding example, the evaluation of the overall quality for good A as 20 could be the result of the following:

Overall quality = 10 x 2 + 6 x 0

In this case, the consumer isn't interested in feature2, to which he gives a weight of zero, whereas an evaluation of 10 in feature1 is weighted by 2.

Apart from these minor details, the three rules for judging "which one to buy" not only bear resemblance to real consumers' criteria but also may give rise to particularly interesting connections with income distribution.

Indeed, we could try to establish a correspondence between income classes and rules of behaviour - at least in probability terms.

The **poor** are more than proportionally consumer of the first type, looking for the **cheapest good**.

The **rich** tend to be of the second type, buying **the best good** they can afford.

The **middle class** tends to be of the third type, looking for **value-for-money**.

It seems plausible and empirically testable. In particular, there is already evidence suggesting that the poor tend to attribute much more weight to price than the rich do (e.g. this paper). This has led further authors to base their models on such hypothesis.

In this way, the simulated population of consumers will be characterised by the income distribution, the rule distribution, and their correlation.

This sets the stage for competing firms with their own products, strategies, and target consumers.

Consumers have differentiated rules and tastes, thus producers will be faced by a quality-dependent demand curve.

Again, since the single consumer is using a rule implying a dis-equation (more than..., less than...), small changes in price or quality will not change anything for most consumers but a critical range of consumers will, instead, pass from zero quantity to quantity one (or the reverse).

A category of goods can thus display **a wide permanent price spectrum**, with no automatic force to level down all prices to the lowest.

You can test this statement by playing "Race to market" and reflect on many arising issues. For instance, which kind of society will appreciate quality the most? Where product and process innovation will be most rewarded? Try to find out your own answer.

For other rules, keeping into account consumer needs and cumulative bundle, see this paper of ours, with particular reference to these 6 new possible rules.

For an independent empirical market analysis connecting income distribution and a vertical segmentation see this beer study for Vietnam.

In what said, the choice was framed in an alternative (which one to buy), leading to the purchase of one. However there are consumers that to this question would answer: "I buy them all!". We shall see in what follows how to cope with this case.

### *3. How many units to buy: this is the third question*

Economic goods on sale aren't infinitely divisible. If you want a car, you buy one car, not 1.234 cars. They can't be irrational quantities. If your family wants some milk, you'll buy two or three cartons, not the square rood of three. If you go to the butcher to buy a piece of meat, he will weigh it and round any result to the nearest 10 grams: his balance will force him to do it - and his common sense, too.

Neoclassical assumption of infinitely divisible goods and services is rejected by economic life itself.

The choice about the quantity to buy is, then, a discrete choice. One, two, three, four...

In many cases, the only meaningful quantity is one - as in the one-off purchases (mostly durable goods). But in other situation, there may be the meanigfulness of duplication (several identical items), usually in connection to non-durable goods.

In the latter case, which rules has the consumer for choosing quantities? Many. But an easiest one that we propose, in line with previous developments, is the following: each consumer fixes a maximum acceptable price for each further unit of the good.

The neoclassical assumption of decreasing marginal utility would imply a falling reserve price for each unit. In our setting, the consumer chooses **purchases** with no explicit link to **consumption** utility, which might well depend on completely different factors emerging in the moment of consumption (e.g. sunny weather conditions making more enjoyable the good or, instead, a quarrel with the wife leading to the opposite influence).

We do not need to impose any particular relationship among the reserve price of the first unit and the reserve price of the others.

Indeed, if the second unit has a higher reserve price than the first, an actual price between the two will result in no units bought, not in a "second unit" purchased with a "first" unaffordable.

In a dynamic setting, the quantity would furthermore depend on the expected **length of time** that will elapse before next purchase occasion and the **expected consumption** in that period, as well as on **the quantity already at home** in the cumulative bundle. For instance, for a good for which the consumer strongly dislike to have an interruption in consumption, if he expects to come back to the shop in 10 days, and during this period he will everyday use a standard dose of 100 grams (plus or minus a small statistical error, whose average is zero), and at home the cumulative bundle includes some 300 grams, then the purchase would be at least 700 grams plus any buffering quantities that would cover any discrepancy from plan.

So if packages contains 100 grams each, a purchase of 8 to 10 packages is likely. Please note that a higher quantity (e.g 16 to 20 packages) might be the result of an expectation to come back to the shop in 20 days instead of 10. It would be unrelated to price.

A special offer with **a discount price** would probably imply a larger number of purchased units if the product can be piled up in inventories in the cumulative bundle at home and will avoid to look for further POS in search of a lower price.

To see how an entire basket of goods is purchased in a retail grocery supermarket, and which kind of rules can be applied by bounded-rational consumers, see our paper on "Size, price, and consumer rules". To verify what happens when several identical items are included in the cumulative bundle of the consumer, see this paper.

A wider discussion of quantities available at supermarket premises and during promotional periods is here, where additional consumer decision making rules and generalizations are articulated. In particular, the paper states that **purchased quantity is not a simple function of price**: it depends on the **categorization** of the good by the consumer (as for suitability of fulfilling certain needs), on the routines establishing the **number of consumption occasions** (arising from need requests to be satisfied through that good in particular) and which occasions are actually **seized**, on the "**consumption dose**", and on the time of repurchase, which is a function of lifestyles and shopping distribution landscape - all this cumulated for **all the people living together** at the household.

In other words, it you see somebody exiting a supermarket with four packages of (1 litre) milk, you can make the educated guess that in their household, milk is considered a necessity, is consumed every day by two person (e.g an adult and a child at breakfast) for a consumption dose of 140 ml and 110 ml respectively, that next visit to a POS for milk will be in two weeks time, that at home there is still some milk in the fridge (cumulative bundle) and that the price has been considered as acceptable. Small changes in the proportions of all variables are compatible with such quantity. However, if you know that there was a strong and temporary price promotion, you might guess alternatively that the four packages were linked to the room on the shelves that a single can devote to piling

up milk she drinks over many months. To discriminate those guesses (and further ones!) some more observation (or interviewing) of the consumer will be needed.

A largely different issue is when the consumer want several versions of the same good (or many different goods): in this case the quantity is a sum of "apples and pears", of heterogeneous goods, counted as "one" each or put on a common indicator (like weight), which temporarily (and possibly improperly) sets aside the underlying heterogeneity. This issue is covered in the concept of cumulative bundle.

### *4. How often to buy: this is the fourth question*

In real life, purchase occasions depend on life micro-pattern. For many working people, Saturday is the day in which the largest shopping takes place, with minor occasions during the week, largely structured along house/work paths and timing.

Housewives are freer to schedule shopping activities, but they tend to follow routines, too.

These occasions usually concentrate in time and space the purchase of several goods in order to reduce transport time and costs through multipurpose purchase trips across point of sales with a definite offer in terms of broad and narrow categories. brands, varieties and size packages.

For an individual, the consumer buying behaviour pattern described by the **number of (re)purchase acts of a category** will depend on two main elements:

1. the typical average of the category (that in turn belongs to macro-categories as non-durables or durables, with all their nuances);
2. the type of consumer (heavy consumer, light consumer and all the intermediate positions).

Heavy consumers repeat very often their purchases. In so doing, they cumulate category-specific knowledge and skills.

Certain empirical researches show that heavy consumers are often early adopters of innovative goods in the category, since they are more conscious of the **unsatisfactory features** of the old good. Here there is much room for debate. What is your opinion?

How often to buy **a specific good in a category** will depend on the **brand loyalty** of the consumer. If he buys always the same brand, the frequency for the good will be equal to his frequency for category. If he alternates few brands (loyalty to a shortlist), his purchase of one will be a share of the total. If he chooses many brands following irregular patterns, the frequency for the good will be erratic.

A perfect brand loyalty can be due to many different reasons:
1. **independent purchases** ending always in the same way because of unchanged properties (quality, price) of the goods and of the consumer (income, decision-making rules, weight of quality features,…);
2. independent purchases ending always in the same way because of rising dominance of the chosen brand;
3. a positive value for **continuity** in itself;
4. a positive feedback loop of choice, satisfactory experience, re-purchase;
5. **inertia** and minimization of choice costs aimed to avoid the repetition of an extended search and evaluation process;
6. high **switching costs**;
7. a perceived **high risk** of dissatisfaction attached to a new choice;
8. monopolistic position of the brand for the specific need of the consumer.

Instead, loyalty to a shortlist of brands combines (i) a bundle of goods that satisfy the consumer with (ii) a preference for variety. When you go out to dinner and choose always something you like but not in a row exactly the same dish, you are in this situation.

Please note that much of the discussion of these issues in marketing science has been oriented to assess the impact of **advertising** and to check a possible un-elasticity to price of brand loyal consumers.

In "Race to market", the present version of the model is purposefully simplified: the good is a durable and a consumer having bought doesn't need to repeat his purchase. This makes the exhaustion of the potential market as the tail of the typical story.

If you like to see what happens with a more complete model, please participate to our experimental sessions, signalling your intention by e-mail.

On a broader perspective embracing all goods

purchased by the consumer over time, the new key concept of "cumulative bundle" we introduced, allows for rules related to breaking inventories and complementarities in order to take decision on timing the sequence of POS to visits.

For instance, if a sufficiently large number of goods are near exhaustion, because of successive **doses of consumption** impacting the cumulative bundle at home of the consumer, the latter can verify the possibility of going shopping in the POS where they can be repurchased on time to avoid an inventory break, especially if those goods are labelled by consumer as "basic commodities" for routine consumption.

***5. Where to buy: this is the fifth problem***

Somehow introduced in the preceding chapter, the issue of where to buy is extremely relevant. Points of sale have their own competition game to play in order to attract customers. Once there, whatever the consumer will select, the seller will be just one - the same retailer that has exposed a variety of items and decided a certain dispersion of prices: the checkout counter remains the same.

POS belongs to many different distribution formats (family shops, specialty shops, supermarkets, hypermarkets, hard and soft discounts, online e-commerce stores, etc.), each one with a general positioning as format, which is more or less originally declined in the specific POS.

The choice across POS can reasonably be dependent on:

1. proximity to routine travels to work and back to home - or any other track where the consumer is when decides to hop in;

2. an explicit route to shopping venues in order to compare offers (e.g. during rabate season or before an important purchase);

3. the expected width of products available (categories and varieties) which will allow the in-shop choice;

4. the expected convenience in term of prices, service, safety, methods of payments, etc.;

5. the social image of the POS (especially if belonging to some chain retailer or a specialty shop strong brand)

- if the consumer expects to be involved in conversations about where she/he made the purchase;

6. all abovementioned points 3-5 related not just to expectations but on experience (with repurchasing being one of the goals of the visit);

7. the preliminary selection that the POS guarantees, with the exclusion of goods that do not meet their criteria (e.g. too low quality, too high prices, etc.), which allows the consumer to express its preferences within a pre-determined "range" of possibilities - this reduces the time and the potential conflicts of choices across undesirable products;

8. a special offer or product in the shop window or on advertisement display (if any).

It's unusual that agent-based models cover all these aspects in detail. However, it is very interesting to develop such models along two alternative roads:

a. a relatively detailed **distribution landscape**, with spatial coordinates of houses, workplace and other reference points for multi-purpose trips (including specialised trips for shopping), where competition across POS involve **localization** as an important leverage; potentially, if in the model there is also the localization of work, the dual dynamics of population agglomeration and production/consumption locations could be studied (with emerging shapes of commercial "high streets", "industrial districts", "logistic hubs", etc.), because the presence of "services" is one of the elements considered in relocation choices of households, what can be purposefully leveraged e.g. in cases of urban regeneration; please note that the disruptive consequences of the introduction of virtual-location online shops can be explored in such a model;

b. a non-spatial approach, where consumers choose POS mainly on issues 2-6, which allows category managers to engage in competition on variety, price and other common leverages; the cumulative bundle represented by all goods on the shelves becomes a key factor on variables like the average cash receipt, its frequency distribution, time to return in the same POS, etc.

Some stochasticity would allow to blur too deterministic results (and include case 7).

A major attempt to model the distribution landscape with several new insights is here.

The consumer should be free to leave the POS without purchasing anything, delaying an expected purchase until she/he finds a satisfactory solution.

The easiest way to model this building block is **a three steps procedure** that would lead the consumer to choose first the preferred format, then the specific POS where to buy and then what to buy (and the other key abovementioned problems). Experience with having chosen a POS would possibly influence the next loop. Over time, the consumer might be POS-loyal to one or a shortlist of POS.

However, this sequence might be switched. For certain goods, the specific presence of a brand or an item can be the "hook" to convince an interested consumer to enter POS and then to cross-sell several other items, as their view reminds consumer of a previously noticed "lack" in his/her cumulative bundle, a mental note to buy or build up an impulse to take it.

Other very relevant "hooks" are the promotion campaigns with leaflets (distributed at home or on the street) with product photos, discounts and claims, valid for a certain period of time (e.g. one or two weeks). Promotions are the key advertising vehicle for POS and are usually quite effective in driving traffic.

The third group of "hooks" is constituted by the private label of retail chain, which supplies close substitutes to industry-branded products, while being exclusive to the chain (whereas the latter are sold across a number of POS in competition, offering the possibility to the consumer to directly compare price, thus inferring the overall price positioning of the POS).

The fourth groups of methods to retain people to POS are fidelity cards and fidelity programs (special discounts for people having the card, gifts for cumulated high purchases,...).

In other words, an agent-based model with explicit consumer choice about where to buy can accomodate several competitive strategies of distribution agents, including the classical "Every day low price" or "Hi-Lo". Please note that in modern economies, the position of distribution vis-à-vis industry is not just a passive "distribution channel" any more: they are usually much

larger and stronger than the industry, negotiating tough prices and deciding sale prices and positioning with an amazing consciousness of consumer behaviour, due to scanner data and analysis.

In another vein, the distribution landscape has to do with the income distribution: hard discount are the preferred choice for the poor, supermarkets for the middle class and specialty shops for the rich. Empoverished middle class can then revert more frequently to the discount, forcing supermarkets to introduce "first price" private labels. Bazaars can have the hourglass shape of top and bottom products, with a wide range of goods whose price can be negotiated.

***6. How much time, attention and involvement to devote to purchasing: this is the sixth problem***

A decision can be taken quickly, based on few drivers, coarsely evaluated by just one person in a hurry. By contrast, the choice can be carefully taken, with a lot of different alternatives evaluated, through a lengthy procedure, involving many people. In agent-based models, this can be reflected in a full-fledged decision-making setting which distributes rules and parametres according to these two extremes and what lies inbetween.

More specifically, the length of time and the degree of attention paid to the decision depends on four broad determinants:

1. the kind of product;

2. the personality of decision-maker;

3. the occasion of choice;

4. the number of people whose preferences are reflected in the decision.

As for 1., the time will be long and attention paid high when the product is seldomly purchased, has a high price, it's technically and socially difficult, produces far-reaching consequences (opening and closing further opportunities), there is a high risk of making a wrong choice, having bad outcomes and being irreversible, and it is located in remote point of sales. Conversely, if the product is easily reached, frequently purchased, involves low prices, it's easy, bears no consequences, can be given back, the time and attention will tend to

be low. However, the other determinants will interplay with the nature of product or service under examination.

In fact, as for 2., personality traits of the decisionmaker can include people ranging from anxious, obsessive, meticulous, undecided, down to light-hearted, uncaring, unaffective, compulsive, proud of being able to choose quickly. If these traits are strong, people will tend to have a distinguishable style in decision-making across different products.

As for 3., one should recognize that the specific location and timing of the purchase could compel a certain simplification (e.g. when in a rush, an external constraint, etc.) or allow for a longer shopping (e.g. while waiting for somebody else).

As for 4., the process will be easier if just one person is involved or he/she is authoritarian and powerful enough to impose his/her will or symmetrically if all the others are inclined to fully implement it or, finally, if everybody agrees on a self-evident focal point. Conversely, if a compromise has to be found across two or more people, whose preferences, rules and styles are not aligned, the time will probably longer, with several proposals made, rejected, modified, bargained and negotiated.

The four drivers will interact (in a more or less fuzzy way) so to determine time, attention and involvement devoted to the choice. Long time and high attention will allow for a wider range of alternatives to be evaluated through high involvement, and a more precise evaluation of each under a higher number of features. Rules-of-thumb will continue to play an important role, because of their capability of bringing back the decision in the realm of the feasible.

Attention tends to go hand in hand with the time devoted, however a number of marketing devices are used in order to attract the attention of consumers, deviating it towards the most favourable light on the product and to activate or deactivate rational and emotional connections and evaluations.

For instance, it seems that most purchases in supermarkets are done within 12 seconds from the moment in which a certain product is looked at. During this short period of time, the potential purchaser can alternatively:

1. recognize brand and product as matching a planned purchase in an acceptable price range;

2. recognize brand and product as needed at home (either because in exhaustion in the cumulative bundle or for other reasons) and judge its price acceptable;

3. compare a few alternatives in the same shelves, by looking at brand, product and prices;

4. compare alternatives present in the point of sale with memorized and expected substitutes in other point of sale;

for a final decision on purchase, as in the preceding chapters. These (and other) alternative attention-driven activities may require material or mental aids (such as planned purchase list).

The experience with previous searches and purchases can reduce the complexity of next purchases, with a reduction from high involvement to low involvement by a routinization of choice and a reduction of time and attention by repeating the successful choice (or a reduction in expected benefits!). Over time there is an evolution of the cognitive and emotional capability of the agent, both in general terms and linked to the use and consideration of the specific good.

All these reflections, in turn, mean that the modeller should allow some room for time, attention and involvement to play a role in the decision algorithm the model contains, while ideally allowing to postpone decisions, re-evaluate choices made (purchaser's remorse,...), etc. Conversely, in the qualitative discussion of the model, it would be advisable to express the underlining assumption about time, attention and involvement paid, if not explicitly included in the model.

## *7. Agent-based consumers and marketing science*

This essay is a first attempt to provide a consumer decision model useful for marketing strategies and tactics.

Indeed, the tree-shaped choice pattern we devised and described in this paper has a good matching with the description of aggregate market variables in marketing science.

The overall result of the individual choice of "buying or not" gives **market penetration**, i.e. the percentage of potential consumers who become actual customers.

The overall distribution of results of the individual choice about "which brand to buy" turns out to be the **market shares** of the different brands.

The overall distribution of results of the individual choice about the number of units to buy distinguishes **heavy users** from **light user**, to the extent that a big purchase is followed by a personal intensive consumption concentrated in time. For instance, if the good is alcohol-based, this variable singles out the (possible) drunkers.

Keeping into account all the abovementioned dimensions of choice, one can better interpret the **amount of sales** over a certain span of time.

More in general, we think that marketing science has much to teach to economics. Agent-based evolutionary economics is ready to learn.

### *7. The golden rule*

In this paper, we proposed a few rules of choice and behaviour to be used in agent-based models comprehending consumers. Other rules have been already employed and many more could be imagined.

In the open debate about which rules should be selected, one **modeller's "golden rule"** might be proposed.

**It should be always possible to convert the formal rule - used in the simulation model - into a question for real consumers in a questionnaire.**

Real-world market research over consumers makes large use of questionnaires, to be submitted to housewives and purchasers by phone, face-to-face interviewing, panel software, Internet, and so on.

Our rules should be convertible into simple questions that a normal consumer can answer.

This "golden rule" has two advantages:
1. it avoids too strange and difficult rules to be used in formal models;
2. it allows for empirical feedback to the model.

It is not irrelevant that this simple first criterion cannot be satisfied by neoclassical theory of indifference curves. You cannot build reasonable questions about "Are you a Cobb-Douglas type?"

Instead, from "Race to market" we could obtain questions - and this is already an important result.

In this moment, you can even **personally answer** to them from this dynamic page.

### *8. Conclusion*

Neoclassical theory of consumer is being challenged with the new strand of evolutionary agent-based theory and models. This paper provides many hints about the rules that could be given to consumers in agent-based simulations.

It proposes four major problems the consumer faces. In order to solve each of them, one or more consumer decision rules are proposed, straightway leading to important consequences on macro level.

In particular, demand patterns are traced back to income distribution. Income and prices are as important here as in the neoclassical model, but easy rules allow bounded rational consumers to take decisions, by limiting the requirements of information and computation capability that make the neoclassical model so unrealistic.

A "golden rule" for the modeller is offered to the open debate about which rule to employ in agent-based models.

By micro-founding demand, the agent-based models can offer important suggestions to marketing strategies and to policies focused on consumer welfare.

### *Impact factor*

Read by more than 23.000 people (counting since 2007), this paper has been quoted, for instance, by:

* "Branding and Advertising" by Seema Gupta (31 Dec 2009);

* Advances in analytics: Integrating dynamic data mining with simulation optimization by Better, M. Glover, F. Laguna, M. in the **IBM Journal of Research and Development** Issue Date: May 2007 Volume: 51

Issue: 3.4 On page(s): 477 - 487.

* a University dissertation in 2010 and another University D-level Thesis on "Impulsive Shopping Decisions - can they be predicted?" in 2007;

* a University seminar syllabus;

* the resource centre of an Oxford University Press book (Strategic Management by Haberberg and Rieple);

* an agent-based simulation of a entire landscape of shops and other distribution channels (2010);

* a peer-reviewed article in the European Journal of Operational Research on a game theoretic approach to coordinate pricing and vertical co-op advertising in manufacturer–retailer supply chains (2011);

* "A Conceptual Reconsideration of Price Issues with Casino Gaming" - Ricardo C.S. Siu. Gaming Law Review and Economics. May 2011, 15(5): 267-277. doi:10.1089/glre.2011.15509.

* TOWARDS A SUITE OF PROBLEMS FOR COMPARISON OF PRODUCT PLATFORM DESIGN METHODS: A PROPOSED CLASSIFICATION - Proceedings of DETC 2006
2006 ASME Design Engineering Technical Conferences.

The Golden rule proposed in this paper has been included in the few major new venues for agent based models in "Artificial markets: A review and assessment of a new venue for innovation research" by Brent Zenobia et al. (2009), published by peer-reviewed journal Technovation.

The relationship between income and decision-rule has been implemented - by quoting this paper - in "Modelling Tourism in the Galapagos Islands: An Agent-Based Model Approach" in the peer-reviewed "Journal of Artificial Societies and Social Simulation" 17 (1) 2014. NEW!

**NOTES**

[1] See in particular the following:

A consumer memory-based model of new product diffusion within a social network by J. Kottonau, J.

Burse, C. Pahl-Wostl

Agent-based Explorations into Consumer Choice Modeling by C. Stumpo

Agent-based modelling of customer behaviour in the telecoms and media markets by P. Twomey and R Cadman

Agent-Based Modeling in Marketing: Guidelines for Rigor by W. M. Rand and R. T. Rust

Agent-Based Model of Transitions in Consumer Lighting by M. Afman, E. Chappin, G. Dijkema, W. Jager

Agent-Based Model of the Transition to Hydrogen-Based Personal Transportation: Consumer Adoption and Infrastructure Development Including Combined Hydrogen, Heat, and Power by M. Mahalik, C. Stephan, M. Mintz

Agent-Based Models by N. Gilbert

Agent-based models of electricity markets (from Finding Ways to Reduce Greenhouse Gas Emissions Using Multi-Agent Electricity Modelling)

Agent-Based Modeling of Innovation Diffusion by R. Garcia and W. Jager

Agent-Based Modeling of Ecological Niche Theory and Assortative Drinking by B. Fitzpatrick and J. Martinez (2012)

Agent-based Modeling of Urban Energy Supply Systems Facing Climate Protection Constraints by T. Bruckner and T. Wittmann

Agent-Based Simulation of the Consumer's Apparel Purchase Decision by Brannon et al.

A methodology for agent-based modelling using institutional analysis – applied to consumer lighting by Ligtvoet, Ghorbani, Chappin

A Model of Bounded Rational Consumers with Endogenous Preferences (2003) by Marco Valente

An agent-based model for consumer-to-business electronic commerce by D.-N. Chen, B. Jeng, W.-P. Lee and C.-H. Chuang

An agent-based model for estimating consumer adoption of plug-in hybrid vehicle technology by M. Pellon et al.

An agent-based model for the study of publicity/consumer dynamics by J.J. Merelo, A. Prieto

Analysing Retailing Opportunities And Threats Using Agent-Based Simulation by V. Vojtko and M. Heskova 


Analyzing the Effectiveness of Marketing Strategies in the Presence of Word of Mouth: Agent-Based Modeling Approach by Ç. Karakaya, B. Badur and C. Aytekin

An Evolutionary Theory of Household Consumption Behavior by R. Nelson and D. Consoli (2010)

An integrated approach to simulating behavioural processes: A case study of the lock-in of consumption patterns by M. Janssen, W. Jager (1999) in Journal of Artificial Societies and Social Simulation

Artificial Life simulations: Consumer behavior modeling for marketing strategy by B. G. Tedesco

Conceptualising and Simulating Insurance Consumer Behaviour: an Agent-Based-Model Approach by A. Ulbinaite, M. Kucinskiene and Y. Le Moullec

Consumer Behaviour and Technological Complexity in the Evolution of Markets by M. Valente

Consumer Decision Making and Beyond by L. Schiffman, L. Kanuk

Demand Dynamics With Socially Evolving Preferences by R. Aversi, G. Dosi, G. Fagiolo, M. Meacci, C. Olivetti

Empirically Based, Agent-based models by M. A. Janssen and E. Ostrom (Nobel Prize 2009)

Engel Curves Specification in an Artificial Model of Consumption Dynamics with Socially Evolving Preferences by G. Fagiolo

Epistemological considerations on agent-based models in evolutionary consumer choice theory by M. G. D. Fonseca and R. M. Zeidan

Integrated Multi-agent-based Supply Chain Management by D. Frey, T. Stockheim, P. Woelk, R.

Zimmermann

Meeting the Challenge of Complexity - Policy-oriented consumer agent based models

Modelling consumer behaviour by W. Jager

Modelling Demand for Innovative Products by M. Valente

Modeling consumer behaviour towards payment system selection using multiagent based simulation by G. Rigopoulos, K. D. Patlitzianas, N. V. Karadimas

Multi-Agent Based Simulation of Consumer Behaviour: Towards a New Marketing Approach" by L. Ben Saida, A. Drogoulb and T. Bouron

Multiscale Agent-Based Consumer Market Modeling by North et. al.

Networks of agents with advertising by F. Alkemade

Simulation Methodology: an Example in Modelling Demand by M. Valente

The Building and Assurance of Agent-Based Models: An Example and Challenge to the Field by Midgley and Marks

The economy needs agent-based modelling by J. D. Farmer and D. Foley (Nature, 2009)

Towards an ABM-Based framework for investigating consumer behaviour in the insurance industry by A. Ulbinaite and Y. Le Moullec

USING ANYLOGIC AND AGENT-BASED APPROACH TO MODEL CONSUMER MARKET by M. Garifullin, A. Borshchev and T. Popkov

Validating agent-based marketing models through conjoint analysis by R. Garcia, P. Rummel and J. Hauser

Waves in Consumption with Interdependence among Consumers by R. Cowan, W. Cowan, G.M. P. Swann.

[2] See Note 1 for agent-based models that propose

other ways to cope with product differentiation, in particular the works by Marco Valente.

[3] Needless to say, this arithmetic, however simple, isn't directly used by real consumers! But this formula allows the artificial consumer to reach a punctual decision corresponding to the informal way of judging quality. Indeed, it is feasible to ask real consumers to rate the importance of different features, e.g. on a Likert scale.

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**Essays**

**More on consumer behaviour...**