

Homo Communitatis: A Rigorous Foundation for Behavioral Finance

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Introduction

Behavioral finance, and behavioral economics in general, are based on the insight that the fundamental conceptual model of neoclassical economics, the rational utility-maximizing homo economicus, is unrealistic. Just as the model of planets following circular orbits had to be replaced with one based on elliptical orbits, human behavior, including economic behavior and non-economic behavior with economic impacts, is not describable in terms of rational self-interest, even if enhanced by boundedness.

This raises the question of what behavioral factors to include. Barberis and Thaler, for example, note that for guidance on behavioral models economists rely on cognitive psychologists for insight into beliefs and preferences (Barberis and Thaler, p. 1054). The basic thesis of this paper is that the range of factors that affect economic actions in general, and financial decisions in particular, is much broader than the subject matter of cognitive psychology, and that therefore both good science and predictive power demand a rigorous framework incorporating as many of these factors as possible.

The question of what factors must be included is inextricably bound up with the fundamental fact that a very wide range of human actions have economic consequences. An example, discussed in more detail below, is the Tongan fakaafe, a feast in honor of a visiting Wesleyan minister (Bennardo, pp. 307-312). These feasts involve a good deal of food gathering and preparation, labor, and consumption of food, and so are quintessentially economic activities. However, they take place when the minister comes to a village, a schedule based solely on social and religious concerns as evaluated by the minister. Because of this fundamental logical connection between economic and non-economic activities, it is impossible to set an a priori limit on what behaviorally significant factors must be included in our economic and finance models. In addition, as the range under consideration expands,

concerns about how to maintain a mathematically rigorous and empirically justified framework increase.

Work to date has primarily focused on the cognitive aspect of behavior, using concepts and methods of cognitive psychology. Intrinsic motivation and identity have been included to an extent, and incorporation of fairness concerns in the utility function is well known, but efforts have been piecemeal, in the sense that there has been no single systematic framework incorporating cognition, motivation, social values, and identity, as well as other relevant aspects of human behavior. Indeed, the discipline in widest use in behavioral economics and finance, cognitive psychology, rejects in toto the concept of motivation, and is similarly silent on the concept of identity. Identity illustrates an important additional difficulty in expanding the model while maintaining rigor: how does one rigorously formulate identity, a concept widely discussed but never mathematically formulated in any of the disciplines of psychology?

In previous work we presented the Community-Practice model, a rigorous framework for creating economic simulations incorporating a much wider range of such behavioral factors (Jeffrey, 2006). This paper is an expansion of that work, in four ways:

- The model has been enhanced to incorporate personality characteristics, a formalization of the concept of identity, and a significantly expanded treatment of motivation and value.
- The simulation algorithm has been enhanced to incorporate the new aspects of the model.
- The model is used to analyze certain foundational issues in behavioral economics and finance, including use of the concept of mathematical probability, and develop a new formulation of action under uncertainty.

- It is further used to develop a new formulation of value as a vector, rather than scalar, quantity.

Less importantly, in recognition of and in deliberate contrast to “homo economicus,” we have re-named the model “homo communitatis.”

Homo communitatis is a rigorous formal model of human behavior, both individually and in groups, that incorporates intrinsic or expressive behavior, identity and all the other aspects of individual behavior that affect decisions and the impact of the group on individual choice: families, professions, firms, work teams, religions, sub-cultures, etc. Having these factors represented formally enables formal treatment of a much wider range of economic-related and finance-related behavior. This includes significantly more realistic simulations incorporating a much wider range of variables, particularly when the economic facts and quantities of interest are affected by, and affect, other, non-economic, factors.

Incorporation of non-economic concepts

Every discipline is based on a certain set of concepts central to it – the states, objects, processes, and relationships (including quantitative attributes) between them. Work in that discipline is devoted to elaborating those concepts and their logical relationships and, to one extent or another, empirical study of the applicability and usefulness of the concepts and derivations to the real world. Simulation is based on explicit formal representation of those concepts. Thus, in chemistry, a simulation of the Belouzhov-Zabotinsky chemical reaction involves representing chemical objects, quantities, and mathematically stated relationships between them (Thompson and Stewart, 1986). In computer science, a simulation of a computer system uses formal variables to represent parts of the system and the processing of

input. In each case, the concepts are elements of the underlying theoretical framework that defines the discipline.

In modeling of economic systems, this logic leads naturally to the conclusion that the objects, facts, processes, conditions, and relations among them to be included and formalized are economic ones. In neoclassical economics, the factors included are limited to those involved in calculation of self-interest, limited by bounds on actors' ability to assess it. Because economic systems address facts and issues directly involving human behavior, limiting analysis or simulation to purely economic facts and processes has been subject to two kinds of objections.

First, the disciplines of psychology, sociology, and anthropology (to name only three) all address human behavior, and the psychologists, sociologists, and anthropologists all tell us that economic factors alone are not sufficient to describe and explain human behavior (Abelson, Ossorio 2006, Ossorio 1981, Putman, Spradley). These disciplines tell us that prediction of behavior, the central concern of economists of all kinds, cannot be done based solely by analyzing economic variables. Second, persons observably act in ways that are not in their self-interest and are not seen by themselves as being so. The kinds of facts cited in such objections include the empirical fact that people engage in "expressive" behaviors (also called "intrinsic practices" in sociology and psychology), that they are commonly observed to act counter to their economic self-interest due to the influence of identity and group membership, that they commonly engage in actions at considerable cost to themselves due to ethical and moral considerations, etc. Further, social scientists have long known that the multiplicity of memberships in significant groups in modern societies – individuals holding positions in a family, a culture, a subculture, an organization, a profession, a church, and several other social groups, all with their own coherence and identity – presents the individual with a multitude of influences on behavior, both personal and group-based, many

of which may conflict. The psychologists, sociologists, and anthropologists note that all of these factors observably affect behaviors with economic consequences, and as a result solely-economic models are incomplete. For example, in his study of the spread of birth control, Chattoe points out that that, even with all other factors taken into account, the choice to adopt birth control practices depends critically on non-economic factors such as the potential-adopter's religion and the devoutness of their beliefs.

While some economists (and philosophers) take the position that these other factors are explainable in terms of self-interest and economic impact, there seems little doubt that if the goal is accurate prediction of economic variables these factors need to be included in some form, whether regarded as legitimately separate factors or “epiphenomenal” summaries of fundamentally economic concepts. Practically speaking, we have little choice but to include these factors in our models, unless we happen to be working in the relatively narrow range of behaviors in which only prima facie economic factors are present.

It can be argued that while inclusion of a wider range of factors may be necessary in principle, in practice the net effect on economic or financial outcomes, when averaged over a population, is insignificant. This is possible. However, whether or not behavioral effects outside the economic realm “wash out” is fundamentally an empirical, not theoretical, question, to be answered by observation and experiment, and without a rigorous and comprehensive framework incorporating these factors and their relationships, there is no systematic and precise basis for formulating experiments or gathering and analyzing data. For example, we know that racial prejudice can and often does lead a loan officer to assess risk differently for members of certain races, a fact leading to a large number of economic consequences. However, we also know that individuals in an organization are expected to adhere to the principles governing choices in that organization. As a result, a racially biased loan officer in a committed race-neutral lending organization has conflicting influences on his

or her decisions. Further, these influences are of more than one kind: cognitive, in that a biased officer may actually judge the risk higher or lower based on race, and motivational, in having motivation to approve or deny a loan in spite of assessed risk level. A comprehensive model incorporating these various factors permits mathematical and/or simulation studies of lending choices and evaluation of results against empirical data. Without such a model, neither step can be done precisely and systematically. The customary way to include other factors in economic models has been to expand the domain of the utility function, but this does not reduce the need for a rigorous and comprehensive model to use in constructing more sophisticated and elaborate functions.

The fakaafe example above introduced this phenomenon. A second example illustrates an important characteristic of it: the need to represent the process-subprocess structure of the activities of interest. Consider a computer software maker building a document management system for a large bank. One of the processes generating load on the computing resources is transfer of files from the document repository. The software maker needs to model the design, to find out whether it can handle the load that actual use will impose on the system. To do this, they must find out precisely what the primary users will use the system for. To achieve a useful level of accuracy, the model must include not only the specific commands, but the entire hierarchically structured set of bank work practices in which the file-transfer is a step: by transferring files, the bank officer is getting ready to do a site visit to a client company; by doing a site visit the officer is doing due-diligence on the customer; due-diligence is a step in carrying out the mission (the practice) of the loan division, namely, to invest in low-risk businesses. Load on the document management system from the file-transfer activity is produced when the larger practice of carrying out a site visit takes place. While in principle empirical data on file transfer might exist, in practice what can be accurately estimated is the number of site visits. Thus, having accurate input

data relies on having an accurate model of non-economic business practices, that is, practices that may have economic inputs and impacts, but do not themselves involve the overt use and manipulation of economic facts, objects, and processes.

In this paper we use the analysis of human behavior and communities by two psychologists, P. G. Ossorio and A. O. Putman, as the basis of a formal model incorporating a significantly wider range of facts and processes that affect economic behaviors and choices in a single, formally articulated, systematic framework (Ossorio 2006, Putman). Descriptions in this framework may be used, directly or indirectly, as the basis for simulations that explicitly represent these several kinds of factors and their relationships.

Homo communitatis

A systematic, comprehensive framework incorporating as wide as possible a range of factors involved in human behavior is, as might be expected, not simple. In the interests of clarity, therefore, we first give a brief summary of its core concepts, without formalism:

- Individuals engage in actions intended to bring about some change in the circumstances, and they do this because they value the new circumstance more than the existing one. (“Value” however does not mean “self-interest”; self-interest is one type of value. This is discussed extensively below.)
- Engaging in action involves having the necessary facts and concepts and the requisite skills.
- The action taken depends in part of the personality characteristics of the actor: attitudes, traits, and priorities.
- Every person is a member of one or more communities, i.e., coherent groups of persons such as families, businesses, ethnic groups, nations, work teams, etc., and

furthermore occupies one or more positions in every community they are a member of: father (in their family), cousin (in their extended family), investment advisor (in a bank), Certified Financial Analyst (in their profession), citizen (of their country), deacon (in their church), etc.

- Every action a person does is an instance of engaging in a practice of a community, a community of which they are a member.
- Communities have priorities, principles governing choices to which members are expected to adhere. For example, Catholics are expected to eschew birth control, Mormons alcohol, Muslims charging interest. The direct effect of a choice principle on actor choice is that it gives the actor motivation to engage or not engage in a practice.
- In the paradigm case, and in the vast majority of actual cases, a person knows what they are doing and chooses to do it, in light of the reasons they have to engage in various alternative actions. (By this we do not imply “rationality,” any “decision-making process,” or any episode of deliberation. It is simply a reminder that an action is always selected from one of several perceived alternatives.) Choice is always a choice between alternative actions, i.e., between engaging in practices (or versions of a practice) actually available to the actor (and known to be).

The specific connections to behavioral economics and finance are:

1. Some of the actions, i.e., practices engaged in, directly impact economic facts, in that the outcome of the practice is a change in an economic or financial situation. Decisions to invest in a security, and not in others, are of this sort.
2. A wide range of actions produce goods or provide services, the focus of economics and, indirectly, finance. Thus, economically significant behavior is a

subset of behavior in general, and there is no reason to expect, a priori, that this subset is simpler than behavior in general.

3. Many actions, whether economic or not, require the use of “resources” quantified in economics – capital, raw materials, etc. – and are therefore impacted by economic behaviors.

The Homo communitatis model in detail

In more detail, the elements of the homo communitatis model are:

- The central concept of the model is that everything a person does is an instance of engaging in a social practice of a community of which they are a member. Following customary anthropological use, the social practices of the community are the organized patterns of action recognizable by members of the community as a single, known, repeatable, “done thing.” (Both of these key concepts are formalized below.)
- Everything that happens in such a group – a community – is an instance of engaging in an instantiated version of a social practice. A version is a set of other, smaller, practices such that accomplishing all of the set is a case of engaging in the overall practice. Investing in a particular mutual fund, for example, requires engaging in several other, smaller, practices: deciding on criteria to base the choice on, getting a list of potential funds, gathering data to assess the degree to which each fund meets each criterion, actually making the choice, and buying shares.
- The practices of a community are organized hierarchically. Intrinsic practices (following customary usage in psychology) are those practices engaged in simply

because the actor occupies the position they do (or, equivalently, has the relationship they do with some other member of the community). Intrinsic practices are at the top of the hierarchy, and are engaged in by engaging in other, smaller or more limited, practices, the instrumental ones. This logical structure includes optional sub-practices and alternate ways of accomplishing the same component practice. For example, in a city one often has the option of walking, driving, or taking a train to a destination.

- Each practice itself has a complex structure, incorporating several factors in addition to the practice-subpractice structure. These factors include the knowledge necessary to carry out the practice, the necessary skills, relevant personality characteristics, the logical roles in the practice, and rules governing the eligibility of actual persons and objects to fill those roles.
- “Knowledge” includes both what the person takes to be the case and the concepts they must have to carry out the action, i.e., the distinctions they must be able to make. The seminal work of Tversky and Kahneman on judgment under uncertainty, for example, deals with what persons take to be the facts, under various conditions (Tversky and Kahneman). “What the actor takes to be the case” includes what are informally called perceptions, beliefs, verified fact, and more generally whatever the actor is prepared, to one degree or another, to act on. However, this is not a version of the customary model of beliefs updated by Bayesian rules, correctly or incorrectly. It is not assumed that what the actor takes to be the case is in any way a probabilistic concept, that probabilities must necessarily be associated with an item of knowledge, or that any rules involving probability calculations are appropriate models of what persons actually do. In

the “Applications” section below we discuss this issue in more detail, including when and how the use of probabilities is justified.

- In addition to its practices, what makes a community what it is includes the concepts, cultural choice principles, and recognizable positions in the community, both official and unofficial. These aspects of a community affect member choices of what practices to engage in and how to do so.
- An individual person is a member of several different communities (as illustrated by Chattoe), and commonly occupies several positions in the same community. For example, a typical academic situation is to be both teacher and researcher in one’s department and both spouse and parent in one’s family.
- Each position occupied by an individual gives him or her motivation to engage in social practices intrinsic to that position. These are the intrinsic practices of the community. Chess players play chess; mountain climbers climb mountains; CEOs devise corporate strategies. Refining the central observation that a person is at all times engaged in a practice of some community, each individual is, at all times, engaged in a practice intrinsic to some position he or she holds in a community.
- Each individual has a number of relationships with members of the community including those due to their position (e.g., having the position of financial advisor means one has the relationship of financial advisor – client. This can be formalized as follows: having relationship R_i means one is tautologically motivated to engage in social practices $P_i^1, P_i^2, \dots, P_i^n$, to degree d_i^1, \dots, d_i^n . More generally, for each relationship R_i and each practice P_j , P_j is consistent with relationship R_i to degree d_i^j , where $-1 \leq d_i^j \leq 1$, where -1 denotes that P_j is the strongest possible violation of R_i and $+1$ denotes that it is the strongest possible affirmation of it. Further, the relationships R_i are not limited to physically

definable ones; as is done in mathematical logic, any relationship may be formally incorporated in a model of phenomena of interest by the mathematical device of giving it a formal name, and measuring the values d_i^1, \dots, d_i^n .

- In general, motivations μ_1, \dots, μ_m , may be of the following four types:
 - Prudential: what is in the individual's direct self-interest. The homo economicus model is a commitment to restricting analyses to this type of motivation.
 - Hedonic: doing something for the pleasure or "the fun of it." Examples include riding a roller coaster, watching a sporting event or reading "for pleasure."
 - Ethical: doing something, or refraining from doing something, for ethical reasons. Ethical motivations are frequently the subject of philosophical argument, with some philosophers and other social scientists arguing that ethical motivations are pre-scientific intuitions or convenient fictions to be replaced with prudential (self-interest) motivations. We regard this philosophical argument as specious, but for the purposes of this paper it does not matter: analyses, including simulations, must take these factors into account in some fashion, whether or not it is possible in principle to replace them with groups of other motivations.
 - Esthetic: motivation to do, or not do, something on the basis of
 - The traditional concept of beauty or esthetic value
 - Appropriateness or "fittingness" of the action with one's position. An important kind of appropriateness motivation is expressive behavior (intrinsic practices). A chess player playing chess, or a grandfather doting on his granddaughter (Abelson), is acting appropriately on their Status (in

the chess and family communities, respectively). Having motivation to engage in a practice due to having a particular relationship is a form of appropriateness motivation: the practice fits the relationship.

As with Ethical motivations, some argue that Esthetic motivations ought properly to be replaced with self-interest ones, but for our purposes the point is that these motivations need to be included in a comprehensive model of human behavior in some form.

Noting that an actor may have motivation to engage or not engage in a practice, it is convenient to model motivations mathematically by $-1.0 \leq \mu_i \leq +1.0$, the strongest possible motivation to not engage or engage in a practice. No assumptions are made as to consistency or inconsistency of these values; an actor typically has multiple motivations, of various strengths, to engage in more than one action, including the strongest possible motivation to engage in distinct and conflicting practices.

- An individual is always engaging in a version of a practice that is one of the several in which he or she could engage in this situation, knows at least some of those possible practices, and chooses to engage in this one.
- The specific practice chosen depends in a complex way on the actor's motivations to engage in each practice, including the following:
 - The Choice principles of each community of which the individual is a member. Choice principles give a member motivation to do or not do a practice.
 - The individual's personal characteristics: attitudes, traits, and states.

- The hedonic, prudential, ethical, and esthetic value of each practice to the individual, including the case in which a practice is expressive of a status the individual holds
- The degree to which each of the individual's relationships give motivation them to do or not do each practice.
- The degree to which each practice is an expression of a status S that the individual has need to affirm. Need may be due to having been treated in a way that will, unless countered, result in loss of the status S, or due to having not engaged in any of the practices intrinsic to the status S for a period of time. A chess player who has not played chess for some time, for example, will have stronger motivation to play.

The novel aspect of homo communitatis is not the various concepts of communities, relationships, motivation, or identity; each of these is a routine part of the subject matter of anthropology, psychology, political science, and all of the disciplines whose focus is human action, individually or in groups. What is novel is that 1) all of these aspects of group and individual behavior are included and are explicitly formulated, rather than being background intuitions, and 2) the concepts of the model are articulated in a single formal framework that incorporates all of the relationships between them.

Example: an anniversary celebration

We illustrate the homo communitatis model with a common event: a couple in America goes out to dinner to celebrate their wedding anniversary. They are both professionals, and have children, aged 8 and 10. The children want to spend the weekend at the nearby city known for its many water parks. The husband has an opportunity to attend an important professional

conference, and the wife has a legal brief due the following week. In addition, their church has a picnic this weekend. Of these practices in these six communities (family, each spouse's company, each spouse's profession, and church), the couple decides to celebrate their anniversary by dining out. They go to a nice restaurant, have wine with their meal, and end with dessert.

“Eating dessert” illustrates the concept of a practice: it is immediately recognizable in America as a known, repeatable, “done thing” – if two people have dessert in separate places on separate occasions, both are instances of the practice, “have dessert.” We see the hierarchical structure of the practices: going out to dinner at a nice restaurant is a practice (a known, repeatable, pattern of action); to do it, one engages in several other, smaller, practices, such as going to the restaurant, dining, and paying; dining in turn consists of several other, yet-smaller, component practices, often called “courses” – have salad, have soup, have the main course, and have dessert.

Many of the s involved are optional or may be achieved via alternate practices. The couple must go to the restaurant (or it is not an instance of the practice “dining out”), but they may walk, take a car, take a train, or take a taxi; salad, soup, dessert, and wine are all optional. There are therefore many possible combinations of sub-practices that could be ways to dine out, but only some of them are so recognized by the community. For example, if the couple went to the restaurant, ordered a bottle of wine, drank it and had dessert, that would not be counted as an instance of dining out, although it might well be considered an instance of going out for dessert. The combinations of sub-practices, including the optional ways of accomplishing some practice, that are recognized by members of the community as ways of doing the practice are the valid versions of it.

When the couple actually has a bottle of wine and their meal, specific objects fill the logical roles of “main course,” “dessert,” “the wine,” and so forth. Thus, what actually

occurs here is that the couple having the dinner is engaging in an instantiated version of the practice of going out to celebrate their anniversary.

Celebrating a wedding anniversary, the largest practice in this example, is a clear example of an “expressive” or “intrinsic” practice. A couple celebrates their anniversary as an expression of their relationship, not in order to gain something or avoid some consequence. (A dinner that was actually a step in forming a business partnership, or a means for one of the couple to avoid the other’s anger, would not be an anniversary celebration.) This is therefore an example of an intrinsic practice with economic consequences. Conversely, economic facts will play a role in the practice, for the couple’s choice of restaurant, and perhaps the food and wine selected, may be affected by their economic resources, a widely recognized phenomenon in the restaurant industry during the recession of 2008-9.

Going out to dinner is only one way to celebrate an anniversary. Two of the more well-known alternatives are buying gifts for each other and going on a cruise. These actions bear no resemblance to each other, and yet are all recognizable, by members of American society, as ways of engaging in the practice of celebrating one’s anniversary, a fact of considerable importance in the jewelry and travel industries. Following (Ossorio 2005), we term these major varieties of a practice its paradigms.

Finally, let us note that the practice of ordering wine with the meal reflects the identity, that is, the community membership, of the individuals. The acceptability of wine as part of dining out is a principle in the community that is modern America, but a number of communities do not share it. If the individuals dining out are members of one or more of those communities, they are making a choice to act as a member of one community or another. This is the situation that Chattoe describes in his discussion of the choice by a

Catholic to adopt birth control. This is a second form of choice which may be impacted by non-economic facts but with potentially very large economic impact.

Figure 1 displays the hierarchical structure of the practice and the sets of sub-practices that are counted as actual instances of dining out:

 Insert Figure 1

Figure. 1

(Although the sub-practices of each practice are numbered sequentially for ease of reference, no actual temporal relationships are assumed, whether sequential or parallel. Any such relationships are explicitly represented as formal constraints on the occurrence of sub-practices.)

Formalizing Homo communitatis

Homo communitatis analyzes actions in terms of communities and practices of those communities. In this section formalize those concepts.

A Community (Putman) is, formally a 6-tuple $\langle M, P, Cp, S, C, W \rangle$ (1)

where:

M = Members

P = Practices

Cp = Choice Principles

S = Statuses

C = Concepts

W = World

- The **Practices** parameter specifies, by formal name, the social practices of the community of interest. Practices encompass everything that a member of that community can do, as a member of that community; whatever they do will be engaging in one or more of the practices of the community.
- The **Choice Principles** of a community constitute one of the key ways in which it differs from other communities differ. This is therefore one of the kinds of information that must be included in a representation of a community whose economics are of interest, because these community-specific values govern choices of members, as well as individual preferences.
- The **Statuses** parameter represents the recognizable positions in the Community. These are all the positions identifiable by members of that community, both formal and informal. “President”, “Senator”, “husband”, “child”, “suicide bomber”, “respected leader”, “doctor”, “farmer”, etc., are all names of positions in different communities. Central to the concept of a Status is that each Status has associated with it certain practices that are intrinsic to a person in that Status, that is, practices done simply because the member that Status. A person in that status will therefore always have motivation to engage that practice.
- The **Concepts** of the community are the distinctions acted on by the members of the community in question – by engaging in the practices. They are specified by formal name and, when further description is necessary by specifying a formal description D, a list of the major constituents of the item (by formal name) and the (formally named) relationships between them. (A

more complete specification of these descriptions may be found in (Ossorio 2005), and a complete mathematical formulation in (Jeffrey 2009).)

- W represents the community's **World**. This is not what it may at first seem, a list of all the items available to members. It is a specification (once again, by formal name) of the major constituents of the community's world and their relationships. In practice, the W parameter represents the most fundamental distinctions found in the Practices of the community. In a business, for example these major constituents are often "customers," "regulators," and "competitors."

The observation that each person is a member of several communities, and occupies one or more positions in each, gives us the means of formalizing identity: actor A's identity is the set $\{S \mid S \text{ is a status of } A \text{ in a community of which } A \text{ is a member}\}$.

Practices have an extensive logical structure, because although practices have a process aspect, and processes have sub-processes, there is more to a practice than the procedures for doing it. To articulate this structure, each practice is further described by formally specifying, for each major variety of the practice (its paradigms), what is necessary to engage in the practice. This formal description is the social practice canonical form (SPCF) for the practice. Each SPCF thus consists of a set of paradigms Π_i , and the details of paradigm Π_i are specified via the following parametric formulation:

$$\Pi_i = \langle G, S, E, L, C, V, Sk, Kn, PC \rangle \quad (2)$$

where

G = the **Goal** of the practice: a formal name of the goal state of affairs. Actors engage in actions in order to bring about some state of affairs; success of a practice is, by definition, the achievement of this result.

S = **Stages/Options** of the practice, the other, smaller, practices necessarily or optionally involved in carrying out this one. Essentially a task analysis, S is specified by a set of formal names.

E = **Elements**: the logical roles of persons or objects in the practice, each specified by formal name.

L = **Eligibilities** of individuals for each role, specified by lists of individuals or formal rules

C = **Constraints** formal specification the dependence of the occurrence of combinations of Stages/Options on either on another Stage/Option or on specified states of affairs being the case

V = **Versions**: the sets of Stage/Options that are considered, by members of this Community, to be valid instances of this practice

Sk = **Skills** needed to carry out this practice, that affect the way in which the Stages are carried out but are not themselves separate tasks, again specified by formal name.

Kn = **Knowledge**: item by item specification, by formal name, of the facts and concepts required for the practice. These are not “cognitive structures” or “mental events,” but are only specifications, by formal identifier, of the distinctions that this behavior is an instance of acting on. For example, the couple celebrating their anniversary is acting on the concept (the distinction) of a wedding anniversary vs. other things; a couple carrying out the actions of an anniversary dinner out but who had no idea what an anniversary was or could not distinguish it from other forms of celebration would not be considered to be having an anniversary celebration.

PC = **Personality Characteristics**. These are identifiable patterns of actions, including attitudes, traits, and values, and specified by giving the formal name of the characteristic. They are not “internal variables,” but rather identify consistent patterns in kinds of actions.

Kn and Sk acquired are of central importance in modeling the economic impact of training and education, because the outcome of education and training is that individuals have knowledge and skills – knowledge and skills that enable them to engage in practices, as articulated in the SPCF parameters.

The SPCF is a parametric analysis originally devised by A. O. Putman to extend Ossorio’s Basic Process Unit. (Ossorio 2005). This formulation encompasses Putman’s SPCF and certain elements of Ossorio’s Intentional Action formulation (Ossorio 2006). The description formally encodes both the logical structure of the practice and the actual individuals involved in instantiations of it. What actually takes place is an instantiated version of a practice, that is, a specific set of Stage/Options recognized in the community as a way of engaging in this practice, with an actual individual person or object filling each logical role (Element).

Using the SPCF, we can now be precise about what is meant by “use or manipulation of economic concepts”: economic practices are those whose SPCFs involve Elements that are economic.

To illustrate this formal structure, Figure 2 presents a substantial portion of the SPCF for a high-level practice in an actual large software development organization. (Jeffrey and Putman). Although not an economic practice, it is a part of a production process in an economically important industry, and one that is, in one form or another, common to every software development organization.

 Insert Figure 2

Figure. 2

Several software systems using SPCF descriptions have been built, including the one this example is taken from, a system to coach managers in specifically human-oriented management practices, an automated marketing coach for a major accounting firm, and a system to be used by loan clerks in a major bank system to create signature-ready documents for filing with state and county offices to perfect the bank's claim on loan collateral (Jeffrey 1989). One of the most interesting features of the SPCF is its demonstrated capability for formally representing a range of human behaviors not normally considered capturable in a machine-usable form.

Each of the practices 1-1,1-2, 1-3, 2, 3, 4-1, 4-2, 4-3, 4-4, and 5 in Fig. 2 themselves have SPCF descriptions that completely specify each of those practices, at that level of detail. This further elaboration continues down to any level of description needed or desired, including persons issuing commands to software and the execution of the command by the software/computer system. The following example illustrates this recursive elaboration capability.

Hierarchical structure of the fakaafe

A wide variety of practices impact economic facts. Conversely, economic facts, because they deal with degree of availability of fundamental resources, impact non-economic practices. This pair of relationships lies at the heart of the well-known phenomenon of feedback in economic systems. As a result, the usability of the homo communitatis model is directly

dependent on the range of practices to which it can be applied. To illustrate this range, we show the SPCF description of a different kind of practice, a feast in honor of a visiting Wesleyan minister, that regularly takes place in Tongan village society (Bennardo). Figure 3 presents a representative portion of the practice-subpractice structure of holding this feast, including planning, gathering resources, transporting the resources, physical processes such as burning wood to prepare the food, and feast itself. The other parts of the SPCFs of the practices and sub-practices (Constraints, Elements, Individuals, Eligibilities, and Versions), which as the No. 4 ESS example in Fig. 2 shows play a central role in capturing the nuances and details of actual life involving these practices, are omitted for reasons of space. The full set of practices and sub-practices, as derived from Bennardo, and a brief discussion of the mathematical structure of a community's practices, may be found in the Appendix.

 Insert Figure 3

Figure. 3

Including descriptions down to the level of the burning wood emitting smoke (4.1.3.3) illustrates the capability of incorporating high-level human practices and low-level physical processes in a single formal model. This capability makes possible unified models of behaviors, at any level, and their impact on physical quantities. For example, the practice structure here is the appropriate model to drive a simulation study of resource depletion (wood) and environmental impact (smoke) under various circumstances involving the community, its high-level practices, and relationships among its members. The kind and amount of detail included in a simulation model depends on the kind of information needed from the study, which in turns depends on what the information is to be used for. A study of

the environmental impact of fakaafes would include information that would typically be of little value to a study of the family dynamics of organizing and holding fakaafes.

Formal, not discursive, specifications

The examples given may give the appearance that an SPCF is simply a set of discursive statements, albeit detailed ones, as might be found in an anthropological discussion. Although the hierarchically organized practices and sub-practices, and the Elements and Individuals, are typically stated in ordinary English sentences for the sake of readability (e.g., “Members of the household giving the fakaafe plan it”), these sentences are being used here as formal names, much as names of methods and variables in computer programs may be ordinary English phrases (usually with blank spaces omitted), not discursive English statements that “refer” to physical things. “Members of the household giving the fakaafe” is the name of an Element in this practice, instantiated by Individuals as articulated in the Eligibilities. In the example of the practice of celebrating an anniversary, “a nice restaurant” is the name of an Element, not simply an adjectival phrase “referring” to a concept that would be essentially impossible to render formally. The SPCF for this social practice includes Individuals and Eligibility rules that specify what Individuals can or must instantiate the Element. SPCFs commonly include identifiers of Elements, Individuals, Eligibilities, and Constraints that can be recognized by members of the community but which cannot be defined physically or algorithmically, such the appraisal of a restaurant as “nice” (Jeffrey and Putman 1983, Jeffrey 1989).

A full derivation of the formal homo communitatis model is beyond the scope of this paper; a more complete discussion may be found in (Jeffrey 2007 and Jeffrey 2009). Briefly, referring to the elaboration of the model above, we note that we have used the technique from

mathematical logic and mathematical computer science of specifying a “thing,” its constituent aspects, and relationships between those aspects by formal name. An SPCF of a practice is a 9-tuple of formal names, and a community specification a 6-tuple of formal names, that identify objects, processes, events, or situations or states of affairs. Further information about any named object, process, event, or state of affairs is specified by a description that is itself a set of (formal) names of 1) constituents of the item, and 2) relationships between the constituents. Thus, each item is specified by a formal ordered pair (N, D) , in which N and D are formal names (or sets of them), and so a specification of a set of communities and practices is a complex, but formal, description.

Applications to Behavioral Economics and Finance

Simulation

With a formal specification of a community or set of communities of interest, including SPCFs of the communities’ practices (as much as possible with the available information), simulation can proceed via mathematical or statistical modeling of the behaviors and phenomena of interest, using the SPCFs to guide the selection of factors to be included. Alternatively, the SPCFs can be used directly as the basis for agent-based simulation (Jeffrey and Nadro).

To give SPCFs for agent-based simulation, we directly represent the life of the communities of interest, i.e., the daily practices engaged in by members, and measure the economic quantities of interest as the community activities proceed. This is done by simulating individuals engaging in the intrinsic practices of the community, which they do by

engaging instantiated versions of the intrinsic practices. Those practices, in turn, are engaged in by engaging in other, smaller, practices, recursing down to the level at which no further SPCFs are available. In practice, this may be small, detailed actions such as issuing a specific command on a computer or large and broad practices for which no further description is available. At that level, mathematical functions specifying input-output relations, including probabilistic ones, are used. As the simulation proceeds, quantities of interest, whether outcomes or resources or quantities derived from them, whether economic or other, are measured.

In more detail, the algorithm is as follows:

Initialization: the community (or, more commonly, communities) to be simulated are specified, including the community parameters for each, and the initial state of the constituents of the community's world (W parameter). Many of these conditions, including attributes of individuals (PCs found in SPCFs of the community's Practices), initial distribution of members in statuses, initial quantities of individuals and objects, and attributes of objects and processes will be probability distributions. Having specified each community to be simulated, simulation now proceeds by:

For each time $t_0, t_0+\Delta t, t_0+2\Delta t, \dots$

For each individual I :

- a. Identify every practice I is eligible to engage in, in all communities of which I is a member.
- b. For each practice P_i for which I is eligible, assess I 's motivations – prudential, hedonic, ethical, and esthetic – to engage in P_i , taking into account:

- Choice principles of each community of which I is a member.
 - I's personal characteristics: attitudes, traits, and states.
 - The hedonic, prudential, ethical, and esthetic value of P_i to I (including the case in which P_i is intrinsic to a Status I holds, and the degree to which each of I's relationships give I motivation to do or not do P_i .)
 - I's certainty that P_i will result in the hedonic, prudential, ethical, and esthetic values. (By "certainty," we do not mean probability, but rather the degree, on a scale of -1.0 to +1.0, to which I is prepared to act on the assessed values. This is discussed in more detail in the section below, "Behavioral certainty.")
 - The degree to which each of I's relationships gives I motivation to do or not do each practice.
 - The degree to which each practice is an expression of a status S that I has need to affirm, due to the need to counter an action that will otherwise result in loss of the status S, or due to having not engaged in any of the practices intrinsic to S for a period of time.
 - Any P_i in which I is already engaging, but which is not yet complete.
- c. Identify I's optimally-motivated practice, P_M . As discussed in more detail below, because there are four kinds of motivation, motivation is mathematically a four-element vector, not a scalar, and therefore the motivations at any time t may not be fully ordered. Nevertheless, persons do make choices among the possible practices whose value to them is this set, and therefore the simulation will contain a function to identify what

we call the “optimally-motivated practice.” Perhaps the simplest example of such a function is Maximum Want model (Mitchell, 1967), in which the practice chosen is the one with maximum total motivation, i.e., the sum of the hedonic, prudential, ethical, and esthetic motivations. Other examples include the vector magnitude of each motivation quadruple, multiplicative models in which the quantity maximized is the product of the four kinds of motivation, and other more complex functions designed to model mathematically the case of possibly-conflicting motivations. These include cases of a single overwhelming motivation and multiple, conflicting, overwhelming motivations of various kinds. A choice of optimally-motivated practice selection algorithm constitutes a choice of a theory of motivation, for the population being simulated. Many such behavior-selection functions will be based on proposed frequency distributions of relative priorities of motivations in the population. In some communities, for example, practices such as theft are much less frequent due to the priority of ethical motivations among members. As noted earlier, choice principles give members additional motivations: sometimes one does something “because one is supposed to.” This is a significant factor in many families.

- d. Individual I carries out the practice P_M for which there is a version for which I is eligible and has the resources – that is, the Individuals necessary to take the places of the Elements in that version.
- e. Each Stage of the Version is itself a Practice with an SPCF, and so the Stage itself is done by engaging in a version of that Practice. This recursion ends when there is no further description of the practice, and

engaging that practice is represented by the fact of occurrence (or, probabilistically, failure) of the bottom-level practice.

- f. I carries out as much of P_M as can be done in time slice Δt . The list of state of affairs descriptions identifying known facts is then updated. Practices do not always succeed, and this is modeled by probabilities of success for each practice. When a practice is completed, the goal state G defines what is to be updated. Partial completion of a practice results in recording that the goal state G is partially achieved.
- g. When a practice occurs whose outcome is the creation or change of a social practice, the SPCF for the practice is created or updated.
- h. Each social practice has an associated latency, a time period after completion of the practice during which the reason to engage in it is zero. Latencies vary by Individual and practice, and are typically modeled by frequency distributions. They model the empirical fact that although a practice may be intrinsic it is common to find a delay before the person wants to engage in it again. They also provide the formal mechanism for including biological and physical facts in the simulation, without the need to specify physiological details such as blood sugar or neurotransmitter levels. Examples include eating a meal, having sex, going to a movie, playing chess, or taking a vacation.
- i. That I is engaging in practice P_i is a fact, recorded and observable by other members of the community (or, if desired, by a subset of the members).
- j. Non-behavioral events, things that happen in and to the community, are specified in a way that represents how those things occur in the real world, namely by alteration of the specification of the facts representing the world

state. In this way events such a crop failure, a bankruptcy, or an attack by someone outside the community are included.

Examining the use of probability

In this section, we employ the homo communitatis model to re-examine some of the foundational work in behavioral economics and show how to re-formulate much of that work to derive models not limited by assumptions of unconscious processing or probability calculations, models that potentially have significantly greater predictive power.

Every field's conceptual framework carries with it, usually only implicitly, a methodology, i.e., a set of related methods for using it, assumptions about what constitutes a valid result and an appropriate theoretical interpretation of a result. Applying the fundamental concept of homo communitatis, work in the field is a matter of engaging in the practices of it. As Formula (2) indicates, this means using the concepts of the field. Physicists, for example, engage in the practices of the field of physics – theoretical and/or experimental – using concepts of energy, mass, time, etc.

The (Tversky and Kahneman) experiment in which subjects were given descriptions of persons and then asked which statement about described persons is more likely to be correct and interpreting the results of the experiment as (incorrect) versions of Bayesian analysis are both instances of practices of the community of cognitive psychology, and the concepts used include the mathematical definition of probability, sample spaces, Bayes' rule, priors, and the more fundamental ones of experimental subject and question and answer.

Behavioral economics and finance are based on the insight that we need to incorporate a wider range of behavioral concepts in models of economic and financial behavior, but to date most of the extensions have come from the relatively narrow sub-field

of cognitive psychology, perhaps because only cognitive psychology provides formal models of its concepts. More fundamentally, the fields of economics and finance as traditionally constituted (the homo economicus model) are embedded entirely in the mathematical model and methodology of probability, and it has been universally assumed that this is an appropriate model of human actions and decisions in the general case. Rationality and subjective expected utility, for example, are defined as updating beliefs consistently with Bayes' law, which is a statement about the ratios of mathematical probabilities, and making decisions in accordance with subjective expected utility, which is defined by multiplication of probabilities and utilities, and behavioral economics as understanding the errors in applying mathematical probability theory, such as Bayesian calculations and sampling theory (Barberis and Thaler).

Behavioral economics rejects homo economicus as unrealistic and a poor predictor, but has retained the fundamental assumption that it is appropriate to model actors making decisions in terms of probability as that term is formally defined, i.e., repeated selections from a sample space. This foundational assumption is seen in the methodological assumption of asking subjects questions phrased in the language of probability, and assuming (without verification) that the subjects are "internally" calculating Bayesian probabilities. Because of the pre-empirical commitment to re-describing empirical observations in terms of "internal" processes for doing mathematical probability calculations, a great deal of the research program in behavioral economics and finance has focused on developing internal process models of the calculation of probabilities.

If we treat the proposition that experimental subjects use probabilistic models in decision making as a hypothesis, rather than an assumption, in many cases we find no empirical basis for it. Unless they have been trained in mathematical probability and its application, we never observe experimental subjects, or persons in the world at large,

identifying a sample space, estimating a probability distribution satisfied by the sample space, determining priors, calculating ratios, or any of the other practices that comprise applying mathematical probability. The exceptions are those cases in which subject are asked questions overtly using the concept of relative frequency, such as, “If you have 100 securities with this balance sheet and this set of industry facts, how many of them would you expect to see 10% growth in stock price over the next year?” In a large number of others, however, we find experimental subjects asked questions such as, “What is the probability the St. Louis Cardinals will win the World Series this year,” and we never observe an instance of subject behavior that resembles constructing a sample space, mentally selecting samples from it, etc. Further, in many such cases it is difficult to see what such a sample space could be. It could be that subjects are mentally constructing a set of 100 baseball teams that all share the characteristics of this year’s St. Louis Cardinals and sampling that space, but there is no evidence that they do so. Further, using homo communitatis, we will see below that there is strong reason to take it that they do not.

The classic work on judgment under uncertainty (Tversky and Kahneman) that led to the development of the concept of the representativeness heuristic and the various errors engendered by its use, such as insensitivity to prior probabilities and sample size, clearly illustrates these issues. In this work, subjects were shown brief personality descriptions of several individuals and asked which statement about the person is more likely to be correct. In one experiment, for example, subjects were shown descriptions in terms of personality traits of individuals supposedly sampled at random from a group of lawyers and engineers, and then asked whether it was more likely that the individual was a lawyer or engineer.

Barberis and Thaler cite an example that highlights the centrality of the mathematical model of probability:

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

When asked which of “Linda is a bank teller” (statement A) and “Linda is a bank teller and is active in the feminist movement” (statement B) is more likely, subjects typically assign greater probability to B.

They then analyze the errors by subjects in terms of probability theory, including Bayesian probability calculations, noting for example that it is mathematically impossible for statement B to have higher probability than statement A.

In more detail, we can see that the procedure followed was:

1. The experimenter presents a subject with a description of a person’s personality.
2. The experimenter asks the subject a question about the person, using the language of probability, such as, “Which is more likely to be correct,” or, “What is the probability that the description is of a lawyer or engineer?”
3. The subject replies.
4. The experimenter re-describes the subject’s judgments as the outcome of (internal) cognitive processes. In this specific case, the judgments have the linguistic form of statements of probability.
5. The experimenter compares the subjects’ answers to the mathematically correct methods and concepts from probability and statistics.
6. The experimenter ascribes deviations from the correct answers to various heuristics for and errors in carrying out the cognitive processes that produce the results.

Incorporating observations from linguistics and psychology (Austin, Wittgenstein, Ossorio 2006), we can note that asking and answering questions are behaviors. Applying homo communitatis, noting that behaviors are instances of engaging in practices of a community, we see that:

- a. The first three steps above comprise an experimental procedure, i.e., a practice, in the community of experimental psychologists.
- b. Each of the steps is itself a practice, and as Formula (2) articulates, steps 2 and 3 involve the use particular concepts concepts, i.e., distinctions.
- c. In Step 2, the experimenter is using mathematical concept of probability, i.e., relative frequency of selection from a sample space.
- d. In Step 3, the subject replies. However, referring again to Formula (2), it is appropriate to ask what concepts the subjects are using in their reply: what do the subjects take the question to be? Are they taking the question to be one of assigning a mathematical probability (the experimenter's concept), or something else? To state it less technically, the subject may or may not have been answering the question the experimenter asked. In the example of Linda, questions the subject may have been answering include at least the following:

- “Which statement is a better description of Linda?”
- “Which statement best characterizes what kind of person Linda is?”
- “Which statement best states what is most important about Linda?”
- “Which statement is the most important thing to say about Linda?”
- “Which statement is most like what you would say of Linda?”

(The author has carried out preliminary, small n, experiments which show that several of these are common. However, sufficient work to allow reliable estimation of the frequency of each interpretation, or others, has not been done.)

- e. The second three steps comprise a second practice, the one customarily referred to as “interpreting the results.”
- f. In this practice, Tversky and Kahenemann re-describe the subjects’ responses as instances of acting on the concepts of mathematical probability. They do not report engaging in the practice of evaluating whether this particular re-description is appropriate.

Item d. above is essentially a restatement, using homo communitatis formulations, of the phenomenon of misunderstanding, but without any assumptions as to the existence, or lack of same, of internal processes, including “interpretation” processes. Misunderstanding or misinterpretation by members of one community of the language of another community is a universally recognized phenomenon in anthropology, linguistics, communication studies, and computer systems analysis. (It is instructive to note that systems analysis and design textbooks caution students to remember that their technical language and concepts are, in the large majority of cases, not shared by the clients, and therefore misunderstandings are extremely common and repeated steps must be taken to ensure that what is asked is what is heard – and answered.)

Members of communities must learn to engage in the practices of the communities. (This not an empirical claim, but merely an acknowledgment that the alternative is to assume instinctive behaviors.) They do this typically in their families, schools, professional training, and in some cases by observation, attempt, and correction (“trial and error”). This is the basis for saying there is strong reason to suppose that subjects are not engaging in mathematical probabilistic analysis: it is unlikely that they have had any opportunity to learn these practices – and here we are using “likely” in the strict, mathematical sense: only a small percentage of persons have a history that would allow them to learn these practices.

As a result, the characterization by Barberis and Thaler that subjects attribute higher probability to statement B, which is the typical characterization elsewhere in the literature as well, is based on the assumption that subjects are assigning probabilities at all, an assumption that does not withstand careful examination and whose implications are misleading. Specifically, it misleads Barberis and Thaler, and has misled researchers and practitioners of behavioral economics and finance, to the conclusion that experimental subjects and persons in general are customarily applying the laws of probability but doing it badly, when in fact, using homo communitatis, we can see that it is much more likely that subjects are not producing probabilistic judgments at all (and here, by “likely,” we do not mean “mathematically probable.”).

To summarize, when a subject reports, “Statement B is more likely true of Linda,” or, as in the Tversky and Kahneman work answers the question, “Is it more likely that Steven is a lawyer or librarian,” there is no reason to take it that they have an internal model of a sample space of statements and personality descriptions. They could have such a model, and cognitive psychology and traditional behavioral economics insists that they must, but they could equally be replying to what they understood the question to be: “Which of the following is the best description of Linda?” Perhaps most importantly, which of these is the case is properly a matter for empirical investigation, not assumption based on a particular theory in psychology.

Implications for practice

The analysis is more than philosophical or semantic nit-picking. Whether economic actors use the concept of mathematical probability or something else affects both the questions an experimenter asks and the conclusions reached about economic decision making. It also

directly affects the professional practices of financial analysts, when they are asked questions by clients and make recommendations. Knowing how a question will be interpreted, and careful avoidance of ambiguity of meaning, are crucial to the practice of finance.

Clinical psychologists, ethnographers, journalists, linguists, computer systems analysts, and public opinion researchers are all keenly sensitive to the phenomenon that what can be discovered by asking subjects questions depends very strongly on the wording of the question. Precise identification of the possibilities and careful choice of phrasing in referring to them is central to experimental design and professional practice in all these fields. If, for example, an experimenter or practitioner wants to know whether a subject would say statement A or statement B applies to a situation, they would ask questions such as, “Do you think A or B is most applicable here,” “Would it be correct to say A here? To what extent? How about B?” or, “You seem to be saying [statement A] here. Is that right?” All of these are ways of finding out applicability, in the subjects’ view, of statements about situations described in a certain way.

Applying this analysis to an investment situation, consider an investor seeking an opinion on the future price behavior of a security. They might ask, “How certain are you that X will be up by p percent in one year,” or alternatively, “If you had 100 securities like this, in this industry, how many of them would you expect to see up by p percent in one year?” These two questions are not the same, are not inquiring about the same possible fact, and the careful investor would not be surprised if they yielded different answers.

Further, financial analysts and investors routinely carry out their professional practices in ways that have no observable resemblance to using the concept of mathematical probability. If we first clarify what exactly we mean by “probably,” i.e., ratio of frequency of outcomes, and then ask analyst subjects whether that is a good model of what they mean when they say, “Security X will probably do Y in the next m months,” the typical response is,

“No, that is not what I do. That’s not what I mean.” They commonly state, “I look at the financial facts about the company and the industry, and sometimes at their management, and based on that I assess what I believe will happen, with as much certainty as I can. But I’m not counting things, in any way.” It is of course possible that a decision maker is, in effect, doing mathematical probability calculations without knowing that they are, but experimental results consistently show that probability is not a good model of certainty determinations (Tversky and Kahneman, Kahneman and Tversky).

Knowledge certainty and behavioral certainty

Mathematical probability has been used as a tool to address the need to model formally the fact that actors must often act in the face of uncertainty: uncertainty about what the facts are and uncertainty about whether an action will bring about an intended outcome (the G parameter). The traditional approach has been to treat uncertainty as an attribute of the knowledge, and thus we have language such as “probability that x is true,” and so forth.

Using homo communitatis, we can develop a different approach, which we term the behavioral approach. Knowing and acting are distinct concepts. Individuals are always acting; they can, tautologically, only act on what they take to be the case. This is the relationship between knowledge and action articulated in the SPCF. For an actor, and therefore for those modeling actors, the central question about any particular belief, regardless of the certainty of that belief, is the degree to which they are prepared to act on it. This is directly the focus of economics and finance: prediction of what actors will do.

Thus, there are two equally important distinctions: 1) what the actor takes to be the case, and 2) the degree to which the actor is prepared to act on what they take to be the case. Preparedness to act on what they take to be the case is a fact about the actor, not the

knowledge. Traditionally, all uncertainty has been considered to be a matter of knowledge uncertainty, with various mathematical models: probability, Kahneman and Tversky's $w(p)$, fuzzy set theory and fuzzy logic (Russell and Norvig), etc. The behavioral approach is to keep the two distinctions separate, formally model preparedness to act, and incorporate knowledge uncertainty insofar as it is necessary or useful in calculating preparedness to act. What the actor takes to be the case is modeled formally by the K_n parameter; we define the degree to which the actor is prepared to act on x as the behavioral certainty of x (to distinguish it from the more common term "certainty," which has a long history of interpretation as "with probability 1"), denoted $\beta(x)$, with $0 < \beta(x) \leq 1$. (The item x may be "doing P will bring about G .") In some cases, it may be that Bayesian probability or a modification of it such as $w(p)$ accurately models β , or is an input to its calculation, a question to be empirically determined. This allows us to generalize prospect theory without using probability (unless it is appropriate in specific cases): a situation x with value $v(x)$ and behavioral certainty $\beta(x)$ has a "net" value $\beta(x)v(x)$. When $\beta(x) = w(p)$, this reduces to $w(p)v(x)$, the formulation in prospect theory.

The behavioral approach and behavioral certainty have further implications for practice. It can be expected that experimental protocols based on the concept of behavioral certainty will yield significantly different data from ones based on mathematical probability and phrased in that language. Examples of such experiments include:

- "How certain are you that X will occur?"
- "How certain are you that X is the case?"
- "Here are two statements, A and B . Which of the following are you more certain is true?"
- "In the following situation, you can do X or Y . Which of these would you do, and how sure are you?"

- “On a scale of -1 to +1, -1 meaning you are certain X is not the case and +1 meaning you are certain that it is, how certain are you that X?”
- “What would you bet that X is the case?” (This is the method adopted by Ramsey to measure degree of belief, and is attractive for its obvious connection to economic and finance decisions. Here we use it not to determine an attribute of X such certainty or probability, but as a technique to discover the degree to which the subject is prepared to act on X.)
- “What are you prepared to bet that X will happen?”

Experimental protocols of this type develop the kind of data that is directly of interest in economics and finance: how is the subject prepared to act?

Value as a Vector

Neoclassical economics postulates that individuals act to maximize their utility, more particularly their subjective expected utility. The well-documented failure of SEU to agree with several cases of actual behavior (Barberis and Thaler, Kahneman and Tversky) has led to prospect theory, in which the function maximized is $U = \sum w(p_i)v(x_i)$. However, both models consider “value” to be a scalar quantity.

Measuring value with a single number conflicts with both common observation and the entire literature of social and clinical psychology, sociology, political science, and anthropology. The homo communitatis framework incorporates and formalizes the much more inclusive and realistic model of persons as having four kinds of motivation: Hedonic, Prudential, Ethical, and Esthetic. While some have taken a philosophical position that these motivations are not “real,” and are aspects of self-interest, for the purposes of creating a

comprehensive, realistic, formal framework to serve as the foundation of behavioral economics that discussion is moot: a complete model of human action must include the four kinds of motivations in some form.

To say that something has value to an actor is to say that that the actor has motivation to try to bring it about. Accordingly, value is of four kinds: hedonic, prudential, ethical, and esthetic. The kinds of value are not inter-convertible; they are logically distinct categories. Prudential motivation, for example, is categorically distinct from hedonic, ethical, or esthetic. An assignment of prudential value (being in an actor's interest) cannot be replaced with a hedonic, ethical, or esthetic value. Further, these types of motivation, i.e., measures of value, may conflict: what is fun (hedonic value) may not be in one's interest (prudential value); what is ethical may be unpleasant, dangerous, and ugly; what is appropriate may be onerous and costly; etc. Because hedonic, prudential, ethical, and esthetic values are categorically distinct, specifying the value of a state of affairs requires specification of four quantities, not one: its hedonic value, prudential value, esthetic value, and esthetic value. This means that mathematically value is a 4-dimensional vector (h, r, e, t), not a scalar quantity. (The symbol "r" is used to avoid notational conflict with the customary use of "p" to denote probability.)

Mathematically, the value of an action is the 4-element vector quantifying the value of the state when the practice is complete. This is the G parameter in the SPCF of the practice or, in the case of intrinsic practices, the state of having engaged in the action, since intrinsic practices are by definition those done in order to be doing it, not to accomplish a result. Each action thus corresponds to an ordered pair $(\bar{v}_{\text{before}}, \bar{v}_{\text{after}})$. If the value of the outcome is $(h_{\text{after}}, r_{\text{after}}, e_{\text{after}}, t_{\text{after}})$, we can define the total value as the vector magnitude $\|\bar{v}\| = \sqrt{h_{\text{after}}^2 + r_{\text{after}}^2 + e_{\text{after}}^2 + t_{\text{after}}^2}$, and the change in total value as the difference of the magnitudes $\|\bar{v}_{\text{before}}\| - \|\bar{v}_{\text{after}}\|$.

Since value is a vector, the axioms that define a preference relation are of course not satisfied, other than in those cases in which $\bar{v}_1 = (h_1, r_1, e_1, t_1)$, $\bar{v}_2 = (h_2, r_2, e_2, t_2)$, $h_1 \leq h_2$ and $p_1 \leq p_2$ and $e_1 \leq e_2$ and $t_1 \leq t_2$, and similarly for the other axioms that define the relationship. Mathematically, the curve $v(x)$, such as in (Kahneman and Tversky), for the value function v are projections of 4-dimensional value surfaces.

The methods and approach of multi-attribute utility (MAU) may prove useful here, potentially including multi-attribute utility theory in defining functions to calculate the scalar utility of the vector (h, r, e, t) . However, in general the functions $h(x)$, $r(x)$, $e(x)$ and $t(x)$ do not exhibit mutual preferential independence. Consider the following example. An investment firm must choose between investments that offer varying rates of return, but also are more or less inconsistent with the firm's choice principles, e.g., a firm whose choice principles are to invest in low volatility large cap companies, with an opportunity to invest in subprime mortgage-backed securities. Mutual preferential independence in this case would mean that the firm preferred higher return ($r(x)$) regardless of how inconsistent an investment is with its principles ($e(x)$), and consistency with its principles regardless of the difference in return, conditions obviously not the case in general. As a result, Debreu's theorem, which in this case would state that the overall value of $x = h(x) + p(x) + r(x) + t(x)$, does not hold. Without this theorem, finding a function to correctly calculate a scalar value from the vector $\bar{v}(x)$ is "burdensome" (Apostolakis), but may not be as much so as in the general case because the components of the value vectors are categorically distinct and the axes of value space therefore orthogonal, unlike the general case in which many attributes of the same type may be involved.

SEU is the special case of prospect theory in which w is the identity function, i.e., $w(p_i) = p_i$, so using the definition of behavioral certainty we can re-formulate and generalize prospect theory and SEU as follows:

Axiom: An individual always chooses the alternative (of the ones of which they are aware) that maximizes $U = \sum \beta(x_i) \bar{v}(x_i)$, when such a maximum exists.

The specifics of the function $\bar{v}(G) = (h(G), r(G), e(G), t(G))$ are a matter for empirical investigation. The appropriate mathematical model of hedonic, prudential, ethical, and esthetic values may be quite complex, are almost certainly not similar to each other, and are similarly a matter for empirical investigation. (Kahneman and Tversky) is an example of one kind of such a study, but the range of issues on which empirical data is needed is substantially broader, including at a minimum investigations into the following kinds of cases:

- “All other things being equal” cases. This are cases in which a decision (a chosen action) results in no net change in hedonic, ethical, or esthetic value, i.e., $h(x_1) = h(x_2)$, $e(x_1) = e(x_2)$, and $t(x_1) = t(x_2)$. The experiments in (Kahneman and Tversky) identify the form of the $v(x_i)$ curve, but mathematically they are deriving data about the projection of the vector $\bar{v}(x_i)$ onto the P axis, and reveal nothing about the curve in various regions of the space, i.e., for various ranges of $h(x_i)$, $e(x_i)$, and $t(x_i)$. For example, does the shape of $r(x_i)$ differ if the x_i are equally unpleasant or equally inappropriate?
- Types of value cases. Behavioral economics experiments commonly conflate types of value, such as cases in which subjects are asked, “Which would you prefer, winning \$1000 with probability 1, or \$2000 with probability 0.6,” and, in the same experimental protocol, asked, “Which would you prefer, a 50% chance of winning a three-week tour of England, France, and Italy, or a one-week tour of England, with certainty?” (Kahneman and Tversky). These are two kinds of

value, prudential and hedonic. While it may be that on average subjects treat the two equivalently, there is no data to support the a priori aggregation of the cases.

- Real conflict cases. At the beginning of this section we cited examples of conflicting motivations: what is ethical may be unpleasant, dangerous, and ugly, etc. Such cases are not the exception; human life includes a very large range of cases in which actors are faced with important conflicting motivations: ethical vs. hedonic, prudential, and esthetic; esthetic vs. hedonic and prudential; prudential vs. hedonic, ethical vs. hedonic, prudential vs. ethical; esthetic vs. prudential, etc. The rise of socially conscious mutual funds of various kinds shows that these are factors in both microeconomic analysis and finance. A great deal of research is needed to identify the shape of the choice surface in 4-dimensional value space, and there is no a priori reason to expect this surface to be simple.
- Since it is by no means clear that subjects take questions phrased in the language of probability (“probable,” “likely,” etc.) as mathematical probability questions, it is quite possible that the behavioral certainty function $\beta(x)$ (including the special case in which $\beta(x)$ is modeled by $w(p)$) may be significantly different if the alternative values involve $h(x_i)$, $e(x_i)$, or $t(x_i)$, rather than only $r(x_i)$ as in previous research.

All investigations in which subjects are asked what they would prefer, or would do, suffer from the problems of self-report data, some of which are discussed in (Barberis and Thaler). There are additional problems in self-report investigations of values including ethical and esthetic values, particularly in cases of conflicting values. Sociologists, for example, know that subjects will frequently lie when asked about something they know is considered dishonest or inappropriate, even when guaranteed privacy.

For this reason we envision simulation as a major tool for investigation into the various choice surfaces in value space. Homo communitatis does not incorporate any theory of motivation; as noted in step b of the simulation algorithm above, choice of an algorithm to select the particular practice for each individual I at time t from the set of possible practices, based on the four-element vector of motivations for each practice, constitutes a choice of a theory of motivation. The research methodology most in accord with the desire in behavioral finance and economics for rigorous, comprehensive, predictive, models of economic behavior appears to be as follows:

1. Identify the population of interest
2. Identify the communities of which members of this population are members.
3. Build homo communitatis models of each of these communities. The most basic model incorporates the Statuses, Practices intrinsic to each status, and Choice Principles. The basic model is complete in the sense of modeling all the practices of the community, but only at the highest level; all finer-grained specification of the practices – the details of how they are carried out – is omitted.
4. Give SPCF formulations of each of the practices in each of the communities. Two points are important here:
 - Specification of the K_n parameter of the practices does not involve theoretical constructs or “internal” processes or states. The value of this parameter is a set of formal names of the facts and concepts (the distinctions) necessary to carry out the practice. These facts and concepts are discovered, in general, by observing and interviewing members of the community, identifying distinctions they appear to be acting on, and verifying the conjectured distinctions by further interviews. This is essentially the practice of ethnography, a methodology developed for this

purpose and used in anthropology, some branches of psychology, and computer systems analysis.

- Nothing, including the simulation of the communities involved (Step 8 below), depends on having complete specifications of either a Community or all of the practices of one or more of them. The impact of greater detail on a simulation is analogous to having more bits in a digitization of a picture: finer resolution. As more details of the practices of a community are added at lower and lower levels of the hierarchy of practices, the resolution of the picture presented by the output of the simulation increases.

The result of these steps is a purely descriptive model, embodying neither normative nor theoretical commitments as to what actors do or how they do it. This model is a framework for incorporating empirical data and theories about motivation, distribution of characteristics, and any of the ways in which the population of interest may vary.

5. Empirically investigate the functions $\beta(x)$ and $\bar{v}(x)$.
6. Empirically determine the choices of each community's members in selecting practices: maximum value vector magnitude, maximum sum of components, maximum sum of components subject to constraint, etc.
7. Write the optimal-value selector module to model the value-based practice selection employed by each community. The selection of an algorithm to do optimal-value selection in a community constitutes adopting a theory of motivation for that community. The results of the simulation then constitute a test of the predictive value of the theory.
8. Simulate the population, using the simulation algorithm presented above.

9. Compare the results of the simulation to actual data.
10. Revise the homo communitatis model of the population to reflect discrepancies between simulated and observed data.

Appendix

Hierarchical structure of the fakaafe

This diagram shows the stage-option portion of the SPCF of the fakaafe and several other, smaller, practices that are parts of it:

- Stage-options of practices 3, 4, 5, 7, and 8
- Stage-options of practices 2.1, 2.4, 4.1, 7.1, and 8.2
- Stage-options of practice 4.1.3

Outline form is used in order to highlight the hierarchical practice-subpractice structure. However, mathematically the structure of a community's practices is considerably more complex than this hierarchical aspect alone indicates. First, it is common for a practice to be part of more than one larger practice. For example, boys capturing free-range animals (3.1 below) is also part of the practice of gathering food for a meal. Physical processes, such as wood burning (4.1.3 below) is part of many practices. Thus, the entire set of a community's practices is a directed graph. In addition, the SPCF includes Constraints and Eligibilities, both of which may reference the occurrence of another practice or a particular stage-option within it.

Name of the Practice: Tongan Wesleyan villagers hold a fakaafe

Stage-Options:

1. People in the village decide who will give the fakaafe
2. Members of the household giving the fakaafe plan it
 - 2.1. Household members decide food for fakaafe
 - 2.1.1. Kainga members decide number and size of pigs for the fakaafe
 - 2.1.2. Kainga members decide number and size of goats for the fakaafe
 - 2.1.3. Kainga members decide number and size of sheep for the fakaafe
 - 2.1.4. Kainga members decide number and size of fish for the fakaafe
 - 2.1.5. Kainga members decide quantity of shellfish for the fakaafe
 - 2.1.6. Kainga members decide number and size of vegetables for the fakaafe
 - 2.1.7. Kainga members decide beverages for the fakaafe
 - 2.1.8. Kainga members decide desserts
 - 2.2. Household members decide who shall contribute food for fakaafe
 - 2.3. Household members decide who shall contribute utensils and decorations
 - 2.4. Member of family giving fakaafe gets kainga member to contribute to the fakaafe

- 2.4.1. Family member sends request for help to famili member abroad
- 2.4.2. The kainga member asked decides whether to contribute
 - Option 1: The kainga member asked agrees to contribute to the fakaafe
 - Option 2: The kainga member asked refuses to contribute to the fakaafe
- 2.4.3. The kainga member asked contributes to the fakaafe
- 2.5. Members of family giving the fakaafe decide who will be responsible for which tasks in special circumstances
- 3. Members of the family giving the fakaafe gather the food for the fakaafe at the premises of the household giving it
 - 3.1. Tongan village boys capture free-range animals
 - 3.2. Tongan village boys bring captured animals to household where fakaafe is to be held
 - 3.3. Tongan village men bring crops from their gardens to household where fakaafe is to be held
 - 3.4. Women and children of the family collect shellfish
 - 3.5. Men and women buy food at the market
- 4. Members of the household prepare the food for the fakaafe
 - 4.1. Men of the household prepare the oven
 - 4.1.1. Men of the household fill the oven with wood
 - 4.1.2. Men of the household light the wood
 - 4.1.3. Wood in oven burns
 - 4.1.3.1. Wood in oven oxidizes
 - 4.1.3.2. Wood in oven emits heat
 - 4.1.3.3. Wood in oven emits smoke
 - 4.2. Men and women of the household cook the food
- 5. Member of family invites church member to fakaafe
 - 5.1. Member of family giving fakaafe issues invitation to fakaafe to church member
 - 5.2. Church member responds to invitation to fakaafe
 - Option 1: Church member accepts invitation to fakaafe
 - Option 2: Church member declines invitation to fakaafe
- 6. Family members prepare the room for the fakaafe
- 7. Family members and guests take part in the fakaafe
 - 7.1. Family members and fakaafe guests sit down for the fakaafe
 - 7.1.1. Chief sits on mua
 - 7.1.2. Visiting Wesleyan minster sits in the place for the visiting minister
 - 7.1.3. Ofisa kolo sits in the place for the ofisa kolo
 - 7.1.4. Other fakaafe guest sits down
 - 7.2. Family members and fakaafe guests say a brief prayer
 - 7.3. Head of household gives a speech
 - 7.4. Visiting minister gives a speech
 - 7.5. Chief gives a speech
 - 7.6. Family members and guests at the fakaafe have the feast
 - 7.6.1. Family members and guests eat the food
 - 7.6.2. Fakaafe guest gives a speech
 - 7.6.3. Chief signals end of fakaafe, leaving the room
 - 7.6.4. Other family members and fakaafe guests leave
 - 7.7. Others who prepared food for the fakaafe eat
- 8. Women of the household distribute remaining food to famili and kainga
 - 8.1. Women of the house distribute remaining food to members of famili present
 - 8.2. Women of the house distribute remaining food to other members of the kainga
 - 8.2.1. Women give food for missing famili given to child to deliver to missing famili
 - 8.2.2. Child delivers food to missing famili

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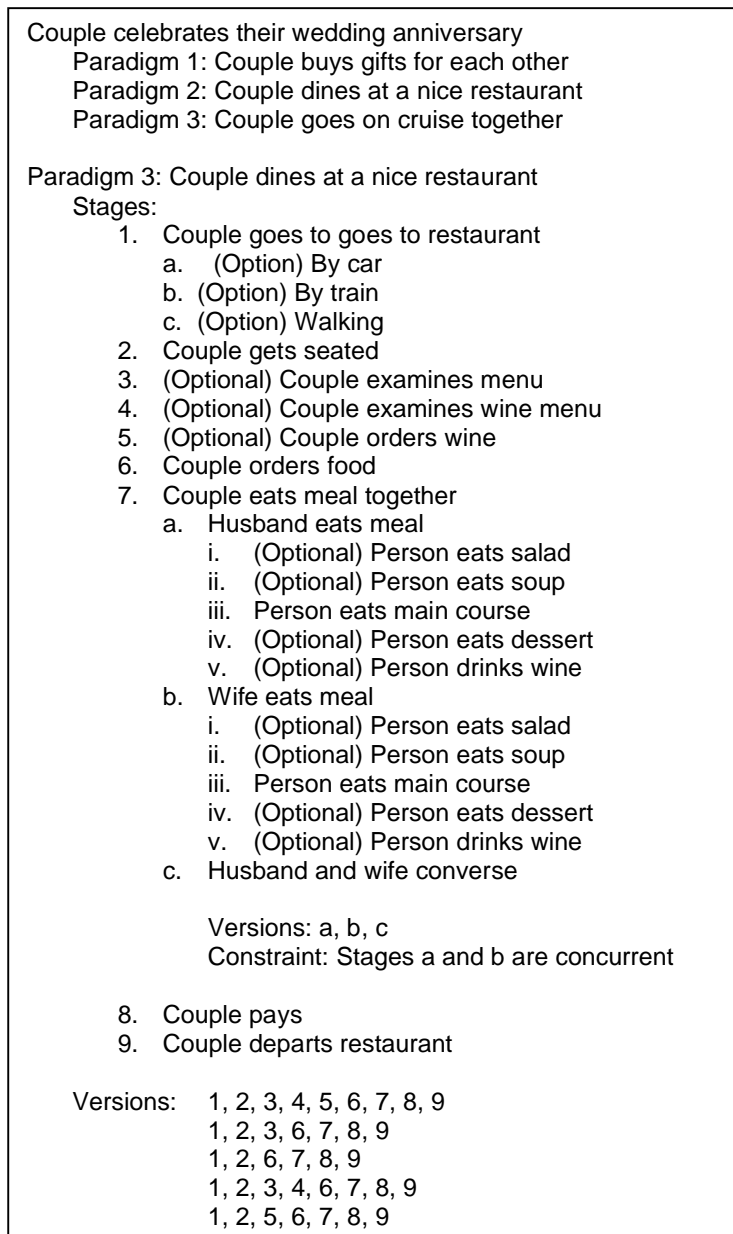


Figure 1

Name: [Responsible persons in the Laboratory] find and fix a problem in [a No. 4 Generic]

Stage-Options:

1. [Responsible persons in the Laboratory] find out about [a problem]
 - Option 1-1: [A person at Indian Hill] discovers a problem and reports it
 - Option 1-2: [A person at Indian Hill] discovers a problem and has [the responsible programmer] file [a Failure Report]
 - Option 1-3: [A person at Indian Hill] discovers a problem and has [the FR coordinator] tell [the responsible programmer] about it
2. [People who keep track of problems] track the course of the problem
3. [The responsible programmer] decides the response to the problem
4. [The responsible programmer] implements the chosen response to the problem
 - Option 4-1: [The responsible programmer] produces the fix for the problem
 - Option 4-2: [The responsible programmer] files a Not-Applicable Correction Report
 - Option 4-3: [The responsible programmer] files a Not-Implemented Correction Report
 - Option 4-4: [The responsible programmer] files a Cancel Correction Report
5. [People in a support group] install the fix for the problem in [a No. 4 Generic].

Elements

1. responsible persons in the Laboratory
2. a problem
3. a person at Indian Hill
4. a Failure Report
5. the responsible programmer
6. a Not Applicable Correction Report
7. a Not Implemented Correction Report
8. a Cancel Correction Report
9. the FR coordinator
10. people who keep track of problems
11. people in a support group
12. a No. 4 Generic

Individuals

0. any person at Indian Hill
1. member of the 4ESAC
2. any technical staff member at Indian Hill
3. 4E5
4. 4E6
5. members of the No. 4 Support Group
6. the FR for the problem
7. the Not Applicable CR for this problem
8. the Not Implemented CR for this problem
9. the Cancel CR for this problem
10. incorrect behavior by a No. 4 machine
11. people in System Test
12. people in a development group
13. people in the Field Support Group
14. Bill Davidson
15. Jane Arment

Versions:

- (1-1 or 1-2 or 1-3), 2, 3, 4-1, 5
 (1-1 or 1-2 or 1-3), 2, 3, (4-2 or 4-3 or 4-4)

Figure 2

Name: Tongan Wesleyan villagers hold a fakaafe

Stage-Options:

1. People in the village decide who will give the fakaafe
2. Members of the household giving the fakaafe plan it
 - 2.1. Household members decide food for fakaafe
 - 2.2. Household members decide who shall contribute food for fakaafe
 - 2.3. Household members decide who shall contribute utensils and decorations
 - 2.4. Member of family giving fakaafe gets kainga member to contribute to the fakaafe
 - 2.4.1. Family member sends request for help to famili member abroad
 - 2.4.2. The kainga member asked decides whether to contribute
 - 2.4.3. The kainga member asked contributes to the fakaafe
 - 2.5. Members of family giving the fakaafe decide who will be responsible for which tasks in special circumstances
3. Members of the family giving the fakaafe gather the food for the fakaafe at the premises of the household giving it
 - 3.1. Tongan village boys capture free-range animals
 - 3.2. Tongan village boys bring captured animals to household where fakaafe is to be held
 - 3.3. Tongan village men bring crops from their gardens to household where fakaafe is to be held
 - 3.4. Women and children of the family collect shellfish
 - 3.5. Men and women buy food at the market
4. Members of the household prepare the food for the fakaafe
 - 4.1. Men of the household prepare the oven
 - 4.1.1. Men of the household fill the oven with wood
 - 4.1.2. Men of the household light the wood
 - 4.1.3. Wood in oven burns
 - 4.1.3.1. Wood in oven oxidizes
 - 4.1.3.2. Wood in oven emits heat
 - 4.1.3.3. Wood in oven emits smoke
 - 4.2. Men and women of the household cook the food
5. Member of family invites church member to fakaafe
 - 5.1. Member of family giving fakaafe issues invitation to fakaafe to church member
 - 5.2. Church member responds to invitation to fakaafe
 - Option 1: Church member accepts invitation to fakaafe
 - Option 2: Church member declines invitation to fakaafe
6. Family members prepare the room for the fakaafe
7. Family members and guests take part in the fakaafe
 - 7.1. Family members and fakaafe guests sit down for the fakaafe
 - 7.2. Family members and fakaafe guests say a brief prayer
 - 7.3. Head of household gives a speech
 - 7.4. Visiting minister gives a speech
 - 7.5. Chief gives a speech
 - 7.6. Family members and guests at the fakaafe have the feast
 - 7.7. Others who prepared food for the fakaafe eat
8. Women of the household distribute remaining food to famili and kainga
 - 8.1. Women of the house distribute remaining food to members of famili present
 - 8.2. Women of the house distribute remaining food to other members of the kainga

Figure 3

Symbols used

=	the equal sign
Σ	summation
β	Greek beta
\leq	less than or equal
<	less than
Π	Greek capital pi
>	greater than
Δ	Greek capital delta
	two parallel vertical bars, used in pairs like parentheses, indicating “magnitude” of a quantity
$\bar{\nu}$	a horizontal bar over the letter; indicates that the letter denotes a vector

subscripts and superscripts are used in several places; I believe they are clearly above or below the text level