The Cognitive Infrastructure of Input-Ouput Relations

Input-Output and General Equilibrium Modeling Conference
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Abstract

This paper presents a mathematical model of the cognitive infrastructure of input-output relations. It is a logical model which specifies information processing (including communications) underpinning economic outcomes. The model is based on two streams with three methodological levels. Each methodological level and each stream is grounded in empirical psychology with identified economic interpretations. The streams are (1) the production of lifestyles (consumption), and (2) the production of incomes. The mathematical levels proceed from (1) base sets and their products to (2) systems of logical formulas (production rules) characterized by instrumental economies to (3) partitions as both a fundamental economic property and the basis of vectors and matrices in input-output analysis.

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I INTRODUCTION

There has been much work done linking empirical cognitive psychology to economic analysis. What is now an impressive volume of both theoretical and empirical studies shows that preference orderings and price signals alone provide an incomplete and unrealistic account of individual or collective information acquisition and processing (Kahneman, 2003; Rabin, 1998; Camerer, 1999). Such research agendas are variously styled behavioural economics (e.g. Camerer et al. 2004) or cognitive economics (Bourgine & Nadal, 2004).

This working paper links logical analytical frameworks from empirical cognitive psychology to input-output analysis.[1]

A table of inputs and outputs is a matrix of rows and columns. Each cell may be seen as a set of outputs (or inputs) corresponding to identified sectors. Each vector of cells (row or column) is a *partition* of a larger set of the whole table, i.e. a division into disjoint subsets in which each element belongs to one set only – the industry relation specified by the cell. Each vector is, in turn, partitioned into cells.

The economy is thus specified by a system of interrelated partitions. These may be aggregated or disaggregated at various levels of detail, in principle from individual persons or enterprises[2] up to broad industry and regional sectors.

The same economy can also be conceived of as an information processing system, in which human beings acquire, communicate and apply information in a learned way to produce, distribute and consume goods and services. The premise is that information processing in an economy cannot be analytically divorced from human information processing; in particular as documented by an growing body of empirical results in empirical psychology.

This paper presents a method to project economic consequences of results in empirical cognitive psychology as economic outcomes into input-output frameworks. Empirical psychology and neoclassical economics differ both in their specification of human

[1] Earlier work was reported at the 13th International Input-Output Conference in Macerata, Italy: Kenning Marchant, Input-Output Properties of an Alternative Mathematical Structure For The Analysis of Markets and Institutions, available at http://policy.rutgers.edu/cupr/iioa/iioa5.htm

[2] 'Enterprise' is used in lieu of the neoclassical term 'firm', because the latter is theoretically confined to a technological production function.

decision-making and in their mathematical structure. Hence the mathematical cognitive infrastructure of input-output relations is differently specified than in computable general equilibrium. In particular, discrete rather than continuous mathematics is emphasized.

The psychological projection, or production rule economics model, has 3 linked methodological levels. Ascending levels provide increasingly composite or aggregate mathematical links between psychological results and the production, exchange and consumption of goods and services. This includes the logico-mathematical specification of institutions such as property, contract and money; and of conflict resolution such as markets, tournaments and hierarchies. Level 2 is highlighted as the most important.

Table 0.1: 3 Methodological Levels

	Mathematics	**Cognition**	**Economics**
Level 1	(1) Base sets and their products and/or (2) formal grammars *generate* (3) composite mathematical terms	Sensory perception and micro-learning	Microphysical effects and indices Detailed features of goods and services
Level 2	**Sets of terms and logical formulas generate equivalence relations[3]↔partitions of skills, money, incomes, ownership, cognitive attention, etc.**	**(1) Individual learning, attention, behaviour and performance** **(2) Intuition and ratiocination** **(3) Producers' Mental Models of consumer lifestyle production rule sets.** **(4) Personality orientations (e.g. altruism, fairness, self-interest)**	**(1) Instrumental economies** **(2) Institutions, structures and patterns of conflict resolution** **(3) Institutions and patterns of exchange**
Level 3	(1) Partitions compose input-output vectors and matrices (2) Input-output matrices as terms in production rules.	Psychological bases for aggregate and cumulative effects.	(1) Micro and macro exchange relationships (2) Linked time – money – material input-output (Stahmer, 1999)

[3] An equivalence relation divides elements in a set into disjoint subsets based on a set of criteria which are shared within but not between subsets, such as sorting by colour, or country, or year.

While presented here as a theoretical architecture, the model is intended to be a descriptive framework to link results in empirical psychology and input-output data for real economies.

The model is also tendered, in a concluding section, as prescriptive in relation to the objective of an economic system as the *production and distribution of choice*. This is in contrast to the neoclassical specification of economics as the allocation of scarce resources among competing ends.

Outline of the Model

The model specifies at the theoretical level of individuals and enterprises, from which aggregations to households, regions or industries can be developed. The full logical system is in discrete mathematical form.

The model is one of continual determination and redetermination of economic outcomes in successive time periods. Any point in the process could be picked as a starting point or focus for analytical purposes.

0.1 Consumer Expenditure

We start with some notional distribution of incomes by individuals.

Each person has, for their income, an expenditure pattern arising from specifiable learning and decision-making in the *purchasing environment*. This is a set of *lifestyle production rules*, which are logical formulas. These are learned ways to pursue by means of goods and services the personal set of evolution-based goals all human beings share: self-preservation and well-being; sexual access; control of material resources; and status.

Aggregated, these consumer decision-making and expenditure patterns have been discovered and *mentally modeled* by producers and sellers. They have responded by producing and creating a marketing environment for a range of goods and services. In the most simplified model, it would be assumed the sale of all goods and services has been perfectly forecast.

Purchase *transactions* occur when ownership or benefit of a good or service is transferred to the consumer, and an amount of money (share of income) is transferred to the seller. In other words, the good or service which is an *output (logical consequent)* of the seller becomes an *input (logical antecedent)* in one or more lifestyle production rules. The price becomes an antecedent for the seller in continuing the production process.

0.2 Enterprise Revenues

When all consumer revenues are aggregated, and then disaggregated backwards across the production chain by means of input-output analysis, *total revenues by enterprise* for a time period $t_1 - t_0$ can in principle be specified.

These could in principle be further disaggregated into the system of individual incomes.

In a simple model, enterprise revenues are the *budget for production in the next time period*.

0.3 Producing Incomes to Produce and Present Products

The production budget is implemented by creating a distribution of incomes which purchases a configuration logical production rules characterized by *instrumental economies*: capital equipment which economizes on setup, labour, energy or other inputs; acquisition of standardized inputs which can be purchased more efficiently than made because economies are shared with others, and assembled more efficiently than making each item from scratch; specialization of labour which takes advantage of learned skills and expertise, economizing on error and labour input time; and management and other organizational capital.

Across an input-output production chain from primary to final goods or services, there are a variety of material and communications features added by successive enterprises, resulting in a presentation to the consumer, including transportation (location), pricing, advertising, packaging, retail display and function. These expressions of combinations of standardized instrumental economies comprise *semantic statements in a combinatorial grammar*, statements which are recognized by the lifestyle production rule system of individual consumers.

The production process thus produces both the incomes and the purchasing environment in which those incomes are expended – the starting point chosen above.

0.4 Error, Noise and Waste

To this simplified model can be added, in an orderly way, features that make real world economies less tidy: waste; information processing errors, including bad decisions; contingencies (e.g. failure of a producer's mental model to correctly forecast consumer decision-making); mismatches between the skills produced by the education, training and on-the-job experience and the production requirements of instrumental economies.

0.5 Institutional Arrangements

Economic activity also requires *institutional arrangements* to organize it.

Arranged predictabilities are instrumental institutions like property, contract and authority (principal-agent). Property arranges for the behaviour of everyone except the owner(s) to be suppressed with respect to the subject matter of the property. Contract substitutes the ownership of property or benefit. Authority substitutes the decision-making of one person for that of the subordinate or agent. All such institutions may be correctly understood as assignments of cognitive control. To function effectively, they must be learned and applied with context sensitivity by all participants in the social, legal/conventional and economic system.

Regulations are rules requiring or prohibiting specific types of behaviour, such as public disclosure in securities markets, or non-discrimination in employment. Effective institutional arrangements and regulations imply logical triangulation by some form of enforcement.

0.6 Conflict Resolution as Variety Amplification or Attenuation

Mechanisms of conflict resolution are of three main types: markets, tournaments, and hierarchies. Each can be specified as sets of alternative production rules. For example, tournament rules set out what it takes to win first, second, or third prize, the remainder being also-rans. Supply (demand) schedules can be expressed in discrete terms as

IF $1	THEN 0 (500,000) units
IF $5	THEN 1000 (50,000) units
IF $10	THEN 20,000 (20,000) units
IF $15	THEN 100,000 (10,000) units

In system terms, institutions to match *varieties* of ‘supply’ and of ‘demand’ are required.

Variety (Ashby, 1961) refers to the denumeration of the types and quantities of states in a frame of reference, e.g. the types and quantities products and services, and the types and numbers of lifestyle production rules into which they might fit. However, for each lifestyle production rule whose antecedent is a particular set of products, there must be an accessible supply of those products (accessible in both psychological (information) terms, and personal budget); and vice versa. If there is more of one than of the other, some mechanism of allocation must occur. Where there is a mismatch, then variety on the one side must be amplified, or on the other attenuated.

Variety amplification can be achieved only through expanded implementation of instrumental economies, i.e. improvement in productivity.

Variety attenuation occurs through rationing arrangements, such as by auction, or first come, first served, or information segregation. Tournaments are a particular form of variety attenuation.

The differences between ‘markets’ and tournaments lie in the different types of system response to the excluded subset, the ‘losers’.

Markets, in principle, should lead to adaptive expansion of instrumental economies to mop up unabsorbed variety, through expansion of production (application of known instrumental economies), or through discovery and implementation of new instrumental economies. In optimal markets, there are no losers; all participate as winners because everyone's skills are employed in generating goods and services which are available for purchase with the incomes obtained.

Tournaments, in contrast, require a continual supply of losers, (e.g. professional sports like tennis; and elections for political office). They may thus attract or consume increasing allocations of resources to achieve the same patterns of outcomes, i.e. instrumental *dis*economies. In contrast, employee hiring tournaments, if there are enough of them to lead to the employment of all or virtually all, approach the characteristics of a market. Their function is then more assignment by sorting than assignment by attenuation, i.e. exclusion.

The model assumes for analytical purposes that the price of each item produced is the cost structure concatenated across its production chain, recorded, and scaled pro rata. Thus the each price is a sum across the partition of tiny contributed cost fractions. This preserves the pervasive role of partitioning in an economic system, and provides the basis for calculating implicit coefficients of interpersonal exchange.

0.7 Efficiency, Equity and Implicit Interpersonal Exchange

The determination of efficiency in a production rule model of the economy is whether there are unexploited instrumental economies. This must have reference to some distribution of income, as expenditure patterns, and therefore production patterns, are different for different patterns of income distribution.

However, instrumental economies are also the basis of efficient income production. Incomes can only be derived from productivity levels, and instrumental economies are coextensive with productivity. In practice, composition of the production process means jointly selecting instrumental economies and the patterns of remuneration with which they are associated, directly as in wages, salaries or carried interests such as royalties; or indirectly through implicit exchange with others through acquired inputs.

The model implies calculation of these implicit interpersonal exchange ratios by means of input-output algebra, in conjunction with the construction of prices as concatenated cost fractions. These ratios are an indicator of income equality or inequality: what is the relative cost of one hour of each person's time to each other person, in which enterprises as well as markets play the role of intermediary? (Note that this requires input-output data in both time and money units (Stahmer, 1999.) The putative results could be displayed as a matrix of coefficients in which the diagonal is self-production, e.g.

Table 0.2: Notional Matrix of Personal Time Exchange Coefficients

	i_1	i_2	i_3	…	…	…	…	…	i_n
i_1	1	c_{21}	c_{31}	…	…				c_{n1}
i_2	c_{12}	1	c_{32}	…					c_{n2}
i_3	c_{13}	c_{23}	1	…					c_{n3}
…	…	…	…	1					…
…					1				…
…						1			…
…							1		…
…								1	…
i_n	c_{1n}	c_{2n}	c_{3n}	…	…	…	…	…	1

Ultimately an economy consists solely of people's behaviour as producers and consumers[4]. Instrumental economies – getting more through coordinated action – are the basis for exchange. An ideal economy would tend toward maximum deployment of instrumental economies, particularly specialization. There would correspondingly be tendencies toward greater income equality as skill specialization increased and differences in bargaining power narrowed. In other words, there is not an inherent equity-efficiency trade-off as the neoclassical Pareto criterion asserts. This is a property styled methodological interdependence, in contrast to methodological individualism, considered in a concluding section.

II THE ANALYTICAL TOOLKIT

1. Six Base Sets and Their Products

1.1 Psychological Basis

Humans operate in a real time physical environment with which their bodies interact, guided by the senses. The purpose of this section is to briefly outline how that happens in psychological terms. (The following discussion draws on survey texts including Ashcraft, 1994, 1998; Guenther, 1998; Rosenzweig et al., 1996; Carlson, 1998; Gazzaniga, 1995; Pinker, 1997).

Experiments have documented how the senses, especially vision and hearing, detect and how memory stores features of the physical environment. There are mechanisms of attention or focus; of perception of features such as edges, colours or distinctive sounds; and of organized storage, so that the patterns associated with shapes or letters, or the clustered characteristics of objects such as the shape, size, colour and taste of tomatoes,

[4] Note, as discussed below, this includes the absence as well as the presence of behaviours; and includes institutions such as property and contract.

may be recovered in association with each other. It has been demonstrated neurologically that different brain cells may respond to different micro-features of the environment.

Micro-features are also economically important. For example, producers of food products, whether natural (e.g. tomatoes) or processed (e.g. breakfast cereals) prepare and package their foods with considerable attention to micro-features which will enhance sales (e.g. colour and firmness in tomatoes).

Cognition economizes by recognizing that a limited number of features may be combined in large numbers of various ways.

Humans also perceive abstractions such as the notion of number, which may be associated with any class of distinct object, and which is the functional basis of money.[5] Counting by ones and tens has an obvious correspondence to the digits in the human hand, though other counting systems are known.

While we can learn enormous amounts and combinations of detail, humans have a significant cognitive limitation: attention, or working memory. We can only consciously process – retain in working memory - 7 ± 2 bits of information at a time (Miller, 1956). A key way in which we economize on this limitation is by 'recoding' or 'chunking', so that groups of features are treated in working memory as a unit (Anderson & Lebiere, 1998). The detailed features are accessible to consciousness from long-term memory.

Correspondingly, pattern recognition in the environment is conceptually driven, or top-down, guided by existing knowledge, current expectations and context. This enables the mind to supply missing pieces and compose a whole; or to implement a bias towards known structures in correcting errors – e.g. an ambiguous final letter is corrected to WORK rather than WORR, which is not a word. Recognition is structured and driven by prior learning.

Face recognition appears to be an innate trait in the normal human being, beginning from early infancy. This is a primary psychological basis on which individuals are distinguished from each other.[6] Most people can learn to distinguish individual human voices as well.

There is also a documented neurological and psychological basis for the development and learning of gross and fine motor control. This begins in infancy, and may be extended by intensive training, as in musicians and elite athletes.

In short, the brain and the senses are organized to apprehend, store, organize and recognize both micro information such as features, and assemblies of features, such as patterns, things or concepts. Through perception and learning, humans acquire a detailed, if incomplete, understanding of how their environment operates, including the behaviour of themselves and others. This includes learning conventions of time and space.

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[5] These are examples of standard texts in cognitive psychology; others could be comparably serviceable.
[6] Identical twins, obviously, pose some difficulty, although less to those who come to know them well.

The first set of tools is to model features and groups (or 'chunks') of features as mathematical terms.

1.2 Base Sets and The Composition of Chunks

The central idea is that every pattern or outcome of interest to a computational psychology-based economics can be specified in terms of

1. base sets,
2. logical operators +/– to indicate that elements are either present or absent, and
3. rational numbers (mainly integers, as in money or units produced).

A term or concept will be a discrete mathematical product of the base sets.

A Cartesian product is a relation between sets in which a set is composed in which each element in the Cartesian set relates an element from each of the base sets. Thus, each element in a Cartesian product $\mathbf{B \bullet I \bullet S \bullet C \bullet T \bullet \Pi}$ of the 6 sets

$\{b_i \mid b \in B\}$ ['human action or behaviour] – *What done?*
$\{i_j \mid i \in I\}$ ['individual or enterprise identifier'] – *Who?*
$\{s_k \mid s \in S\}$ ['physical state'] – *To what?*
$\{c_l \mid c \in C\}$ ['location'] – *Where?*
$\{t_n \mid t \in T\}$ ['time'] – *When?*
$\{\pi_m \mid \pi \in \Pi\}$ ['money cost or price'] – *How much?*

would be of the form

$$(b_i, i_j, s_k, c_l, t_n, \pi_m)$$

relating these particular base set elements the one to another: intuitively, something produced by a particular person at a particular place and time, with a price tag.

Alternative product sets could omit one of the base sets. For example, an object to which nothing was being done and to which no price or ownership was attached would be an element (s_k, c_l, t_n) in the product $S \bullet C \bullet T$. A technological action without reference to a particular place would be some sequence of elements (b_i, s_k, t_n) from the product set $B \bullet S \bullet T$. (A technology itself is a *transition*, discussed below.)

A composite element from the product set can be treated as an object in its own right. It will be called a 'chunk' for information processing (in accordance with usage in cognitive psychology), or a 'term' for logical processing.

Such a term can also be expressed as a *string* with exactly the same symbols:

$$b_i\, i_j\, s_k\, c_l\, t_n\, \pi_m$$

A *string* is a set of symbols with order. A string in a formal mathematical language is a string composed from base sets of symbols.[7] This is a formal basis for signaling. Accordingly, a chunk can refer either to a coded symbol or the underlying reality into which the symbol would decode. Absent coding errors, there is a formal equivalence between information and variety (reality) (Ashby, 1961).

It can be seen that each element $\mathbf{b}_i\ \mathbf{i}_j\ \mathbf{s}_k\ \mathbf{c}_l\ \mathbf{t}_n\ \pi_m$ in a Cartesian product set or string occurs only once: i.e. such a composed "chunk" is 'unique' in the Cartesian product set. Similarly, each string is a unique term.

The concept of a *power set* (symbol, **P(set)**) of a Cartesian product is the set of all subsets of the product; in other words, combinations or sequences of terms as well as individual terms. These subsets, too, can be represented as chunks.

Some further characteristics of the base sets follow.

1.3 Human Action

- **B** is the abstracted set of all human behaviours or actions, mechanically, i.e. physically defined, but separate from human bodies, which are part of **S**;
- it represents skills, including where associated with a past physical state, embodied skills;
- it includes presence *or absence* of potential behaviours; absence is important to people leaving other people and their things alone: i.e. privacy and property; a ¬ (not) or + / – signs are used as indicators;
- it includes symbolic behaviours, accommodated because the model functions as a 'language', i.e. expressions (actions, or actions expressed in symbolic form, as language, musical notation) may be 'recognized' by other participants for incorporation in their own production rules;
- only human action can operate, i.e. trigger a logical implication; hence human action occurs as an operation only in the antecedent a term of a production rule; if in a consequent, it is 'embodied' (e.g. singing on a CD);
- future behaviours are potential behaviours, e.g. things one can do with a 'product' if one were to acquire it, including *mental models* of how others may behave, their imagined production rules.

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[7] In this paper, the specification of reality, and the encoding of that reality into information, and vice versa (decoding) are treated as a 1 : 1 mapping, i.e. there is no encoding or decoding error. 'Reality' is represented by an element of the Cartesian product set, and 'information' by the corresponding string, e.g.

$$(b_i, i_j, s_k, c_l, t_n, \pi_m) \rightarrow b_i\ i_j\ s_k\ c_l\ t_n\ \pi_m$$

Where there is encoding or decoding error, this can be accommodated in the model, but is omitted at this time.

1.4 Actors

- **I** is the index set of unique human identifiers, at bottom individuals, but aggregatable to teams, households, enterprises, etc.;
- identifiers are critical to economic partitions – the allocation of skills, resources, money by individual, enterprise, household, industry - i.e. the definition of *equivalence relations*;
- hence this is a functional set as well as an index set.

1.5 Physical States

- **S** is all physical states in the environment, defined as sets or combinations of physical properties;
- sets of properties can be both psychologically (perceptually) and scientifically defined;
- states include all physical properties including the presence of human beings;
- may also include states resulting from the presence or absence of other people's behaviour as a 'goal state', e.g. whether people respect one's property.

1.6. Spatial Coordinates

- **C** is the set of locations, e.g. spatial coordinates (also an index set);
- this is actually a set of pairs of coordinates (or triplets if 3 dimensional location);
- as such, it is an index set; however, it can become a material set if used to indicate actual spaces.

1.7 Time Coordinates

- **T** is the set of chronologized time (an index set), e.g. date and time.
- time as an index set may be adapted to elapsed time as a material set as the difference between two times, e.g. $\mathbf{t_1 - t_0}$.

1.8 Some Shared Properties

Each of the base sets in the production rule–partition model is finite and partitionable, i.e. in principle subject to economizing, using less to achieve the same or more. Three of the sets consist entirely of unique elements. They therefore have the property of *index sets*. These sets are **I** (actor identifiers), **C** (locations) and **T** (chronological time). As noted, combinations of **C** (spaces) and **T** (elapsed time) can operate as material as well as index sets; which should be specified in the context. If these are the basis for equivalence relations (partitions) they are material. Coincidence in time and/or space are nonetheless of critical importance to actual transformations or transactions, including those sought to be avoided such as trespass, accident or injury.

Sets of individuals, including sets of one individual, similarly operate as functional sets in the composition of equivalence relations.

Two other sets are capable of some repetition of elements across partition blocks.

Standardized physical states can be identical or virtually identical except as to time and place, from a standard quantity and quality of a unit of durum (pasta) wheat to the same year, model, trim and colour of a new automobile. While the same or similar items could appear in the same block in an equivalence relation based on physical similarity, they could also appear in different blocks where the equivalence relation was based instead on one or more of the index sets, such as items by ownership, or physical location.

Analogously, very similar human actions may be performed by different individuals. Skills might be grouped on the basis of similarity – all taxi drivers, perhaps, or sewing machine operators. Indeed, this is the basis of a skills interpretation of input-output tables, where the focus is on the skill rather than the individuals doing it. The identity of the individual may be incidental – any individual with the requisite skill sets may be logically substituted.

1.9 Money

Π is the set of integer partitions on a numéraire of large but finite quantity (intuitively, money supply at some specified velocity, e.g. for V = 1, the number of different ways € 1 million can be divided, from a set of a million sets of { €1 } to one set of {€ 1,000,000}, and everything in between).

The finite money set is unique in that it consists entirely of discrete homogeneous units. These can be partitioned in denumerable ways (Andrews, 1984) subject to the requirement that no block (subset) has less than 1 unit. It is this feature which makes money so useful in its role as a medium of exchange. Because a block can take any discrete value $\leq \Pi_a$ (= supply of money or funds), money is sometimes treated as a cardinal measure which, strictly speaking, it cannot be. It is always a partitioned subset of some available supply of numéraire. A money-based economy is a constantly readjusting set of money partitions.

1.10 Concluding Comments

In each case the above descriptions are, in principle, at a “fine” level of detail. This is to illustrate the fundamental basis of the model. Psychologically, this level of detail relates to sensory perception or detection of features or micro-learning. However, for human information processing, ‘chunks’ can, as stated, be at any level of detail or abstraction, representing goups of features (tomato, the sum of 2+2); or groups of chunks.

The above lay the basis for *chunks* as terms in logical formulas – production rules with both a psychological and an economic interpretation.

2. Lifestyle Production Rules

2.1 Psychological Foundations

Psychologists make a distinction between two types of memory:

1. declarative or episodic, i.e. factual information or "what"; and
2. procedural or semantic memory, i.e. process information, "how", or "how-to".

This paper follows the conventions of empirical models of cognition such as ACT-R (Anderson & Lebiere, 1998) that model 'chunks' of information are representations in declarative memory. The ACT-R model is an empirically based unified theory of cognition which has demonstrated impressive empirical results in a wide range of human learning and performance domains. The following is an outline.

The logical basis for learning is the possibility of future action; this also implies purpose or goals, even if misconceived, e.g. based on error (and subject to correction).

Goals usually involve several steps to achieve them. Even a simple task like making a trip to the store involves a series of steps or sub-goals, including choice of clothing and footwear for the weather, means of transportation, items to be purchased, etc. (Miller et al., 1960). There is thus a tree or logical 'stack' of sub-goals which must be learned and performed to accomplish some purpose.

This means learning procedural, or production, rules. These are logical formulas in which sub-goals and chunks of information are related by logical operations, including a statement of implication or transition, e.g. (formally) IF A THEN B OR C – (intuitively) IF rain, THEN umbrella and/or raincoat.

These can be modeled as production rule decision trees or goal stacks (Anderson & Lebiere, 1998). As a sub-goal is achieved, it is 'popped', and processing moves on to the next sub-goal. In an iterative production rule set, sub-goals may be inserted.

In human learning as demonstrated in the ACT-R framework, three critical statistical factors influence which chunks and production rules are stored in memory and recalled for performance: *frequency* (i.e. how often something is repeated in exposure or rehearsed), *recency* (i.e. how recently has there been exposure to this chunk or production rule) and *noise* (factors which interfere or distract).

What goals and chunks and what production rules are selected is based on empirically determined activation, in particular arising from effective learning.

Such programs (Anderson & Lebiere, 1998; see also Meyer & Kieras, 1999; Newell, 1990) demonstrate that human learning can be effectively modeled as systems of production rules, logical formulas statistically selected on an empirical basis. Moreover,

all information, including decision-making rules, must be either previously learned or presented in the current stimulus environment.

Both human learning and performance demonstrate that humans are goal seeking. But where do the goals come from? Evolutionary psychology (Barkow et al. 1992) has documented 4 top-level goals which human beings pursue with varying weights and priorities depending on the individual. In materialistic societies we are encouraged to try to implement these goals with consumer purchases as sub-goals, such as :

1. *Personal well-being and self-preservation*: processed foods, pain killers or, in some countries, gun ownership for self-defence.

2. *Sexual access*: cosmetics, clothes, diamond rings.

3. *Control of material resources*: contractual employment, lottery tickets, stock market investments.

4. *Status (membership or rank)*: peer group clothing, university degree, expensive car.

Not only will individual weightings of these goals vary, the learned ability to implement them by means of acquired goods and services will also vary, as will economic ability based on income. Evolutionary psychology has also demonstrated that these goals may be extended to one's relatives, particularly children. Maslow's 'hierarchy of needs' (Maslow, 1970) expresses broadly similar notions.

A key factor in human cognition is limited attentional resources or working memory, how much information we can consciously attend to and process at a time. Limited attentional capacity affects both learning – how quickly we can absorb new information – and performance – how many tasks we can accomplish at a time (generally, only one).

The cognitive apparatus uses several mechanisms to compensate for limited working memory.

One is chunking, coding groups of related information into one information unit. Note that this requires learning, which requires lead time. This is also related to why recognition of concepts is conceptually driven, or top-down (see subsection 1.2 Psychological Basis).

Another very important device is overlearning, or automaticity. These are tasks or procedures which are so thoroughly learned they can be done automatically with only limited demands on conscious attention – such as walking, and talking in one's native language (another language you are in the process of learning is far harder). This is also the basis of expertise.

Unfortunately, it is only possible to acquire expertise in a limited number of areas. Thus, while most of us buy cars, few of us are automotive engineers or mechanics. So, in purchasing cars, or other goods and services, we rely on intuition, or rules of thumb. Rules of thumb, too, may become largely automatic, as they acquire the status of habits.

It has now been extensively documented that human beings operate with two systems: intuition, and ratiocination, styled System 1 and System 2 in Kahneman (2003) after Stanovich & West (2002).

System 1 evidences a number of biases in individual decision-making, especially decision making with economic implications. It is the most used, because it is automatic, effortless, and quick. System 2 lightly monitors System 1. While in theory it could produce better results in many instances, it is slow, effortful, and impractical as a general strategy for human living and activity. Hence, System 1 patterns dominate, except in areas of learned expertise. System 2 is mainly a long-term process of skill acquisition.

In particular, System 1 is much more likely to be deployed by consumers, and System 2 by producers.

A recent survey article by Kahneman based on his Nobel Prize Lecture documents the operation of System 1 (Kahenman, 2003). In most of the experiments referred to the economist's rational agent model was the source of the null hypothesis, i.e. the empirical results cast doubt on or contradict neoclassical assumptions.

Most judgements are made intuitively. The rules that govern intuition are similar to those that govern perception by the senses – they are fast, parallel, automatic, effortless, governed by habit, and difficult to control or modify. However, unlike perception, System 1 is not restricted to processing current stimulation, it also draws automatically, on memory (prior learning), and can be evoked by language. Intuitional decision-making can be cued by stimuli in the current environment which increases accessibility of previous learnings (e.g. advertising or display).

People make only light use of System 2. They are not accustomed to thinking hard all the time. Instead, they readily accept plausible judgements that come quickly to mind. Moreover, because working memory is limited, effortful System 2 processes disrupt other cognitive activities, whereas intuition, being largely automatic, interferes less, if at all, with other tasks. Intuition reacts to what is most *accessible*.

Framing, or how a matter is presented, is a powerful determinant of accessibility. People typically assess what is apparent and convenient. They do not imagine equivalent or similar alternatives. Hence, for example, the powerful role played by default options. For example, Johnston, et al. (1993) showed that opposite default options on car insurance led to opposite purchase patterns in the adjacent US states of New Jersey and Pennsylvania, despite the fact one option is more expensive.

Similar factors often apply to consumer purchasing - habit and last purchase of a similar item if satisfactory often lead to repeat purchases of the same item, without active consideration of alternatives. People are susceptible to anchoring effects, or being influenced by outside suggestions or irrelevant prompting. (Rabin, 1998).

People are susceptible to the 'availability heuristic' (Tversky &, Kahneman 1981): undue weight is given to particular facts because they are in view or in mind, than to other factors which may be relevant, or more relevant. Note the connection to the limited capacity of attention and working memory.

People's choices exhibit 'context effects'. They are influenced by the properties of the choice sets presented. For example, more people chose a particular model of microwave when a more expensive model was added to their choice set. In another, experiment, adding a less attractive pen to a choice set including elegant Cross pens increased selections of the latter (Simonson & Tversky, 1992).

The environment, especially the commercial environment, is structured with knowledge of how the typical mind works. Suppliers are frequently, if not systematically, able to induce or influence consumer preferences by the control or restriction of information, sensation and choice environments (e.g. various contributions to *Psychology and Marketing*). This includes the use of involuntary eye and ear responses with which humans are 'hard-wired'. Human decision-making generally occurs in such 'narrowly framed' environments.

Some aspects of the psychology of money should be noted. Both consumer and supplier decisions are tallied in a common, cognitively external metric, money. However, the psychological semantics of money may be different for individual consumers than for businesses. The latter are more likely to approach the economist's model of rationality, which translates into money as a measure. However, individuals do not behave in such as consistent way. They value losses, or out of pocket costs, more than prospective gains or opportunity costs of the same thing. Technically, there is a violation of 'monotonicity' – linear arithmetic consistency in measurement. They make decisions based on reference levels against which gains and losses are assessed rather than final results (Kahneman, Knetsch & Thaler, 1990). People are more sensitive to changes than to absolute levels, from ambient temperature to personal income or habitual levels of consumption (Rabin, 1998). Reference levels are also subject to change. New or adjusted reference levels, which may be higher or lower, are styled 'adaptation'. They are the basis for habitual levels, e.g. of consumption.

Relative proportions or financial ratios can also be important. People will spend more effort to save $5 on a purchase when that amount is a significant proportion of the price (e.g. $20) than when the same amount is a small proportion (e.g. $150) (Lea, Tarpy & Webley 1987). Similarly, people often react more strongly to nominal rather than real prices (Shafir, Diamond, Tversky, 1997).

Thus, different properties such as ordinality, cardinality, intervals (e.g. comparative prices), ratios and reference levels can affect decision-making involving money quantities. Cardinality often does not dominate individual decision-making as neoclassical rationality would require.

2.2 Logical Structures

Each person has a set of ultimate personal goals derived from evolution of the human species (personal well-being, sexual access, control of material resources and status (membership or rank), weighted by their personality and experience. To advance these goals, people learn beliefs (or are 'taught' by mass media or personal experience) as to what particular goods and services will contribute to their achievement, such as salads for health, lipstick for sexual attractiveness, savings for college, or brand name footware for peer group approval. These are, logically, production rules – e.g. IF liptstick THEN more attractive. Together a plethora of such learned rules compose a 'lifestyle'.

A production rule is a logical statement which expresses a transition from one state to another or to the same state at a different time. This paper distinguishes two forms of transition: (1) transformation, and (2) transaction. These play distinct roles in relation to input-output analysis, corresponding to 'production' and 'exchange'. A transition (transformation or transaction) includes at least one relation of implication ($\rightarrow$).

A *transformation* is a physical or mathematical change represented by a logical formula such as

carbon and oxygen and heat produce carbon dioxide

$$A \;\&\; B \;\&\; C \rightarrow D$$

or

$$5 + 2 = 7$$

$$p \;\&\; q \rightarrow r$$

Human procedural (how to) learning, it has been empirically demonstrated, proceeds in this format (Anderson & Lebiere, 1998). The terms of such formulas are called "chunks" – information units (concepts) which are capable of cognitive processing. "Chunks" can be at any level of detail or abstraction which a particular human mind can grasp, from sub-atomic to monumental. The terms are linked in logical formulas styled production rules.

The operations of production rules are those of predicate logic:

&	and
$\vee$	or, including and – choice of either or both

∇	or, mutually exclusive choice; implies conflict
$\neg$	not, e.g. property is NOT the behaviour of everyone except the owner with respect to the subject matter of the property
$\square$	substitution, e.g. authority of the principal substitutes for decision-making by the agent; or 'identical' skill set of one individual substitutes for that of another
$\rightarrow$	implies, or IF…THEN … - production rule
$\leftrightarrow$	bilateral implication

A *transaction* is a institutional or 'ownership' change, which may be unilateral, as a gift, or, more commonly, bilateral, such as a notional contract:

George sold his car to Helen for € 11,000

$$Car_{George} \rightarrow Car_{Helen} \quad \& \quad €\,11{,}000_{Helen} \rightarrow €\,11{,}000_{George}$$

Human learning consists of acquiring production rules which relate "chunks" to each other by means of combinations of these operations.

2.3 Formulation of Production Rules

At any time, there is a set of initial conditions comprising environmental physical states $\mathbf{S_0}$, $\mathbf{B_0}$ (skill sets), at time $\mathbf{t_0}$ for 'country' $\mathbf{c_n}$, and $\mathbf{\Pi_0}$. As part of initial conditions, it is assumed that there is an assignment or 'allocation' of $\mathbf{I_0}$ to each of $\mathbf{B_0}$, (skills), $\mathbf{S_0}$ (resources), and $\mathbf{\Pi_0}$, (money). Note that $\mathbf{I}$ can include enterprises or organizations such as governments.

The initial conditions are a set of partitions on equivalence relations. An equivalence relation groups and divides up elements of a set into disjoint subsets based on shared characteristics. A production rule transformation or transaction on the same base sets may reassign or maintain an assignment[8] within such a partition, i.e. change or maintain equivalence relations.

The principal bases of equivalence relations – partitions, allocations - in an economic system are individuals and enterprises (or aggregations thereof, such as households and industries).

As noted, initial conditions are assumed to include a complete allocation of ownership of both physical states [$\mathbf{S}$], space [$\mathbf{C}$] and 'money' [$\mathbf{\Pi}$].[9] This allocation defines an

[8] Note that maintaining assignments can be important, e.g. because people generally assign a higher value to ownership loss than to ownership gain of the same item.

[9] An incomplete assignment implies that allocations may be made by discovery, e.g. by mineral exploration. Such additions to base sets can be accommodated in the model, although not dealt with in this paper.

equivalence relation by individual or enterprise or other institution (allowing for government, for example). Assuming a property regime, this defines an initial conditions partition.

If presented as a matrix it mght look like this (**i**'s signify individuals, **e**'s signify enterprises (as a component of the identification set):

	i1	**i2**	**i3**	**….**	**ij**	**e1**	**e2**	**e3**	**….**	**ek**	Total[10]
Π	**π1**	**π2**	**π3**	**….**	**πj**	**πj+1**	**πj+2**	**πj+3**	**….**	**πk**	**Π**
S	**s1**	**s2**	**s3**	**….**	**sj**	**sj+1**	**sj+2**	**sj+3**	**….**	**sk**	n/a
B	**b1**	**b2**	**b3**	**….**	**bj**	**bj+1**	**bj+2**	**bj+3**	**….**	**bk**	n/a

Transitions – transformations or transactions – proceed from the initial conditions.

A term in an input-output production rule is an element of $\mathbf{B \bullet I \bullet S \bullet C \bullet T \bullet \Pi}$, $\mathbf{(b_i, i_j, s_k, c_l, t_n, \pi_m)}$ or, expressed as a symbol string,

$$\mathbf{b_i\ i_j\ s_k\ c_l\ t_n\ \pi_m,}$$

or an element of a Cartesian product on a subset of those base sets, such as $\mathbf{I \bullet S \bullet C \bullet T \bullet \Pi}$, $\mathbf{(\ i_j, s_k, c_l, t_n, \pi_m)}$ expressed as a symbol string,

$$\mathbf{i_j\ s_k\ c_l\ t_n\ \pi_m.}$$

or a set or power set of such a string.

A simple *transformation* production rule of two terms is defined as:

$$\mathbf{[b_a\ i_b\ (sct)_a \pi_a] \rightarrow\ \ i_b\ (sct)_b}$$

Intuitively, an operation by an individual or enterprise results in physical or locational and temporal change without a change in ownership.

A simple *transaction* production rule is defined as:

$$\mathbf{[_{b1}\, i_1\ (sct)_a] \rightarrow\ \ i_2 (sct)_a}$$

Intuitively, $\mathbf{i_1}$ gifts to $\mathbf{i_2}$.

More frequently, a transaction production rule will be in the form of a contract. A simple form would be:

[10] The S and B sets are in principle not, or not necessarily, in commensurable units.

$$[_{ba}\, i_1\, (sct)_a] \rightarrow\ i_2(sct)_a\ \ \&\ [b_b\, i_2\, \pi_a\,] \rightarrow\ i_1\, \pi_a$$

Intuitively, individual 1 sells a product to individual 2 for a defined price (assumed for present purposes to be a price provided by a competitive market).

For purposes of 'transactions', 'property' as well as 'contract' are specified by production rules. These are considered in more detail in section 3 of this part, Institutional Arrangements.

Logical relations in a production rule system may be compound so long as there is at least one relation of implication. For example, using arbitrary terms

$$A \vee \neg B \,\&\, C \rightarrow (D \,\&\, C) \vee (E \vee F)$$

(A or not-B and C implies D and C, or E or F)

2.4 Sets of Production Rules

As part of initial conditions, there is also an initial set of previously learned production rules, and their association with particular identifiers, both consumers and producers. These can be augmented or replaced by learning.

A set of 'production' production rules is called a 'skill set'.

A set of 'consumption' production rules is called a 'lifestyle'.

In an actual lifestyle, there would be a 'stack' of production rules, both intermediate (self-production such as cooking) and terminal (the meal having been eaten). In an actual production process, there would similarly be a 'stack' of transformations before a transferable product is produced:

$$[b_1\, i_1\, (sct)_a\pi]_a \rightarrow\ i_1(sct)_b$$
$$[b_2\, i_1\, (sct)_b\pi]_b \rightarrow\ i_1(sct)_c$$
$$[b_3\, i_1\, (sct)_c\pi]_c \rightarrow\ i_1(sct)_d$$
$$[b_4\, i_1\, (sct)_d\pi]_d \rightarrow\ i_1(sct)_e$$
$$\ldots\ldots \qquad \ldots\ldots\rightarrow\ i_1(sct)_{xxx\ldots}$$

Sub-goal sequences or other structures may also be seen as paths. For example, the Critical Path Method works backward from the notional completion of a project to identify the sequencing and coordination of intermediate steps. The concept of path dependence (Liebowitz & Margolis, 1998) can account for psychological (e.g. learning, or learning failures) and economic phenomena (e.g. enterprise development, economic development).

2.5 Intermediate and Terminal Production Rules

It is conventional to distinguish between ‘producers’ and ‘consumers’, and 'intermediate' and 'final' demand.

In a production rule model, logical terms which are ultimate goals for individuals (consequents in 'terminal' production rules) are distinguished from subgoals (intermediate goals, or means to an end; Miller et al., 1960) which are to be incorporated in the composition of antecedents in subsequent production rules.[11]

A ‘lifestyle’ is a production rule set which includes terminal production rules. A terminal production rule is defined by a consequent which is not incorporated in a subsequent production rule *because that term is cognitively appraised as a terminal state at time* t_z . In general, such a state will be so appraised when it is a constituent of a ‘top level’ goal set, e.g. as delineated by evolutionary psychology (Barkow et al., 1992). The previous discussion included what may now be identified as sub-goals (goods and services) which may advance, or are believed to advance, top-level goals:

1. *Personal well-being and self-preservation*: processed foods, pain killers or, in some countries, gun ownership for self-defence.

2. *Sexual access*: cosmetics, clothes, diamond rings.

3. *Control of material resources*: contractual employment, lottery tickets, stock market investments.

4. *Status*: peer group clothing, university degree, expensive car.

5. *1-4 for genetic or adopted relatives*: some or all of the above for one’s children

In an actual lifestyle, there would be a ‘stack’ of production rules, both intermediate (self-production such as cooking) and terminal (the meal having been eaten). In an actual production process, there would similarly be a ‘stack’ of transformations before a transferable product is produced:

$$[b_1\, i_1\, (sct)_a\pi]_a \rightarrow i_1(sct)_b$$
$$[b_2\, i_1\, (sct)_b\pi]_b \rightarrow i_1(sct)_c$$
$$[b_3\, i_1\, (sct)_c\pi]_c \rightarrow i_1(sct)_d$$
$$[b_4\, i_1\, (sct)_d\pi]_d \rightarrow i_1(sct)_e$$
$$\ldots\ldots \rightarrow i_1(sct)_{xxx\ldots}$$

[11] A production rule consequent which is not included in a production rule because it is a ‘failure’, e.g. unwanted product, can be accommodated in the model as ‘waste’ but this discussion is not included in this paper.

Each stage in the production process must be 'recognized' by the subsequent one for information processing (incorporation into production rules) – e.g. incorporation of parts into assembly operations; sale to customer; ingredient in recipe. This is why formal grammars of interpersonal and inter-enterprise communications are essential to the operation of economic activity.

A full specification of an input-output row would then be an extended sequence of (with stacks omitted for simplicity of presentation):

$$[b_1\, i_1\, (sct)_a \pi]_a \rightarrow i_1 (sct)_b \downarrow b_2\, i_2\, (sct)_b \rightarrow i_2\, (sct)_c \downarrow b_3\, i_3\, (sct)_c \rightarrow i_3\, (sct)_d \ldots\ldots \rightarrow i_t\, (sct)_{it}\, !$$

until a terminal term (terminal goal state) is reached. The symbol **!** is used to indicate a terminal state and the i_t subscript to the **(sct)** term to indicate that this is cognitive and affective (appraisal-based) rather than externalized.

2.6 Application to Input-Output

The full chain of production rule stacks and transitions is the cognitive structure across a notional row in an input-output table. These can in principle be developed for a whole input-ouput table, or for selected cells rows and / or columns.

It is obvious that if all rows are specified, that all columns are specified. However, an interpretation must be given to columns as well. It is straightforward. 'Inputs' are production rule antecedents; 'outputs' are consequents. Each row summarizes the full production rule stack for that sector with 'transactions' occurring between cells and 'transformations' within cells. Rows are organized by antecedent identifiers and columns by consequent identifiers.

In turn, each row (column) is a partitioned block of the matrix defined by the equivalence relation by sector; and each cell is a further-partitioned block of both the row and the column defined by input and output sector.

2.7 Production Rules and 'Mental Models'

Production rules are also the formal basis for imagined 'mental models' of how others will behave – i.e. what their production rules are, and what items might be presented to those production rules to elicit purchasing or other behaviour.

Such mental models are the basis for production planning by enterprises. In general, products are made before they are sold, i.e. they are not pre-ordered or custom made.[12]

[12] In custom-ordering, the customer may supply her own mental model.

Thus the supplier must have a 'mental model' of customers' relevant production rule systems, production rules in which the supplier's product would form an antecedent. A supplier must also have mental models of 'inputs' – the consequents of upstream production rules, and downstream production rules with which its product or service will be combined.

A transaction (sale) occurs where there are matched production rules in which the consequents of each are the antecedents of the other's production rule except for the **b** and **i** elements. The output of one production rule set is acquired as the input to another's.

$$\text{Car}_{\text{Acme}} \rightarrow \text{Car}_{\text{Helen}} \quad \& \quad €\,11{,}000_{\text{Helen}} \rightarrow €\,11{,}000_{\text{Acme}}$$

$$\mathbf{b}_{\text{transfer}}\,\mathbf{i}_{\text{Acme}}\,\mathbf{s}_{\text{carz ownership}}\mathbf{c}_{x}\mathbf{t}_{y} \rightarrow \mathbf{i}_{\text{Helen}}\mathbf{s}_{\text{carz owwnership}}\mathbf{c}_{x}\mathbf{t}_{y}$$
$$\& \quad \mathbf{b}_{\text{pay}}\,\mathbf{i}_{\text{Helen}}\pi_{11000} \rightarrow \mathbf{i}_{\text{Acme}}\pi_{11000}$$

If the *productive direction* of an economy is from primary products to intermediate products to goods and services which are antecedents in lifestyle production rule sets, the *cognitive information processing design* of an economy conceptually works the other way: from mental models of consumer 'lifestyles' (production rule sets) backwards through mental models of primary and intermediate products and services. In a marketing-intensive economy, this includes adding to that production rule set through product design and advertising.

2.8 Lifestyle Partitions

An individual or household will partition available income into purchases based on a lifestyle production rule set. How are 'lifestyle' production rules learned? How are lifestyle *partitions* acquired or determined, i.e. how is it determined how what share, large or small, may be spent on what?

Standard neoclassical analysis provides an account of price and quantity determination in relation to each other. However, it is an unrealistic account of information processing in an economy. It assumes that the decision-relevant information of all actors is expressed in terms of one, cardinal signal, price. Moreover, the purported psychological justification for price formation, a complete and transitive ordering of preferences across goods and services, is empirically disconfirmed (Kahneman, 2003). In particular, people as consumers work with learning-based sets of production rules rather than preference orderings.

This paper prefers an operationalization of Duchin's (1998) approach in *Structural Economics*: that preferences are structured as 'lifestyles' rather than transitive preference orderings (at p. 49):

> Households differ in their choice of lodgings …. and even those with similar incomes make different choices about the contents of their homes and where they shop, what they eat and how frequently they eat outside the home, their degree of mobility and modes of transportation, what they read and do for recreation, and so on. These various choices are not independent of each other, because value systems and financial means affect them all. The set of choices made by a particular household is not unique because most cultural practices are widely shared (and the number of distinctly different lifestyle behaviors is limited). Many households will have essentially similar patterns of behaviors regarding food, housing, and so forth. I call each of these patterns a lifestyle …

The production rule sets which compose lifestyle partitions are, of course, matters for empirical investigation, just as mainstream input-output analysis is based on data inputs projected through symbolic operations. However, it is clear that there will be a fair amount of structure to most such lifestyle partitions to begin with.

With rare exceptions, all lifestyle production rule sets will include food, clothing and shelter. Most also include a variety of other categories, including medical care, recreation, transportation, entertainment, personal care and hygiene and so forth.

There is evidence of learned and culturally driven patterns of expenditure at various income levels. Habits are important. (Robertson & Kassarjian, 1991; Solomon, 1996).

In economies which are based on lending for shelter and personal transportation vehicles, lenders structure purchases by limiting the per cent of income which may be devoted to debt servicing, and therefore the size of the loan. This is an example of an institutionally imposed constraint which operates as a partition. However, it may also be a representative allocation of income to loan-dependent purchases such as cars or homes.

Lifestyle production sets are combinations of

- acquisition, involving both action (e.g. to shop) and expenditure;
- self-production, i.e. personal transformations (making a meal, or driving one's car); and
- terminal productions (sometimes by acquisition itself, such as high status goods; more commonly, through production rule transformations (from getting dressed to winning at bridge).

Each of such elements may be analytically important. For example, where shopping is considered inconvenient, higher prices (a larger share of income) may be charged and accepted.

Thus, while the detail of lifestyle production rules must be empirically, i.e. exogenously, determined (e.g. by expenditure pattern surveys), the structure of 'lifestyles' as

production rule sets can be expressed in a 'language' of recognizable economic terms: products and services in relation to top-level human goals.[13]

3. Institutional Arrangements

3.1 Forms and Rationales: Assignments of Cognitive Control

We live in a world which is structured in many physical ways. However, no physical law ensures, for example, that people will respect copyrights or refrain from chatting during a concert performance.

The organization of a hunter-gatherers' economy without property rights is that they help themselves to whatever their cognitive apparatus appraises as interesting. Where human effort creates the available choices, that doesn't work. Institutional arrangements are needed as a practical and therefore logical precondition.

There are five main interpersonal mechanisms required :

1. non-interference with other people and their possessions: notionally 'property', and 'human rights';
2. arranging for others to do something I would like done: notionally private contract, or public duty (e.g. of a police officer) by way of 'collective contract';
3. selection of someone else's behavior by communication; notionally authority (principal-agency, hierarchy);
4. collective decision-making, such as majority vote;
5. economic partitioning - mathematically, disjoint sets; notionally, who gets what. This is considered in a separate section under Money.

Institutional arrangements are based on human rules, which may be formal laws (promulgated by governments) or informal norms based on social sanction (e.g. other members of the audience).[14] These rules supplement the constraints of physical laws.

An important class of rules arranges organized restraint. 'Property' involves everyone except the owner suppressing all or virtually all their behaviors with respect to the subject matter of the property, which can be a thing or a pattern (patent, copyright or trademark). This produces the result that, in principle, the owner has exclusive cognitive control over its use. Human or civil rights involving avoidance of physical injury to others or institutional harm (e.g. discrimination) are similar in logical form.

Other rules provide a framework for joint action where both participants supply specific behavioral content. A contract involves specific reciprocal promises: if you pay $X, I will

[13] This can, of course, include pathological production rules such as addictions.
[14] Rule sets often operate together as a grammar, e.g. slightly different rules apply to the first and subsequent members of a queue.

do Y studio sessions, and vice versa. Individuals adopt their own specific rules within a legally sanctioned framework. Again there are specific assignments of cognitive control.

Authority[15] involves one person selecting other people's behavior by symbolic communication, such as those of a conductor of an orchestra, or an executive of a corporation.

In each of these cases, part of the cognitive logic is contingent third party sanctions for non-compliance. 'Third parties' may be government agencies or members of a group to which one, even if temporarily, belongs (peer group, fellow members of a queue).

None of these arrangements work perfectly, but in many societies they work remarkably well (Tyler, 1990; Tyran & Feld, 2002). People in many countries even self-assess and pay their taxes. Why?

Institutional enforcement involves, in principle, losses – of money or other property, or freedom, or of status. As previously noted, losses are generally valued more than gains of the same thing, including out-of-pocket costs. However, it is doubtful that sanctions are a principal factor in widespread compliance. Indeed, it is not even clear that people typically engage in 'efficient breach' – incurring a cost in sanctions which is appraised as less than the advantages of breach.

Other factors are likely to be more important even if some enforcement is, in principle, a necessary feature.

First, institutional arrangements are learned rule sets which are so well learned that they have become intuitive and automatic. Few of us give much thought to avoiding harm to our neighbours, respecting others' property, using public spaces, including roads, in the way they are intended, responding largely automatically to environmental cues, from traffic signs to informal boundaries defined by lawns or gardens.

Second, institutional arrangements are instrumental for most people. People personally benefit from all the common institutional arrangements. This includes the arranged predictability which general compliance with institutional arrangements provides. Not least, predictability economizes on everyone's cognitive resources.

Institutions such as property, contract and authority, as well as torts (delicts) and human rights (behaviour in relation to other persons) have the common feature that they make clear assignments of cognitive control. This clarity is of practical importance.

It is also of analytical importance, because it facilitates specification of the institutional content of the cognitive architecture of economic activity. As outlined below, institutional arrangements can be expressed as sets of production rules (logical formulas). The rules on which institutions are based can also be *instrumental economies* (see next section, Instrumental Economies).

[15] Note that the root of 'authority' is 'author'.

Third, compliance is often made relatively easy. Any single institutional arrangement is restrictive, but together, there are practical and accessible arrangements for most kinds of human activity.

Fourth, institutions often express social norms (e.g. Ostrom 1990, 2000; Kraus, 1997). This means that one's behaviour is subject to scrutiny and social sanction by others. People are less likely to litter in tidy environments (Kraus, 1978; Tyran & Feld, 2003).

Fifth, institutional arrangements are an alternative to active conflict. They represent the resolution, or preclusion of future, conflict. Conflict is both economically and psychologically costly.

3.2 Institutions for Transaction and Organization

A primary rationale for coordination between individuals is achieving outcomes which, directly or indirectly, one cannot achieve alone. Coordinated action therefore depends on the presence of (a) instrumental economies, intuitively, advantages, discussed in the next section; and (b) institutional arrangements to achieve coordinated behaviour. In particular, institutional arrangements are essential to the functioning of an exchange economy.

Institutional arrangements manufacture 'rights', *the content of which depends on what some other set of people are supposed to do or not do*. This is a central insight of Hohfeld's (1917 [1964])) analytical scheme. A "claim" on someone else's behavior, implies that they have a "duty". A "privilege" implies a "no-right" - other people have no right to interfere (e.g. others may not use my car without my permission). "Power" is the ability to create or alter behavioural relations, such as 'management' which can determine departmental budgets, purchasing and hiring decision, and issue corporate directives. Those subject to such an authority are under a "liability". Unless, of course, they have "immunity". In that case, one who would exercise such a power, but cannot, is subject to a "disability", e.g. regulations which prohibit discrimination. To produce a privilege, or an immunity, one must suppress other people's interfering or power-exercising behaviors; to produce a claim, or to give effect to power, specific compliant behavior must be arranged, i.e. must be learned and applied by all or virtually all participants:

<u>Suppression of behavior:</u>		<u>Deployment of behavior:</u>	
no-right	disability	duty	liability
↓	↓	↓	↓
privilege	immunity	claim	power

Since selected behaviour must go through cognition, selecting another's behavior means arranging for a learned production rule whose appraisal will elicit that behavior. There is

a logical structure to the way each institution works. This logic must be learned; but it represents constraints imposed on, rather than apprehended from, the natural world.

3.3 Property

The basis of property is the suppression of behaviors by everyone except the 'owner' with respect to the subject matter of the property. This 'produces' ownership, cognitive control of behaviors with respect to that property. If the property is a moveable object, the 'ownership' applies to that object, anywhere. If it is immoveable property, land or buildings, it applies only within the applicable physical boundaries. So for a moveable object, where **P(B • I • S • C• T)** refers to power set of Cartesian products as previously defined, property is produced by the following rule:

$$(-\ P(B),\ P(I-i_{owner}),\ s_{property},\ C,\ \{t\}) \quad \rightarrow \quad (\{b\},\ i_{owner},\ s_{property},\ C,\ \{t\})$$

But how is the behavior suppression produced? In a simplified form, legal rules are of the form

IF [compliance] THEN [no sanction]
&
IF [non-compliance] THEN [sanction]

and these contingencies are (subject to the discussion above) supposed to produce compliance, i.e.

IF
[IF [compliance] THEN [no sanction]
&
IF [non-compliance] THEN [sanction]]
THEN
[compliance]

3.4 Contract

A contract is a rule set which parties legislate for themselves by a rule of unanimity to meet conditions which will attract third party enforcement. Contracts often involve the bilateral exchange of property. They are of the general form:

$$(A \rightarrow B)\ \&\ (C \rightarrow D)$$

where, for example, $(A \rightarrow B)$ signifies that Peter transfers ownership of a 1956 Carmen Ghia to Guido and $(C \rightarrow D)$ signifies that Guido pays Peter $8500. Both terms are necessary for a contract. In each case, $(A \rightarrow B)$ and $(C \rightarrow D)$ involve only a change in the **i** element of the '**bisct**', e.g.

$$(bi_{Peter}sct)_{Carmen\ Ghia} \rightarrow (bi_{Guidor}sct)_{Carmen\ Ghia}$$

with $(-P(B), P(I-i_{owner}), s_{property}, C, \{t\})$ implied with respect to both the property and the money.

In practice, most contracts are 'agreed' in symbolic form at one time period, and performed (decoded into actions) in one or more later ones. Once a contract has been agreed, the standard contingencies are supposed to produce compliance, i.e.

IF [contract in valid form]
&
IF
[IF [compliance] THEN [no sanction]
&
IF [non-compliance] THEN [sanction]]
THEN
[compliance]

3.5 Authority

The institution of authority is defined as the selection of one person's behavior by means of symbolic communication from another, particularly in a hierarchy. The 'scope of authority' is a set of behaviors which the authority may select. Once a relation of authority is established, the standard contingencies are supposed to produce compliance, i.e.

IF
[IF [compliance] THEN [no sanction]
&
IF [non-compliance] THEN [sanction]]
THEN
[compliance]

3.6 Organization and Institutionalization

An *organization* may be represented by a set of property and contractual relations subject to a common authority.

Within an organization, a fourth institutional category, collective or *multi-person decision-making*, such as majority vote by a board of directors, may be (mathematically) specified as logically prior to the exercise of authority.

The purpose of organization in this sense is to *institutionalize*, i.e. armor with legal triangulations, configurations of instrumental economies (see next section), and transmit 'rights' to output streams. Without institutional rules, property-free rules apply and

anyone may help themself. With institutionalization, transferable property rights attach to each unit output: the **sct**s have been changed by production to a saleable output set, but the –**bi** (suppressed behaviours) in the institutional –**bisct** has not: others are still excluded by the rules of property.

In turn, a transfer, e.g. by contract, means only the $\mathbf{i_x}$ (identifier) in the $\mathbf{P(I)\text{-}i_x}$ term of the property –**bisct** has changed. In both cases, substitution of terms occurs while preserving the logical structure of the institutional arrangement.

Another way of saying the same thing is that, by definition, all property is owned by someone or some enterprise - there is always an $\mathbf{i_x}$ term specified in the initial conditions.[16] This in turn means that any set **H** of items of property is always partitioned on - owned by - some set of individuals and enterprises $\mathbf{I_H}$. Partition, who gets what, is one of the most fundamental properties of an economic system. Partition is a also a principal function of money, discussed below.

3.7 Status

A fifth institutional category is *status*, including status hierarchies, principally triangulated by social sanctions. Approval or disapproval behaviors, deference or the absence of deference, may be wholly symbolic, or they may be *allocative*, giving priority access to valuable resources, from food to mating to economic opportunities. (Some forms of status, like citizenship, immigration or majority, are legally triangulated.) Status may be defined in terms of rank, or some combination of membership and rank. Hence it may have the features of tournament results[17]. Indeed, that is typically how non-hereditary forms of status are determined. (Inheritance avoids the risk of a particular status being either lost to or inflicted on one's offspring.)

3.8 Money

A sixth category of institution is *money*, conventionally (1) a medium of exchange, (2) store of value; and (3) unit of account. Through exchange, money permits almost anything to be converted into anything else. This is the Rumpelstiltskin effect - even straw into gold.

These immense practical advantages are widely appreciated. However, a most important role of money is enforcing *partition*: the fact that each person's time and behavior must be partitioned among a limited set of activities. To preserve its integrity, an exchange system must preserve this partitioning property, which is the fundamental economic property.

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[16] The model could accommodate 'ownerless' property being assigned, as in discovery (e.g. mineral rights) or lost and found.

[17] See companion paper for this conference, Tournament Determinants in Input-Output Relations.

Money (or its derivatives) is not a product, but a service, a place holder for real **{bisct}**s. It is used to re-arrange *partitional assignments* of (1) individuals or organizations to property (ownership) or (2) between individuals or organizations (exchange). Money is both an abstraction or generalization of property and a measure of contractual capacity. For strict partition, quantity of money must be constrained to map onto, and only to the extent of, present transaction needs, including those with the past and the future (savings and investment). For a given level of productivity (see Instrumental Economies, next section) too much money means inflation; too little, deflation. Both can be *dis*organizing.

Money partitioning has other important properties. As a unit of account, we think of money in cardinal terms, but all money quantities are really subsets[18] of money supply or of income shares. The same cardinal price for a loaf of bread is a different fraction for each income level.

Each exchange carries a price 'tag'. This amount accumulates as revenue in the partition calculation for each enterprise (which typically makes outlays *before* revenues are received). It accumulates as expenditure for each individual (who typically makes outlays *after* earnings are received). Saving and borrowing can be similarly addressed.

Partitioning is enforced by a test: expenditure share must not exceed income share. For organizations, solvency is also an existence or viability test.[19] The outputs of the economic process thus include (1) an enterprise existence (viability of organizational structure) set, and (2) a non-viable set whose members either adapt or are eliminated.

The concept of money as a unit of account can be the source of much misunderstanding. It is sometimes presumed that money is a reliable economic metric, such that a dollar measures or indexes economic value in a consistent way, much the same way as a meter or a degree Celsius measure length or relative heat content, respectively. But this is not the case. Indeed, where incomes are unequal, that cannot be; money is partitionable set. For a nominal price which is identical to all, expressed as a fraction of income, which is the real transactional value, it can vary as widely as incomes themselves do.

In addition, as previously indicated, System 1 human psychology (Kahneman, 2003) does not correspond to such arithmetic, cardinality-based decision-making, or monotonicity.

The notion of money as a 'unit of account' has similarly led some to propose that it can be used to place a 'value' on anything, including life and death, or hypothetical products or situations (such as peace and quiet on city streets) for which there are no 'markets' in which to buy and sell the item. However, where the same item cannot be bought and sold at all, let alone at an identical price, money "measures" must, at best, be subject to significant qualification. For example, where risks of injury in, say automobile use, and the costs of compliance with some regulation to reduce accidents are both actuarially

[18] For some purposes, they can also be approached as rational numbers, fractions of money supply or a budget, for example, in which appropriate subsets are the numerator and denominator.
[19] In a multi-product enterprise, the 'portfolio' of products provides some basis for internal loss distribution, i.e. self-insurance.

known, one can calculate the cost point at which the regulation effectively stops protecting life and limb - but no life can be replaced at that or any other price. A similar point applies to ‘life’ insurance.

For reasons such as these, money is not a uniform or consistent metric of ‘value’, for a single person or enterprise, or between two or more persons and enterprises. It is a partitionable set which can map into other partitions in the economy. Its principal role is to enforce partition rather than measure ‘value’.

This is, of course, consistent with input-output method, since both rows and columns are partitions on matrices, and cells are partitions on rows and columns.

3.9 Regulations

Regulations can be expressed as production rules in the same general logical form as property. If the regulation is to proscribe classes of behaviour, such as discrimination, then, as with trespass to property, engaging in the prohibited behaviour will in principle attract enforcement. Regulations could also require that certain actions be taken, such as mandatory public disclosure as in public securities markets. In this case, the failure to take the requisite action will attract enforcement.

A key role for regulations is to preclude the unilateral infliction of external diseconomies, such as various forms of pollution, damage or unwanted interference. This raises the question of the ‘Coase theorem’ (Coase, 1960) to the effect that externalities should be dealt with by negotiation, and that the sole obstacle to that occurring is the transaction costs, e.g. negotiating and legal costs to arrive at a solution.

The applicability of the Coase theorem is contradicted by psychological research (Kahneman et al. 1990; Hoffman & Spitzer, 1993). Because gains and losses are asymmetrically valued (commonly by a factor of 2:1), it is not merely transaction costs which are at issue, but different valuations on the same thing by the producer and the victim of the externality. Willingness to pay and willingness to accept are two quite different things.

4. Instrumental Economies

4.1 Characteristics

Instrumental economies roughly correspond to forms of ‘capital’. Learning is storage in long-term memory as the basis for future context-specific action. It the basis for ‘human capital’. Other forms of ‘capital’ such as machines and organizations also involve ‘storage’ for future action. Machines embody the actions which fashioned them to repeatedly accomplish the specialized tasks they are designed for. Organizational capital reflects the notion that organizations may be said to ‘learn’ and ‘think’ as coordinated patterns of human action which are called forth from members of the organization (e.g.

Douglas, 1986) or from records which members of the organization and their successors can implement (Merlin, 1991). Physical and organizational capital can thus be seen as extensions of human capital.

A primary rationale for coordination between individuals is achieving outcomes which, directly or indirectly, they cannot achieve alone. Coordinated action therefore depends on the presence of *instrumental economies*, i.e. some economic advantage. Thus a characteristic of rule sets in the production of goods and services must be the instrumental economies.

The 'more' of something which an instrumental economy produces involves *repetition*.[20] What is being 'economized' on is, ultimately, our own behavior, the only thing we have to change or maintain the world to our liking, and the only thing an individual can directly control. If each product - say a CD with music recorded on it - had to be made from scratch for each listening without tools or previously learned skills, there would be no economies. An economy comes from repeating something previously learned, or repeated use of effort stored in the structure of a object, appliance or information record.

An instrumental economy economizes on inputs to produce the same or greater quantities. (This may mean > 0 for something which cannot be accomplished alone.) There are two analytical classes of instrumental economy: (a) repetition, and (b) configuration, including variants based on coding and decoding. The main examples of instrumental economies are: economies of scale (repetition), assembly from standardized components (configuration), skill specialization (repetition) and management or organizational capital (configuration). Diseconomies can be analogously specified as arrangements which reduce rather than increase.

Instrumental economies (diseconomies) can be formally defined as follows

An instrumental economy (diseconomy) is an object or behaviour which increases (decreases) the number of a specific state **(sct)** accessible to behavior in a time period. An instrumental economy and its output may be expressed symbolically as **{bisct}** $\rightarrow$ **(n·sct$_1$, m·sct$_2$, p·sct$_3$, ...)** where **n**, **m**, **p**, ... are integers. Intuitively, a set of **bisct**s produces a stream of products or services in various quantities. It is presumed these outcomes are wanted, i.e. are, directly or indirectly, antecedents in some lifestyle production rule(s). ('Outcomes' is used since there can be instrumental economies in the reduction of wastes or pollution.)

Instrumental economy or diseconomy is a comparative term, e.g. that **n$_1$ > n$_2$**, or **m$_1$ < m$_2$**, or **p$_1$ = p$_2$**. The latter three examples are a combination would be a clearly 'improved' production process if the **n** and **p** were quantities of saleable outputs, and the **m** were quantities of waste emissions.

[20] For a new invention the comparative term at the beginning is zero, for the product did not previously exist. However, it is not a true (successful) instrumental economy unless it is then repeated (repeatedly applied or produced).

Instrumental economies are a necessary feature of every production process, but, in money terms, they are specific to particular cost structures. Instrumental economies in physical terms may or may not be economies in time or money units (the 3 dimensions of input-output (Stahmer, 1999)). An instrumental economy or diseconomy in time or physical units is likely to be recalibrated, or reweighted, by money costs, perhaps turning an economy into a diseconomy, or vice versa. An instrumental economy could be rendered a diseconomy if, for example, it economized on person hours by substituting similar quantities of expensive skilled labour for inexpensive unskilled labour. Alternatively, one might make a diseconomy 'economical' in financial terms by reducing capital costs at the expense of increased wastes which are valueless to the enterprise, i.e. generate externalities which shift costs to others.

4.2 Types and Categories

There are 6 main types of instrumental economies which are associated with different functional roles. (They may also be associated with different typesof revenue claims, e.g. patent royalties vs. skilled wages – see below).

1. [**Invention**] *Tools.* Type 1 modifies the structural interface with an individual's environment to access a new type of state **s**. This includes tools, unique skills or two or more acting together to accomplish what cannot be accomplished alone. In the case of things, it works because of physical properties which the tool can alter occur repeatedly in the environment, such as trees in relation to an ax, or water in relation to a bucket. An important property of many technological economies is arranged repetition, i.e. standardization - so that male and female stereo plugs fit together, for example. In the case of a machine – a compound tool - functional specialization economizes on set-up behaviors. Set-up economies are extended to multiple functions in the case of 'programmable' machines.

2. [**Capital Equipment**] *Pattern repetition* involves using the same physical capital (tools, equipment) or human capital (skills) to make multiple items, or an item for use in multiple time periods, etc. Buildings are repeatedly used over time. Management is spread over many enterprise activities. This may be repetition in different time periods, in different places (a technology) or different populations (e.g. broadcasting). Mechanically this usually involves harnessing external energies (sun, water, animals, fuels, etc., or human beings in the case of standardized procedures) to Type 1 economies.

   'Variety' is the term designated in Ashby (1961) to describe the number of states which a system can take or generate or to which it is restricted. Making a tool or machine *attenuates* the variety of the material of which the tool is made, i.e. limits the states it has. The repeated application of external energy *amplifies* the output of the attenuated variety pattern. This is thus a generalization to instrumental

economies of the principle of mechanical advantage: amplification can only be purchased with attenuation.

3. [**Combinatorial Assembly & Standardization**] *Combinatorials.* 'Combining' refers to the ability to transmit instrumental economies by combining various outputs of specialization, coding and capital spreading: final products can be more economically produced by breaking them down into parts and materials which can be produced with greater economies across a range of final products, then assembled combinatorially. In this way, individual instrumental economies are not isolated to single applications. An assembled band of different instruments and musicians is an example. An input-output table is an aggregated way of summarizing the combinatorial properties of an economy or sector which is based on specialization.

4. [**Information Processing as Energy Conservation**] *Cybernation.* Type 4 could equally be expressed as a set of coded counterparts of types 1-4. Cybernation permits generation and selection of states through information processing, i.e. at much lower energy consumption than trial and error in the real environment. As required it can be 'decoded' back to reality, as in a computer-controlled machine. It substitutes information processing for real behavior; but it is dependent on accurate symbolic storage and logical processing. A computer simulation of aircraft take-off and landing operates at a much lower (more economical) energy level for pilot training than operating an aircraft; it may also be safer. A pilot's training decodes into more effective operation of an actual aircraft when that occurs.

5. [**Specialization**] *Specialization.* Type 5 is cognitive specialization paired with particular behavior sets (which may be instrumental or symbolic). 'Specializing' refers to reducing the variety of things which are done by individuals or things. In the case of humans, it works because it economizes on the limited attentional, learning and performance capacities of humans[21], alone or in teams. In cognitive psychology, it involves 'overlearning' which leads to 'automatic processing' or 'implicit memory' - things done with limited call on conscious attention because they have been so thoroughly internalized through learning and repetition.

6. [**Management**] *Variety engineering.* This involves putting all the instrumental pieces together. Settled agriculture is an example of human variety engineering. It reduces (attenuates) the variety of species of plants in a plot. At harvest time, this eliminates most of the walking between plants in the wild, and all of the walking required to find them, thus increasing (amplifying) output in relation to effort. In the modern economy, it involves selecting and combining technologies, skills, equipment, and external inputs, and fashioning and nurturing organizational capital, to provide particular ranges of production or services.

[21] This applies to 'natural' limitations (not everyone has the unusual height generally required for professional basketball) as well as to learned ones (in a lifetime one can only master at most a few professions).

These 6 categories can be analytically reduced to 3, and then to 2. Functionally, they are based on either repetition (tools, equipment, specialization), configuration (assembly, variety engineering) or coding and decoding (saving energy by processing as information rather than the uncoded reality). However, coding and decoding occur for the purposes of both repetition (e.g. broadcasting) and configuration (computer programming). This is reflected in Table 3, summarizing shared and distinct properties of the principal categories of instrumental economy.

Table 4.2.1: Characteristics of Instrumental Economies

Instrumental economy classification	Repetition (Physical Capital)	Configuration (Standardization/ Assembly)	Repetition (Human Capital Specialization)	Configuration (Organization and Technology Choice)
Physical (bisct) representation	Stored pattern physical capital Intellectual property / know- how	Primary or intermediate inputs	Learned human skill sets	Organizational capital
Coding	Coding variant e.g. numerical or computer control – cybernation	Current business information, e.g. inventory, production statistics	Knowledge workers	Executive and executive support (e.g. information technology, accounting & legal)
Some analytical properties	Behavioural transactions in time (see below)	Inventory with various time sensitivities (e.g. airline seats, perishable goods, obsolescent goods, just-in-time supplies)	Skill acquisition or switching takes time Unemployed time not recoverable	Management as variety engineering Absorption or reorganization of employees takes time

4.3 Transactions in Time

Instrumental economies operate in real time, a succession of continuously ephemeral present tenses. However, most instrumental economies are produced in one time period and used in another – often several. This means they are inherently transactions in time. In each time period, there are physical transactions among the past, the present and the future:

Source	Application	Illustration
Past **(t_{a-b})**	Present **(t_a)**	Wear and tear on equipment
Past **(t_{a-b})**	*Future* **(t_{a+c})**	Physical capital or natural resources retained for future use
Present **(t_a)**	Present **(t_a)**	Current consumption
Present **(t_a)**	*Future* **(t_{a+c})**	Physical investment
Future **(t_{a+c})**	Present **(t_a)**	Real borrowing, e.g. consumption of scarce non-renewable resources

Transactions in time give rise to assets and liabilities: arrangements which instrumentally economize or diseconomize on behaviours (human skills) across time periods. They can be physical, such as a building, a machine or a forest . They can also be cognitive, such as intellectual property, human organizations, or the social capital of learned, and shared, rules for the conduct of economic life.

Assets and liabilities depend on reference levels, because 'economies' (or diseconomies') are themselves relative. Assets such as machine tools are substitutes for more time-consuming behavior sets, such as trying to do the same task by hand. They therefore can be exchanged for other behaviors. Liabilities - such as a building which is under a work order - exhibit a behavior 'deficit'.

Implementations of instrumental economies are in principal entropic and must be maintained and, ultimately amortized: machines wear out, skills become obsolete. Education is also appropriately amortized across a working life (Stahmer, 1999). Note that human capital is 'amortized' by the individual, in contrast to physical capital which is amortized by the enterprise. Organizational capital is entropic but arguably not sufficiently or predictably stable over time to be amortized in the way conventionally understood.[22]

[22] 'Goodwill' acquired as part of a business – e.g. customer base and reputation is a partial exception.

4.4 Instrumental Economies and Financial Claims

Institutional arrangements associated with claims between time periods (financial assets) play an important role in the distribution of economic benefits and costs.

Physical assets can be 'owned' as property; so, in principle, can incorporated organizations. Although shares in a corporation are in one sense a financial asset, they can also be interpreted as a pattern-of-behavior asset. One owns a share in the patterns of behaviors - economies and diseconomies - which the enterprise represents, and in its financial returns.

It is in the determination of incomes that different shares of the benefits of instrumental economies may be allocated or captured. This occurs partly through differences in the functional effect of assignments of 'property' rights; and partly through choice of conflict resolution, i.e. allocative mechanisms – markets, tournaments or hierarchies (see next section, Conflict Resolution).

Different forms of income claims may be associated with different types of instrumental economy, as suggested by the following chart:

Table 4.4.1: Instrumental Economies and Financial Claims

Instrumental Economy	Description	Financial counterpart
Invention/Composition	Patent/Copyright/Industrial Design/TradeMark	Royalties; goodwill; 'rent'; ownership
Pattern repetition	Plant, tools, equipment	Ownership or leasing
Cybernation - physical	Information technology	Ownership or licensing
Combinatorial standardization	Processing or assembly products from standardized inputs	Input purchase/transfer prices from other enterprises / units
Specialization	Skills, trades, expertise	Salary or wages or service contract
Cybernation - cognitive	Knowledge/information workers	Salary or wages or service contract
Variety engineering	Management	Executive compensation
Variety engineering	Organizational capital	Profit participation

There are, of course, constraints on the process. At any given time, the available instrumental economies – 'stored' in physical, human and organizational capital - are limited.

In addition, instrumental economy systems are subject to a market, or solvency, test. They must generate at least as much revenue as their implicit income shares. (In a multi-

product enterprise, the ‘portfolio’ of products provides some basis for internal loss distribution, i.e. self-insurance.)

4.5 Institutional Arrangements as Instrumental Economies

Institutional arrangements are themselves instrumental economies if appropriately designed. There are three main types of economy which institutional arrangements can provide:

1. extending assignments of cognitive control;
2. arranging predictability in others’ behaviour;
3. pre-emptive resolution of conflict.

Each of property, contract, and authority can have these features, in line with the previous discussion. They function as instrumental economies by virtue of being utilized across multiple individuals (repetition), and by being used in combinations to accomplish economic and social purposes (e.g. enterprises as configurations of property, contract and authority), and in conjunction with physical instrumental economies. They operate in both ‘real’ and ‘coded’ (information processing) form. For example, a contract is negotiated (coded) and later implemented (decoded into implementation behaviour).

As with physical instrumental economies, the nature of institutional arrangements is important to its economic contribution. Institutional arrangements in the nature of official corruption, or which impede the introduction of physical instrumental economies, such as cumbersome licensing procedures, are diseconomical.

5. Transactional Conflict Resolution: Markets, Tournaments and Hierarchies

5.1 Conflict and Conflict Resolution

To specify conflict resolution, one must first specify conflict. Conflict implies alternatives (more generally, sets of alternatives) which are not jointly or simultaneously accessible.

A distinction in perspective may be made between conflict at the ‘local’ individual or enterprise level, and systemic conflict across multiple persons and enterprises.

At the ‘local’ level, conflict may be defined as mutually exclusive choice, formally $A \nabla B$ (A or B, but not both), or $A \nabla \neg A$, where A and B would each be antecedents in a lifestyle production rule of an individual or an instrumental economy production rule of an enterprise. Presence of a term as an antecedent in a production rule indicates instrumental utility in relation to a goal.

Individual conflict may be addressed in a number of ways. Sometimes a consumer chooses between 2 or more brands or models of the same thing or an enterprise chooses a between competing suppliers. The customer only wants one of these items; the implicit conflict is between manufacturers or suppliers, i.e. is a 'systemic' conflict as well as 'local' conflict. In most other cases, 'local' conflicts are choices among sets of choices – e.g. buying less expensive clothing leaves more expenditure room for other purchases, so that more of a desired mix of goods and services are available. This is true even if only implicitly, because any expenditure reduces the financial resources available for other purchases. Most consumer expenditures appear to involve learned patterns of behaviour among choice sets rather than multiple pair-wise trade-offs.

At the 'systemic' level, conflict is defined in terms of Ashby's law (Ashby, 1961), that only variety (number of states) can match or 'absorb' the variety of corresponding reciprocal states in the transaction set, such as the requisite number and size of containers required to hold a volume of liquid; or that 'supply' must equal 'demand' for markets to clear.

To balance varieties, e.g. because there are more potential purchasers than product with the right specifications, or vice versa, requires either that the one be amplified or the other attenuated, if matching is to occur, i.e. varieties equalized on both sides of the transaction set. In the short term, it is commonly the case that amplification is not a feasible option, so some form of attenuation, i.e. conflict resolution, is required.

It is generally assumed that the quantity of a product or service which could be supplied is greater than the effective demand. This is commonly the case, which is why producing enterprises are in competition with each other.

5.2 Systemic Conflict Resolution

'Systemic' conflict resolution mechanisms are production rule sets on interpersonal or inter-enterprise choices, institutional mechanisms of variety attenuation or amplification. For example, the production rules of express tournaments specify in advance the prizes, and what is required to win them. Markets operate on the basis of 'supply' and 'demand', as conventionally understood; or as lifestyle production rules in the model in this paper. Hierarchies are systems of authority in which some make decisions (formulate production rules) and others are subject to them.

There are several other kinds of active *attenuation* processes in modern economies. There is first-come-first-served, such as tickets to major entertainment or sports events, or some unusually popular seasonal products, such as the latest fad in Christmas toys. There is segregation by information or other accessibility; one can't buy what one doesn't know about, or participate in a discount program one isn't exposed to. There is conventional price 'rationing', meaning that people do not buy because it is too expensive for them to afford; a variant is not buying because it is judged too expensive even if affordable. There is 'rationing' by need, as in the provision of publicly funded medical services. Some items such as government licenses or permits involve administrative rationing.

Variety *amplification* must mean either the introduction of new instrumental economies or increases in incomes (also based on instrumental economies - see following section, Production of Incomes). Indeed, the central characteristic of an instrumental economy is to either amplify of facilitate the amplification of some variety. The central nature of *entrepreneurship* is to identify and cater to opportunities which can be met by configurations of instrumental economies which are not being presented.

The processes of variety amplification and attenuation can be analogized to biological natural selection. Genetic reproduction and mutation increase varieties in both numbers and species. These processes are amplifying. Natural selection – such as environmental limits on available food, disease, predation and climate – attenuate, so that not all species, and not all conspecifics, survive.

5.2 Markets vs. Tournaments

There are important contrasts between *markets* and *tournaments* as conflict resolution mechanisms. Markets involve exchange of value for value; indeed, the purpose of markets is generally to secure the implementation of instrumental economies through competition in relation to lifestyle production rules. In tournaments, all participants compete, i.e. contribute effort in advance of any return, but winners are disproportionately rewarded while 'losers' are unrewarded, or under-rewarded. Tournament-based examples include pursuing a career in professional sports or the entertainment industries; educational attainment; and pursuing election to political office.[23]

Tournaments, whether formal or implicit, limit the variety which will be matched with 'winnings'. Express tournaments specifically require a continual supply of losers. Many tournaments are part of tournament systems: for example, the tournaments to develop and select professional athletes for team sports are infrastructure for the formal tournament of league competition; and this may in turn be part of an implicit tournament for survival of teams in bigger vs. smaller cities.

Markets, in principle, should lead to adaptive expansion of instrumental economies to attract unabsorbed variety, though expansion of production (application of known instrumental economies), or through discovery and implementation of new instrumental economies, i.e. improvements in productivity through introduction of new enterprises and products. In optimal market systems, there would be no losers; all participate as winners to some extent because everyone's skills are employed in generating goods and services in which are available for purchase with the incomes obtained.

In both markets and tournaments the properties of the 'excluded' sets are of interest, and not merely a focus on the 'winners'. What are the consequences of variety attenuation under alternative forms of conflict resolution? In particular, is the direction of the economic system is to enhance implementation of instrumental economies?

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[23] See companion paper for this conference, Tournament Determinants in Input-Output Relations.

Markets which are open to entry or expansion generally have the latter characteristic. The 'best' resolvers of most economic conflict are instrumental economies – providing more product so there is less conflict. Instrumental economies are, in terms of Ashby's law, variety amplifiers. Inherently conflictual 'positional' goods which are necessarily limited because they signal 'rank' (Hirsch, 1976; Frank, 1985) are an exception. However, many types of 'status' goods can over time be produced in larger quantities, such as luxury cars, prestige clothes and accessories, and coastal holiday properties.

Competitive markets inherently allow for instrumental economies to be introduced. However, they do not necessarily require that. Producers and sellers face choices between amplifiers and attenuators, i.e. constraining, or 'structuring' people's choices. This need not be an absolute constraint; as the psychological evidence shows, it may be done be default or 'negative' options; or by other forms of structuring, such as complements and compatibility, e.g. where intellectual property (patents, copyrights) limit competition. Where the items sold have positional features – luxury goods, or fashion items – attenuation is necessary to maintain their positional character.

5.4 Production Rules in Tournament/Market Conflict Resolution

Contrasts between tournaments and markets can be expressed in terms of production rules.

In a formal tournament, the rewards and terms are specified in advance. What the actual tournament determines are the winners, and therefore the losers. (A roughly similar pattern occurs in implicit tournaments, e.g. book best sellers or pop stars.) A simple tournament might be:

IF [fastest]	THEN $100,000.
IF [2d fastest]	THEN $50,000.
IF [3D fastest]	THEN $10,000.
IF [4th or slower]	THEN $0

It is implicit in tournaments that no more than a specified number will be rewarded as winners, i.e. that the reward variety cannot be amplified to extend to all participants, or to all participants more equally. The pattern of economic outcomes is set in advance. Only the assignment to certain individuals and not others is to be decided by the tournament.

Markets, in contrast, are conventionally understood to determine price and quantity according to 'supply' and 'demand'. Supply (demand) schedules can be expressed in discrete terms as

IF price $1	THEN 0 (500,000) units
IF price $5	THEN 1000 (50,000) units
IF price $10	THEN 20,000 (20,000) units
IF price $15	THEN 100,000 (10,000) units

In this schedule, the market would clear at a price of $10/unit with 20,000 units bought and sold.

However, the model in this paper advocates that markets are better understood in terms of income-based lifestyle and instrumental economy production rule sets. Incomes are the determinant of the sets of goods and services which can be can be purchased at prevailing prices. They generally reflect the patterns of consumption which are established in that culture (Duchin, 1998). The actual sets selected will depend on the interaction of learned lifestyle production rules, relating goods and services to the achievement of personal terminal goals, and the information and marketplace environments to which the individual is exposed. Sorted by product, different lifestyle production rules, aggregated across individuals, imply different combinations of instrumental economies to achieve them.

Thus a 'market' generates 'demand' variety in the form of sets and aggregations of lifestyle production rules; and 'supply' variety in the form of products and service as expressions of combinations of instrumental economies in response to mental models of demand (section 2, Production of Lifestyles). If in a time period there are aggregations of demand for products or services (lifestyle production rule antecedents) which are unmatched by supply but could be, production should expand or new products/enterprises be introduced, if markets are competitive.

5.5 Hierarchies

The selection and implementation of conflict resolution approaches are significantly influenced by enterprise management function. Managers choose what products to produce, and how to produce and market them, and in what numbers. This also selects, along with other factors, what combinations of inputs will be acquired and used, supported by what budgets. This is conflict resolution by *hierarchy*. Choices are made which limit, and perhaps determine, the range of choice available (from that enterprise) to incumbent or potential employees, to upstream or downstream businesses, or to consumers. In particular, hierarchies play a major role in determining incomes (see next section, Production of Incomes).

5.6 Markets and Tournaments vs. Hierarchies

Markets and tournaments as interactive institutions between suppliers, between customers, and between suppliers and customers, are a form of accountability for enterprise management hierarchies. They test the validity the mental models which production and marketing express – i.e. to what extent they correctly forecast sales transactions. They thus promote adaptation, elimination or reinforcement of the implicit production rule sets or 'grammars' of those mental models and of organizational capital.

5.7 Competition and Cognition

'Competition' is a term which requires consideration, as it can be used in several senses, or occurs in several different variants. Sometimes it is used to refer to participants in the competitive process –'the competition'. Sometimes it refers to the quality of participants' performance (the competition is 'weak' or 'strong'). Sometimes it refers to the actions taken by participants to attempt to secure more favourable results for themselves.

There are also important differences between forms of competition: those which are very highly structured with limited access, such as an Olympic track and field event; and those which are relatively unstructured, or at least far more varied in its opportunity structure, such as the production and sale of food for individual consumption.

For the purposes of this production-rule-information-processing model competition is defined as the actions of suppliers and sellers to attempt to participate in the cognitive decision-making frames (accessible choice sets) of customers or consumers. Thus, competition occurs, or it does not, in two related modes, one behavioural, the other informational:

1. as a set of actions by suppliers directed to gaining the attention of customers or consumers with decision-making relevant information;
2. as information processing and cognitive appraisals in the minds of consumers.

Typically, suppliers of a class of products will participate in the decision-making frames of some customers, but not others (not everyone is exposed to the same advertisements or the same stores). Thus, not all suppliers are actual competitors in the minds of all consumers. In addition, different considerations, both price and non-price, as presented by competing suppliers, may influence individual decision-making. However, in all cases, 'competitiveness' will reflect *accessibility*: information accessibility; intuitive accessibility (Kahneman, 2003); and economic accessibility, affordability, a function of income.

6. The Production of Incomes

The neoclassical approach to income distribution is based on the marginal productivity of labour as wage determinant. However, it has long been observed that labour markets and incomes commonly don't behave this way (e.g. Malcolmson, 1984).

6.1 Instrumental Economies and Incomes

Instrumental economies are the basis of exchange, and therefore the basis of income production as exchangeable productivity because contributions are not separately exchangeable. In actual production instrumental economies are mixed together. Incomes cannot be explicitly based on individual instrumental economy (productivity) contribution because of commingling of various direct and indirect contributions. Instead,

incomes are determined by hierarchical and organizational factors, subject to constraints imposed by markets, regulations, or individual willingness to stay or go.

There is a tendency for wage structures in organizations to have a wage hierarchy, to be based on the higher the incomes, the fewer such positions or significant numbers of those in higher paid jobs are promoted from lower-paid jobs in the same organization, with new employees recruited only at specific points in the hierarchy, thus segregating an 'internal' labour market from market entry by 'external' participants(Stiglitz, 1975). Most (Doering & Piore, 1971; Gibbons & Waldman, 1999). Doering & Piore also found that wage differentials are set more by corporate policies than by reference to external market wage rates. Others have found that wage rates rise with seniority and experience faster than productivity does (Medoff & Abraham, 1980). In this model, the production of incomes can be shaped by psychological considerations, instrumental economies and institutional arrangements, particularly the role of hierarchies and tournaments in lieu of markets.

6.2 Psychological Issues – Distribution

Empirical psychology demonstrates that a significant proportion of people care about outcomes of others, and not merely their own self-interest (Lowenstein et al., 1989)

Many people tend to make 'fair' rather than (in neoclassical terms) 'welfare maximizing' discretionary allocations of benefits. The most common form of 'fairness' is to equalize changes in endowments rather than net total endowments. This applies whether the allocations are disinterested, i.e. involve others than oneself (Yaari & Bar-Hillel, 1984), or involve allocations between oneself and others (Andreoni & Miller, 1996 cited in Rabin 1998).

People are inclined to treat 'deserving' and 'undeserving' people differently, or make decisions about others based on assessment of differences in perceived motives for the same behavior (e.g. volunteered vs. induced assistance; accidental vs. deliberate harm) (Goranson & Berkowitz, 1966; Blount, 1995; Croson, 1999).

People (and enterprises) may engage in reciprocal altruism, conferring benefits or making contributions beyond those dictated by strict self-interest. This includes donations to public goods, such as public television; water conservation; and efficiency wages, i.e. wages paid above market rate to encourage superior effort (Charness, 1996). At the same time, there are the self-interested, who may play different roles than those motivated by fairness or altruism. For example, they may seek and obtain organizational positions or occupations which provide extraordinary rewards, such as chief executive officer pay packages.

Different motivational patterns - altruism, fairness, self-interest - occur in typical human populations (e.g. Loewenstein et al. 1999;; Kollock, 1998; Ostrom, 2000; Rabin, 1998; see also Axelrod, 1984). As the experimental or analytical models in those studies indicate, different motivations can be modeled with differentiating production rules: they each represent different consequents or patterns of consequents in response to a common

antecedent. It is beyond the scope of this paper (although not beyond the scope of the model) to investigate how different motivational patterns are absorbed or accommodated (e.g. by the environment offering a range of opportunity sets), or how different motivational patterns aggregate to contend for influence or dominance.

6.3 Psychological Issues – Skills and Employment

There is also a psychological basis for specialization. The primary economic basis for exchange is specialization, and the psychological basis for specialization is learning – indeed overlearning and practice so that (a) automaticity is engaged; and (b) System 2 (ratiocination rather than intuition - Kahneman, 2003) is more extensively used (hence we call it 'work').

Overlearning skills so that they have been practiced so often they are routine, takes considerable time. Hence any particular set of skills cannot be produced at short notice. Many take years of study and practice.

Part of most skills is recognizing that more careful judgement is required than intuition alone supplies. While many judgements may become routinized as well, in many areas, such as medicine and management, not everything is routine. (Rasmussen, 1986; Moray, 1997, 1999; Kahneman, 2003).

There are also important psychological factors in how people approach selecting careers and getting jobs.

The empirical evidence contradicts 'rational expectations' as a basis for decisions involving uncertainty. There is a strong psychological basis for tournaments: people display systematic overconfidence in making economic choices, and about their own prospects for success (Fischoff et al., 1977; Kahneman & Tversky, 1983; Mahajan, 1992; Paese & Kinnaly, 1993; Clark & Friesen, 2003). This can lead some to overinvest in high prestige but low odds careers such as professional sports.

Adding moderate financial incentives does not appear to make that much difference in terms of eliciting performance. Camerer (1999) came to that conclusion having surveyed a wide range of experimental evidence. In some circumstances, this may be due to intrinsic motivational factors, both gross (career interest) and fine (intrinsic learning motivation, or motivation to do a job well).

On the other hand, people's satisfaction with their money income may depend significantly on comparisons with others rather than absolute amounts (Clark & Oswald, 1996).

6.4 Demand for and Supply of Incomes

Market economies are organized to produce goods and services, not to produce jobs and incomes. The 'demand' of individuals for incomes through jobs is not the same as the

‘demand’ for products and services. The demand for jobs must be expressed as supply, and supply and demand are quite different in a money economy, because of the role of money. The mathematical similarity in price-quantity demand and supply curves distinguished only by slope disguises a fundamental asymmetry. It is much easier to exchange generalized exchange value, i.e. money, than limited-application skills or products. In most cases marketable skills can be acquired, and credentialed with experience, only with time and difficulty. Most products fit very specific purposes, such as a screwdriver for a particular screw head or a kiwi fruit as one of a large number of alternative items one might eat. The market participants with money on their side of the exchange are generally in a preferred position. Hence the economic system is more oriented to producing goods and services for those who already have money than producing incomes for those who want money.

Moreover, little marketable production today can be done by individuals acting entirely alone. Where ‘teams’ or organizations (teams with hierarchy) are necessary for production, few individuals are in a position to ‘make it happen’ all by themselves. They are dependent on the ‘choices’ – the limited choices – presented by production environment, which may or may not display desired patterns of entrepreneurship.

Hence the ‘demand’ for incomes through jobs, if expressed as such, is more of a political demand, a demand for policies and regulations that will lead to more jobs and higher incomes.

6.5 Transactional Logics of Income Production

Most jobs are assigned by some form of tournament in which the prize(s) are the position(s), wages and perks on offer. In this case, the production rule set of the enterprise specifies what skill sets are required. The purpose of the tournament is to determine what individual(s) will be incorporated in the **i** term of the **bisct** formulation. The ‘price’ – the income – may be set by the employer, or maybe subject to some negotiation. Sometimes the negotiation is post-selection rather than part of the selection process, i.e. price is determined outside the market.

An employment transaction substitutes the consequent of the employee’s education and experience as an antecedent component to the production rule system of the employer. The employee’s skills, and costs, thus become part of the production/cost equivalence relation of the enterprise, to be projected into products and prices.

The wage or salary output of the enterprise becomes a key antecedent in the implementation of the individuals’ lifestyle production set.

There is a good case for the detailed objectives of an economy to be derived from the production and distribution of goods and services. This is because individual goods and services can play the primary role of penultimate terms in the pursuit of individual goal sets. (Income levels may appear to be such a term, in relation to top level goals such as status or control of material resources, but it is because of their actual or potential ability

to influence the acquisition or distribution (by denying a share to others) of goods and services.)

However, if jobs and incomes are logical derivates of goods and services production rule sets, 'markets' can provide only a part of the coordination needed because of the short-term time frame in which any given market necessarily operates. 'Markets' cannot effectively call forth by means of prices a supply of skills which require years of training and sophisticated educational inputs. A much more elaborate information acquisition, distribution and processing system is required. Effective skill requirements must be forecast, to which the educational and training systems must then respond with appropriate programs and credentials. (Employers may also need to anticipate and provide on-the-job training and experience in advance of need.)

Obviously, it is not possible to predict precisely what goods and services will be required in future time periods. However, demographic forecasting has the advantage of knowing with considerable lead time how many will be in most future age cohorts, because most of them are already born. In addition, human needs and standard wants forecasting, and technological forecasting, can go a long way. This can be materially assisted by input-output based forecasting models, to identify direct, indirect and multiplier effects.

6.6 Production Structure and Income Production

In addition to skill set requirements, other production rule systems in the production of job and income opportunities must be considered. There are constraints on the scope and nature of the job opportunity sets - implied by three factors:

1. Available plant, equipment and infrastructure. These imply certain sets of job skills rather than others.
2. Incumbency reinforced by experience and internal labour markets. (Doering & Piore, 1971; Gibbons & Waldman, 1999).
3. Configuration of upstream and downstream production.

Thus while the 'system' generates sets of employment opportunities ('logically' like products but roles reversed – buying income with skills), the job opportunity set may or may not be suited to 'demand' for jobs in the form of skill sets supplied.

At any given time, there is in place local infrastructure inertia due to prior year commitments to plant and equipment. The nature of plant and equipment defines the types of human skills required for operation and maintenance.

There is also a set of production and distribution arrangements across the input-output vector for each industry, a pre-specified upstream and downstream production rule system, into which the enterprise production rule system must fit. This includes parts and equipment supply, transportation and distribution arrangements. An enterprise must configure its operations to fit in with these arrangements on which it is dependent and

over which it may exert little structural control. These factors constrain, or structure, production rule set choice.

There is also organizational inertia and incumbency. Organizations, especially large ones, take time to develop and are not easily changed. In most organizations, only a small proportion of jobs are open to be filled in any one time period. Most of those which are open to non-employees are likely to be entry level. For various reasons, higher level jobs may be filled from within: because they are known quantities; because of morale effects if jobs to which existing employees aspire are filled from outside; or because only incumbents are familiar with organization-specific production rules, i.e. the organizational culture.

Management must also address regulatory issues, including non-discrimination on the basis of gender, race or ethnicity; the environment, securities regulation, etc.

The outputs of all of these factors will be job or skill set requirements (a) to the outside job market; and (b) to internal labour markets, i.e. selection from within.

6.7 Claims Structure and Income Production

Incomes are a necessary mechanism to distrtibute accessible productivity levels, that is, production rules expressing instrumental economies. Tension between returns to 'capital' versus 'labour' (e.g. Dietzenbacher & Lahr, 2004), or 'management' versus 'labour' refer to alternative appropriations of the benefits of instrumental economies: how much of the contribution is that of the worker, and how much that of the tools and equipment with which she works, how much that of the management of the process, and how much that of those who actually do it.

Different forms of payment have different properties. Where an item such as a machine or a trademark is purchased outright, the cost is fixed; as a proportion of unit cost it declines with each increase in volume. Carried interests such as royalties are different: if the unit cost or royalty rate is fixed, total outlays increase with volume. Residual interests may also increase with volume; and they, like other income streams, may be capitalized[24], and will be liquid if, for example, it is in the form of traded shares on a stock market.

Not all forms of remuneration are available to all participants. For example, managers may have readier access than other employees to forms of remuneration which capitalize their contributions. Only some kinds of effort produce intellectual property with royalty potential such as patents or copyrights. Shareholders 'own' the physical and intellectual property of the enterprise (after provision for prior claims such as secured lenders), and organizational capital. The latter includes 'profitability'.

[24] This has important partitional effects, to be considered in a forthcoming paper.

6.7 Income Production vs. Lifestyle Production

Incomes may vary by individual; but prices in consumer product markets are the same for all. Thus incomes are the most important determinant of the *economic* accessibility of choice sets. (*Psychological* accessibility in relation to choice was discussed in the introduction to section 2, Lifestyle Production Rules.)

There is a further contrast between the production of lifestyles and the production of incomes. In the former, the production, distribution and acquisition of products and services was presented (sections 1 – 2) as a 'bottom-up' logical progression from

1. base sets and products thereof,
2. production rule systems of suppliers and purchasers, which are
3. linked prospectively by mental models, and actually by logical transactions in which consequents of supplier production rule systems become antecedents in those of purchasers;
4. these transaction sets define equivalence relations by assigning ownership indices;
5. transaction sets accumulate as equivalence relations by enterprise, individual and product/service as disjoint sets, i.e. partitions;
6. partitions express vectors in input-output matrices;
7. vectors compose the matrices themselves.

In the income production system, the logical linkages are preserved, but also reordered, some of them being 'top down', or, in part, at least, 'hierarchically' determined.

6.9 Non-Market Conflict Resolution

In this connection, the two *non-market* forms of conflict resolution (operations on sets of alternative choices) play an important role in job and income markets:

Hierarchies. A hierarchy is organizational management expressed as authority. Hierarchy is a logical relation. It involves certain persons selecting and configuring, or selecting and configuring in part (e.g. constraining) the production rule sets by which others are contstrained to act. Setting organizational standards and procedures, and setting budgets for organizations and their sub-units are examples of hierarchy.[25]

This includes production rule sets which determine, or partially determine, equivalence relations, i.e. income partitions. Examples are enterprise budgets, and the choice of technologies (e.g. high, moderate or low labour or capital intensity); organizational forms (e.g. make or buy, sourcing in high, medium or low labour cost jurisdictions); and, to the extent not constrained by labour market conditions or collective bargaining, wage scales by skill or seniority groupings.

[25] The narrower concept of authority, or principals selecting the actions of agents, as in issuing specific instructions in a military command is a not of present analytical interest, but is important in other contexts.

Tournaments.[26] These are characterized by skewed reward structures, including winner(s) take all recruitment. Unlike market exchange, where value is exchanged for corresponding value, tournaments involve unrewarded or under-rewarded contributions, often for a significant proportion of participants. Hierarchical organizations' management often select tournaments over markets where they are in a position to do so. (In employment subject to unions and collective agreements, they may be less able to do so.) Most job selection processes are tournaments: if there enough of them, and almost all are able to find jobs, the results increasingly approximate market rather than tournament outcomes.

6.10 Modelling in Input-Output

A top-down approach in the model could begin with an enterprise-by-enterprise input-output table. We assume for analytical purposes that the revenues of the prior year are the overall budget for the succeeding year.[27] 'Management' establishes a partition for the overall amount into tasks and budgets for various components of the enterprise's activities, including profit targets and management compensation. Production budgets are associated with production rules, including what mix of physical capital, inputs outsourced from other enterprises, and human capital (skill sets)[28] will be employed, and what returns to each (having regard to market, i.e. price-taking, conditions). Subject to external constraints such as markets and regulations, the partitions – i.e. equivalence relations – are decided within the enterprise from the top down, rather than from the bottom up.[29] This would include pay scales by skill type or employee level, including collective bargaining agreements if applicable. So determined, too, are the implied sets of actual transactions when an operating budget is complete. The only item left to be decided is who the specific individuals will be if there are not already incumbents. (In terms of base set products (**bisct**πs), only the identifying index (**i**) remains to be determined.)

In terms of incomes, income partitions, and enterprise budgetary structures, the financial claims structure is likely to be different for different classes of instrumental economy: (a) capital equipment; (b) make versus buy (cf. Williamson, 1985); (c) labour costs which have a significant impact on unit cost; and (d) labour costs which do not have a significant impact on unit cost (such as management and management services in a large corporation: even though remuneration may be high, it is a small per unit cost item). (See subsection 4.4, Instrumental Economies and Financial Claims.)

6.11 Employees as Skill Sets

On the prospective employee side:

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[26] See companion paper for this conference by the same author, Tournament Determinants in Input-Output Relations.

[27] Cash flow and loan or other financing can be logically accommodated in the model.

[28] Note that human capital is from the perspective of the individual, and skill sets as current inputs from the perspective of the enterprise. Sometimes enterprises may invest in human capital, but not necessarily.

[29] Obviously management may seek information and submissions on budgets from other levels within the organization. There may also be internal 'negotiation'.

First, all individuals are subject to the outputs of the educational system, to the extent that the educational system produces skill sets which 'transact' with the production of goods and services sectors, i.e. provide outputs which others accept as inputs.

Each individual can offer, or is likely to be recognized as offering, a limited range of skills. They thus operate in a fairly narrow range of 'markets'. Education, training and experience also play an important signaling role. Employers are likely to be most comfortable with someone who has already successfully performed a similar job before. There may be a perceived hierarchy of educational or other credentials. Those lacking recognized education or experience credentials may be losers in hiring tournaments.

Matching of jobs with individuals commonly occurs through tournaments of the winner takes all variety; as previously discussed, if there are enough tournaments for most to be satisfactorily employed, this approaches market conditions. For both employers and employees, the employment 'market' may operate primarily as a constraint – either or both are likely to be approximate price takers, except where there are collective bargaining agreements or high demand specialty skills. Some 'markets' may be notional or artificial markets, such as remuneration based on a consulting report on similar jobs, rather than a real market of competing individuals who might otherwise get the job. This is often the case for senior management remuneration. These different remuneration bases can be expressed as production rule sets.

The individual is pursuing the same top-level goals as in consumption – felt personal well-being, status, control of material resources – but, as to the latter, on a wholesale basis – income equates to 'lifestyle', if it is to fund the personal production rule set. Status is consumed on the job, and may or may not carry over to outside, or may not; income is what you 'take home'; some perks such as travel may be on-the-job-consumption; some benefits (e.g. medical or day care) supplement income.

There is downward rigidity in wages (and status) because it forces inconvenient adjustments to lifestyle. As noted in section 2, humans are strongly influenced by reference levels, and losses (reductions in lifestyle) are valued more highly than comparable gains.

6.12 The Production and Placement of Skills

Skills are based on learning – overlearning for expertise, through education, practice, and experience. They are signaled by credentials, particularly educational certification and prior job experience. However, everyone who can become credentialed in a field does not necessarily find employment in that field.

Moreover, not everyone can pursue development of any particular skill; no one can acquire more than a small number of marketable skills; and switching careers involves a significant investment of time and money. Education is an asset acquired through the

investment of time and money which one expects to amortize over a working lifetime (Stahmer, 1999 for the application to input-output).

Put another way, in a specialized economy, *sorting* out who does what is an important and complicated function. It is mainly done on a non-price basis – e.g. admission places in nursing training or veterinary college are not usually for sale. Self-selection plays only a partial role in narrowing the sorting process.

The other side of the coin is what skills are needed by the production process. From a high altitude vantage point, one might ask how the economic system coordinates, reconciles, and locally signals the desire for incomes, the desire for career choice, and the needs of the production process to produce the goods and services the same people want as consumers rather than producers.

While most products and services are professionally marketed, most job seekers are amateur marketers of their own skills. They respond to demand, filing applications to participate in a selection tournament. And while employed, they are likely to lack more than amateur skills and informal sources of information to forecast future demand – such as a layoff, or closure, or transfer of production offshore. They are similarly amateurs at addressing redundancy when it occurs.

Of course, there are support systems and services: seminars on personal marketing and networking; outplacement and job centre services made available to some. Educational institutions commonly have placement offices for those graduating into the workforce; and many vocational and professional programs are geared to ‘product design’ for the immediate workplace. Similarly, unions or like associations (e.g. National Hockey League Players Association) may be involved in some marketing as part of collective bargaining activity.

However, in general, after initial placement, most people are their own marketers of their own second-hand human capital. They face significant information deficits or asymmetries, in comparison to employers, or in comparison to the marketers of other (new) products. Yet most people are more akin to improved products after their first jobs, than they are to depreciated goods like used cars. They have more experience, typically more training. What they usually do not have is a sophisticated marketing system – from intelligence to promotion – to match.

The rules are somewhat clearer for promotion in some well-defined contexts, such as academic tenure or access to professional partnerships. These also tend to be up-or-out, i.e. they create replacement requirements for others.

6.13 The Production of Future Skills through Experience

Educational systems are part of the input-output framework, and their direct and indirect contributions can be displayed and calculated.

However, experience on the job is a very important part of skill development. It may also be a key requirement for access to internal labour markets, such as internal promotion or transfer. A significant proportion of jobs may only be filled that way, or in variants of 'internal' markets, intra-industry or job-specific experience markets.

Thus, a by-product of each time period's production of goods and services is the production of job experience skills – learning by doing. In production rule terms, this is a simple formulation in which only the **t** term in the **bisct** changes e.g. $\mathbf{bisct_{5-t_0}}$ might epitomize 5 years experience in a particular role.

For an economy as a whole, however, a 'macro' production rule would use entire input-output tables (or production sectors) as the terms in the production rule, from one time period to the next as patterns of accumulated experience. Since education takes time, this component of the input-output system is also part of the 'macro' production rule.

This is an illustration of input-output matrices, or components thereof, being themselves terms in production rules (logical formulas) specifying economic transactions in time.

7. Production Rules as Grammars : A Mathematical Economic Language

7.1 Language as Communication

The outputs of instrumental economies (products and services) and of institutional arrangements (specific forms of property, contract, technical standards, etc.) can be expressed as logical production rules on '**bisct**'s and their underlying sets (see section 1), as can entries in personal lifestyle production rule sets. This means they can also be expressed in a formal mathematical language (Davis, Sigal & Weyuker, 1994), by coding each '**bisct**' (which is a relational mapping **(b, i, s, c, t)**) as a symbol string with the same characters i.e.' **bisct**' (see section 1, Base Sets).

A language is functionally important as a shared (communicable) source of symbolic isomorphisms between real and cognitive phenomenon. That function can only be performed, of course, if expressions in the language are *recognized* by the relevant parties. Each formal language in discrete mathematics corresponds to an automata (an extension or generalization of mechanism) which recognizes, i.e. acts on inputs expressed in, that language. 'Syntactical' means the recognizing mechanism can receive the information because it is in an appropriate form in terms of eligible symbols and ordering rules. 'Semantic' means it is effective in controlling – eliciting some meaningful response from - that mechanism. For example, an expression in a 'language of institutions' is recognized when people attribute institutional significance to each other's behaviour : a police officer recognizes an offence; an offer is accepted, making a binding contract; a check is honored by a bank; a ceremony is recognized as a marriage; a divorce is recognized, or not, in another jurisdiction. A product is a combination of properties imparted by a corresponding combination of instrumental economies. Those properties

are ‘semantic’ if they are recognized by consumers as antecedents in their lifestyle production rule sets in terms of function, size, features, etc.

In this model, production rules take the form of logical expressions, with combinations of instrumental economies, institutional arrangements, lifestyle production rules and money subsets playing the role of ‘semantics’. Productions of an economy expressed in such a ‘language’ underlie row vectors in a Leontief-type input-output table (Leontief 1986). There is an implicit grammar to each input-output cell, and each input-output row; these include instrumental economies, institutions, conflict resolution and lifestyle production rule sets with terminal goals particular to each cell, row or column.

7.2 Outline of Formal Language Structure

A ‘language’ in discrete mathematics comprises

> (1) a set **M** of symbols, including starting, terminal (**M’**) and non-terminal (**M’’**) symbols;[30]
>
> (2) a set **M*** of all strings of those symbols of some maximum finite length; and
>
> (3) production rules between strings of the form **abc… → cde…** which generate subsets of strings which are ‘valid’ (syntactical in the sense of conforming to the production rules for the language; and ‘semantic’, i.e. meaningful, i.e. effectively goal-related).

A natural language such as English begins with symbol strings from an alphabet of 26 letters plus a space to distinguish one string (word) from another and 7 punctuation marks to distinguish strings of words, e.g. clauses or sentences. Of the set of all possible letter strings of some finite length, only a small subset are valid words, e.g. ‘man’ and ‘name’ but not ‘nam’. Words may then be assembled into strings of some finite length. Only a subset of such word strings meet syntactical requirements for a valid sentence, such as subject-verb-object. But even the subset of word strings which are syntactically correct contains expressions which are nonsense, such as Noam Chomsky’s famous ‘Colorless green ideas sleep furiously.’ Only a further subset are semantic, i.e. convey meaning between two speakers of the language.

An institutionalized instrumental economy - a machine, an enterprise, a product, a particular form of human capital - is a set of production rules on ‘**bisct**’s or strings of ‘**bisct**’s. Each expression must start from a string which contains **sct**; intuitively, some initial state, at some place and point in time, to which some behavior is then applied.

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[30] The reason for ‘starting’ and ‘terminal’ symbols is that starting and ending points are needed for chains of logical implication, which is what a mathematical language comprises.

Take all the symbols **±b**, **i**, **s**, **c**, **t** (sets **B, I, S, C, T**). Add to this the logical symbol **&** and the set **{π}** of rational numbers (to represent 'prices' and discrete fractions of prices). This is the 'vocabulary' of the language.

Specify that only the following may be included in expressions :

(a) letter strings of the form **±bisct**;

(b) a number which immediately follows a **±bisct**;

(c) an **&** which follows a **±bisct** and which precedes either a number or a **±bisct**. (This is to permit combinations of terms.)

Production rules in the language are then of the form

$$\pm\mathbf{bisct}\pi_m \rightarrow \pm\mathbf{bisct}\pi_n$$

or terms of strings of **±bisct**πs connected by an **&**. These rules define 'syntax' by generating subsets which comply with the production rules.

Call the set of all possible strings of the symbols, **N***. Only a subset $\mathbf{M^*} \subseteq \mathbf{N}$ of the results those strings represent what is physically possible: one can't do different things in different places at the same time (although one can, of course, *not* be in lots of different places at the same time, a natural feature which 'property' takes advantage of.). Only a subset $\mathbf{L^*} \subset \mathbf{M^*}$ involves instrumental economies. Only a subset $\mathbf{K^*} \subseteq \mathbf{L^*}$ of those produce institutional consequences (e.g. property rights; sanctions for rule non-compliance). Only a further subset $\mathbf{J^*} \subseteq \mathbf{K^*}$ will successfully transact with customers' lifestyle production rules. Omitting money subsets for the moment, the production rules (technologies and associated legal rules) which produce these subsets comprise an *economic grammar*.

In summary, the production rule set for a language of economic production would include three rules of syntax and four levels of semantics before provision for money partitions, starting from a set **N*** of all possible string combinations :

(a) a subset $\mathbf{M^*} \subset \mathbf{N^*}$ of the physically possible;

(b) a subset $\mathbf{L^*} \subset \mathbf{M^*}$ which are correct in form because they express instrumental economies;

(c) a further subset $\mathbf{K^*} \subset \mathbf{L^*}$ which are correct in form because they comply with institutional arrangements;

(d) a further subset $\mathbf{J^*} \subset \mathbf{K^*}$ which conform as product presentations to lifestyle production rules, i.e. are semantic.

7.3 An Example : The Recording Industry

A ‘product’ and an ‘industry’ can be defined in informational rather than, or than just, physical terms. Consider, for example, the ‘inputs’ and ‘outputs’ of the recording industry. For an ‘output’ which is a set of new owners of original CDs, many direct and indirect ‘inputs’ are required. A record label (enterprise) buys blank CDs, packaging materials, and recording and duplicating equipment, and skilled production staff. It contracts with songwriters and performers. It contracts with delivery services to ship its products to broadcast outlets and to retail stores. It relies on the production and widespread purchase of standard format CD players. People hear the songs on radio or TV and may go to retail outlets to buy the CDs with the songs they like on them.

Table 7.3.1 Modified Recording Industry Vector
(focus industry/enterprise in italics)

A	B	C	*D1*	D2	E	F	G	H	I	J	**{O}**
CDs	Pack-aging	Perfor-mers	***Prodn & Dupln (1)***	Prodn & Dupln (2) comp-etitor	Trans-port-ation	Broad-cast-ing	CD player mfrs.	Retail	Govt.	Indivi-duals	**Set of Users**

A	&	B	&	C	&	D1	&	not-D2	&	E	&	F	&	G	&	H	&	I	&	J	→	**{O}**

The vector at the bottom presents a simplified production rule statement for this industry.

If potential buyers go online to file sharing websites and download only the songs they like, for free, this is a different sequence of connections with a different structure. The business model implicit in the above sequence of production rules is to that extent falsified.

Exchange depends on more than physical production and distribution: it depends on effective property rights - the conditional right and effective ability to exclude - on a basis which has been widely learned in the relevant population. Exclusion is relatively straightforward in the case of objects. In the case of intellectual property such as copyright, it is the pattern or information in any manifestation from which exclusion is sought, rather than a particular physical object.

Thus the dilemma for a record label is not merely to make a product and set a price. A successful business model requires an orchestrated arrangement of behaviors on the part of many players:

- compliance with CD and CD player standards across many manufacturers, broadcast media and individuals

- effective copyright and contract laws to exclude competitors from recording or duplicating the same material
- broadcast outlets for pre-purchase exposure to potential buyers
- methods to protect downstream integrity of copyright, such as restricted distribution channels, encryption or widespread respect for copyright
- availability of compatible CD players
- individual pre-purchase behavior as a necessary element, such as going to a CD store, or placing a phone or internet order

Table 7.3.2. Combinatorial Grammar for Recording Industry

A	B	C	*D1*	D2	E	F	G	H	I	J	**{O}**
CDs	Pack-aging	Perfor-mers	***Prodn & Dupln (1)***	Prodn & Dupln (2) comp-etitor	Trans-port-ation	Broad-cast-ing	CD player mfrs.	Retail	Govt.	Indivi-duals	**Users**
blank discs	boxes, labels	reh - earsed music			truck trans-port	air play	CD play-ers	dis-play & sales		go shop-ping	
Prop-erty + contr-act + stand-ards	Prop-erty + contr-act + stand-ards	Prop-erty + contr-act + stand-ards	***Prop-erty + intell-ectual prop-erty + contr-act + stand-ards + author -ity (orgn)***	Intell-ectual prop-erty	Prop-erty + contr-act	Prop-erty + intell-ectual prop-erty + contr-act + stand-ards	Intell-ectual prop-erty + stand-ards	Prop-erty + intell-ectual prop-erty + contr-act	Rules + enforc ement	Prop-erty + intell-ectual prop-erty + contr-act + stand-ards	(Hier-archi-cal goal port-folios)

A	B	C	D1	not-D2	E	F	G	H	I	J	**{O}**
&	&	&	&	&	&	&	&	&	&	↔	

7.4 Grammars with Money Partitions

As described in previous sections on the production of lifestyles and the production of incomes, production rule combinations also generate equivalence relations, i.e. partitions, on money sets. The implementation of lifestyle production rules generates an expenditure

partition on personal income. Sales of products and services by enterprise accumulate (sum) as revenue partitions conceived in an input-output framework. Enterprise revenues are partitioned by hierarchy, tournament or market production rules into income shares.

This is an extension of the grammar arising from the nature of money as a partitionable set, in a Cartesian product with the set of identifiers of individuals and enterprises, $\mathbf{I \times \Pi \rightarrow \{i, \pi\}}$ or in string form, $\mathbf{i\pi}$, for $\mathbf{i \in I, \pi \in P(\Pi)}$[31]

To the summary of the grammar previously presented will now add a further subset: $\mathbf{G^* \subset J^*}$ (highlighted below). $\mathbf{G^*}$ will be a proper subset because the nature of money imposes a partition:

> (a) a subset $\mathbf{M^* \subset N^*}$ of the physically possible (e.g. same thing not in two places at the same time);
>
> (b) a subset $\mathbf{L^* \subset M^*}$ which are correct in form because they express instrumental economies;
>
> (c) a further subset $\mathbf{K^* \subset L^*}$ which are correct in form because they comply with institutional arrangements;
>
> (d) a further subset $\mathbf{J^* \subset K^*}$ which conform as product presentations to lifestyle production rules;
>
> (e) a final proper subset $\mathbf{G^* \subset J^*}$ which includes money partitions generated by conflict resolution production rules.

$\mathbf{G^*}$ also records the matching of varieties of 'supply' and 'demand'. The difference between the sets $\mathbf{G^*}$ and $\mathbf{J^*}$ is the set of excluded transactions.

Intuitively, from the very large set of possible outcomes and combinations of outcomes and transaction sets, instrumental economy, institutional, lifestyle and conflict resolving production rules generate a much smaller subset. This large-scale process of matching by means of variety amplification and attenuation requires information processing which is distributed among large numbers of human participants. This means communication, i.e. that economic information can be transmitted from one individual to another for further processing and onward transmission. The components are psychological 'chunks'; the processes are logical production rules; and the outcomes are subsets of the larger set of possibilities. All can be encoded and decoded between symbols and 'reality'.

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[31] $\mathbf{P(\Pi)}$ is the power set (set of all subsets) of Π. See section 1, Base Sets.

8. Partitions, Vectors and Matrices

8.1 Equivalence Relations (Partitions) as the Central Economic Process

Partitions are the pervasive and characteristic feature of an economy:

1. *real partitions*, whether of scarce human attention, skills, time, space, physical state opportunity sets, or actual behaviours; and
2. *money partitions*, incomes, prices as a fractional subset of income, prices as having a notional partitional infrastructure of the direct and indirect costs which compose it, revenues as enterprise shares, etc.

8.2 Partitions and Input-Output

Since a partition is a fundamental economic phenomenon, if an activity does not change or maintain equivalence relations, i.e. partition, on a on a finite set, it is not of economic consequence.

It is the genius of input-output analysis to present systems of intersecting partitions as a central analytical framework.

The composition of an input-output table can be understood as intersecting equivalence relations based on configurations of instrumental economy production rules. This has the logical implication that input-output tables could be constructed based on any other logically coherent set of production rules which generate equivalence relations, including psychological production rules. For example, input-output tables could be organized by lifestyle production rule sets classified by top-level goals as specified by evolutionary psychology; or tournaments vs. markets reflecting, in part, different psychological principles. More generally, the input-output framework can in principle be used to demonstrate the impact of projecting alternative production rule sets into an economy. Input-output can thus be seen as a central analytical framework in both micro- and macro-economic analysis.

8.3 Input-Output and Cognitive Infrastructure

The cognitive infrastructure of input-output matrices developed in this working paper may be highlighted as follows:

1. There is an overall framework of exchange relationships defined by a matrix in which, notionally, all enterprises plus all individuals are listed both horizontally and vertically. “Enterprises” and “individuals” are conceived as index sets, that is, as a set of unique identifiers for each element of the two sets, respectively.

Table 8.3.1. Notional Exchange Framework

	e_1	e_2	e_3	e_4	e_5	…	i_1	i_2	i_3	i_4	i_5	i_6	i_7	…
e_1														
e_2														
e_3														
e_4														
e_5														
…														
i_1														
i_2														
i_3														
i_4														
i_5														
i_6														
i_7														
…														

2. There is a combinatorial grammatical structure of production rules – instrumental economies and incomes, lifestyle production rules and expenditures, and institutional arrangements.
3. Different grammatical combinations of these production rules are implied horizontally – "production" – and vertically – "distribution".
4. The relationships among enterprises expressed in currency or in physical quantities are similar to those in a classic Leontief-type input-output framework – the structure of the cell includes input-output relations among enterprises.
5. Further,
    a. Enterprises and individuals in columns (horizontal identification row) are purchasers, converting currency into services or goods.
    b. Enterprises in columns purchasing from individuals in rows are distributing incomes. As this is an input-output framework, individuals' incomes are derived from direct and indirect 'value' added across all enterprises that purchase goods or services in which their services are embodied. It is assumed that, in principle, indirect purchases are in proportion to the cost structure of the enterprises from which the purchased goods/services are obtained.
    c. Individuals in columns purchasing from enterprises in rows are consumers making consumer purchases. Again, by implication of the input-output framework, these are both direct and indirect.
    d. The production rule grammars for enterprises purchasing services from individuals are different from the grammars for individuals making (direct and indirect) consumer purchases from enterprises. This is in contrast to the neoclassical paradigm, in which price or cost is the determining factor in both cases.
    e. This draws attention to the "forward cognition" role of enterprises, in anticipating with production decisions in advance of consumer purchasing decisions.

   f. Both monetary losses and monetary gains can occur in the system, and must be accounted for as negative and positive incomes.
6. A complete row and a complete column each define a partition. There are in fact several sets of partitions and of subpartitions: the partitions
   a. (1) among enterprises;
   b. (2) among individuals;
   c. (3) between enterprises and individuals, and
   d. (4) between individuals and enterprises;
   e. (5) the subpartitions within each enterprise, and
   f. (6) the subpartitions by each individual, converting incomes into the acquisition of goods and services (with allocations to savings – deferral to a future period).
7. There are, grammatically speaking, four distinct quadrants:
   a. $\{e\}\ X\ \{e\}$ (enterprises and enterprises)
   b. $\{e\}\ X\ \{i\}$ (enterprises and individuals)
   c. $\{i\}\ X\ \{e\}$ (individuals and enterprises)
   d. $\{i\}\ X\ \{i\}$ (individuals and individuals – a derivative – see below.

8. There is also an analytical progression when enterprises make direct purchases and direct sales. They are engaged in two processes of *indirection*.
   a. When they purchase goods and services, they are implicitly acquiring indirectly a package of services embodied in their direct purchases. This would include the educational services and experience-based learning which specific human capital embodies (cf. Stahmer, 1999).
   b. When they sell goods and services to other enterprises they are distributing (and redistributing) human services both directly and indirectly.

Enterprises are thus, by means of physical and institutional (cognitive control) transformations, economic intermediaries. They should be seen as such, not merely as instrumental technological production functions, or as a nexus of contracts, or as "private" enterprise. They may be most successfully captured analytically as sets of production rules reflecting context-specific interdependencies.

8.4 Implicit Exchange Among Individuals

An important analytical product is the implicit direct and indirect matrix of exchange coefficients between individuals, the relative cost of one hour of each person's time to each other person, in which enterprises (hierarchies) as well as markets (and tournaments) play the role of intermediary (the diagonal, coefficient 1, represents self-production):

Table 8.3.2. Notional Matrix of Personal Time Exchange Coefficients

	i_1	i_2	i_3	…	…	…	…	…	i_n
i_1	1	c_{21}	c_{31}	…	…				c_{n1}
i_2	c_{12}	1	c_{32}	…					c_{n2}
i_3	c_{13}	c_{23}	1	…					c_{n3}
…	…	…	…	1					…
…					1				…
…						1			…
…							1		…
…								1	…
i_n	c_{1n}	c_{2n}	c_{3n}	…	…	…	…	…	1

The effect of income distributions can be seen in such an exchange matrix. It implicitly defines hour-for-hour terms of trade between individual producers. For example, for individuals whose annual wages in some standard currency unit are

i_1	100,000
i_2	40,000
i_3	20,000
..	...
..	...
i_n	1,000

the implicit exchange ratio matrix is :

	i_1	i_2	i_3	.	.	.	.	i_n
i_1	1.0	0.4	0.2	.	.	.	.	0.01
i_2	2.5	1.0	0.5	.	.	.	.	0.025
i_3	5.0	2.0	1.0	.	.	.	.	0.05
.	.	.	.	.	.	.	.	
.	.	.	.	.	.	.	.	
.	.	.	.	.	.	.	.	
i_n	100	40	20	.	.	.	.	1.0

In words, i_1 needs to work 1/100th of an hour to buy an hour of i_n‘s time; while i_n must work 100 hours to buy an hour of i_1‘s time.

Imagine a product 100,000 units of which are produced by these labor inputs - say with management (i_1 - 1 unit), design (i_2 - 1 unit), component manufacturing (i_3 - 5 units) and final assembly (i_n - 1000 units), each in different countries. The average production cost of a unit is then 3.40 currency units.

Management	100,000	1
Design	40,000	1
Component management	100,000	5
Final assembly	100,000	1000
Total	340,000	1007
Per unit @ 100,000 units	3.40	

To purchase this unit would cost

	Fraction of Income	Units of Working Time
i_1	3.4/100,000	0.034
i_2	3.4/40,000	0.085
i_3	3.4/20,000	0.17
i_n	3.4/1000	3.4

Using a money numéraire is a simplified way to summarize a more complicated underlying process. Individuals allocate time between behaviors to be exchanged, and other behaviors (e.g. sleep or leisure). Those to be exchanged are 'embodied' in goods and services, and exchanged for money, which is exchanged for goods and services made by others.[32] A multidimensional matrix would show what behaviors each individual is implicitly exchanging, directly and indirectly, with each of multiples of others, and at what exchange rates.

8.5 Input-Output Matrices as Production Rule Terms

An input-output table as a mathematical unit can itself be a term in a production rule, as

$$[M]_{t0} \rightarrow [M]_{t1}$$

which expresses reconfiguration of the infrastructure of the table from one period to the next, e.g. as a result of skills production in the educational sector and on –the-job experience.

One could thus use input-output production rule systems to chart or simulate the infrastructure of 'development': of instrumental economy systems, of institutional arrangements; and to discover or demonstrate feasible paths of economic progress. Of course, this will include deletions and substitutions, and not merely addition of products (e.g. which become obsolete), enterprises (e.g. which fail) or jobs (which become redundant). Economic change has many dimensions.

[32] Barter can be accommodated in the conventional way based on the ratio of exchange of the products.

III SOME IMPLICATIONS OF THE MODEL

An input-output table can be imagined as a projection screen for the human information processing infrastructure which underpins it. However, is more like a pixel-generated cell-by-cell projection than a geometric projection.

This section looks at 5 main implications of the model:

1. The Roles of Production Rules and Partitions

2. Economics as Learned Patterns of Behaviour and Information Processing

3. Enterprises vs. Markets as Determinants of the Structure of Economic Activity

4. Methodological Interdependence vs. Methodological Individualism.

5. Operationalization of the Model.

1. The Roles of Production Rules and Partitions

The model specifies a logical infrastructure of information processing and decision-making underlying input-output tables. The central concept is that an economy is a system of partitions generated by sets of logical formulas called production rules. There are 3 main classes of production rules. All production rules must be learned before they can be used.

1. Lifestyle production rules, which specify how goods and services may be acquired to advance personal goals. Different combinations define different personal lifestyles.

2. Instrumental economy production rules, which specify how goods and services are produced and presented in the marketplace. Each instrumental economy imparts some standard feature, combinations of which define products and their presentation.

3. Institutional production rules, which specify relations of exclusion (property), authority/hierarchy, exchange (contract) and conflict resolution (matching varieties of ‘supply’ and ‘demand’ through amplification or attenuation).

In money terms an economy can be specified as follows:

1. Sets of production rules define discrete partitions of income and of personal expenditure.

2. Across all individuals, expenditures accumulate to partitions of revenues among enterprises.

3. Enterprise revenues are in turn partitioned into incomes to implement production.

4. For analytical purposes, prices are understood as recorded fractional partitions of these incomes, i.e. attributable direct and indirect input costs. There are proportions for individual wages, carried interests such as a royalties, and residual interests, i.e. profit or loss to shareholders.

5. An input-output table is the set of intersections of input partitions and output partitions of industries (enterprises at the micro level) and households (individuals at the micro level).

6. Thus, sets of production rules which define money partitions underlie each cell in an input-output matrix.

In ‘real’ terms:

1. Individuals (consumers) are specified as learned lifestyle production rule sets which recognize the contribution of products and their presentations to evolution-based personal goals.

2. Product-by-product lifestyle production rules are ‘mentally modelled’ by producers as the basis for production. The objective is to produce an output (logical consequent) which will be a logical antecedent (input) in a consumer lifestyle production rule set.

3. Enterprise management decides how these mental model production rule sets will be implemented by configuring instrumental economies such as capital equipment, acquired inputs, skill specialization, and coding, and their associated income streams. Instrumental economies produce more, or the same with less.

4. A product or service presentation (which includes its marketing) is a combinatorial expression (ordered subset, or string) of various instrumental economies.

5. Since industries can also be represented by the corresponding sets of instrumental economy combinatorial strings, the production rule systems of both individuals and enterprises can be located as rows and columns in input-output matrices.

6. Input-output matrices may be presented in linked money, time and physical units (Stahmer, 1999). Exchange ratios between pairs have analytical importance (e.g. time/money exchange ratios, money-physical units in relation

to consumption of non-renewable resources or generation of pollution externalities).

7. Learned institutional arrangements are essential to producing, communicating and transacting. The system is knitted together by both systemic and sector-specific institutional arrangements.

The model is different from neoclassical analysis in several respects. Its starting point is a range of findings from empirical psychology. As a result, it treats personal 'utility' as a discrete logical relation, a sub-goal to a goal, rather than a monotonic cognitive measurement scale, which empirical psychology demonstrates is inconsistent with the way the human mind works (e.g. Kahneman, 2003). It also treats money not as a cardinal scale but as a partionable set, in which discrete subsets or shares rather than continuous quantities are the relevant variable.

Furthermore, all economic results depend on joint outcomes, both directly (roles of shared learning, communications, instrumental economies and institutional arrangements) and indirectly through input-output linkages. By always being rooted in partitions, i.e. allocations, the model is faithful to the essence of 'economizing'.

2. Economics as Learned Patterns of Behaviour and Information Processing

It is a truism that the only way humans can affect what happens in the world around them is by means of their own action (or inaction). Physical states of the environment – 'resources' - have meaning only in relation to the human effort required to change or maintain them in some respect, identifying them, moving them or leaving them alone. The traditional land, labour and capital of classical economics, are reduceable to one thing: surrogates for patterns of human effort, past or present, to secure actual or possible future results. It takes different behaviours (and more effort) to cultivate poor land, directly or indirectly (e.g. with fertilizer made by others), and it takes less effort to recover accessible natural resources, or to operate an ergonomically designed machine.

Moreover, all behaviours are learned behaviours, usually over a considerable period of time. This applies to skills, including repetition-based skills such as specialization, and configuration skills such as design and management. It applies to the learning and composing of lifestyle production rule sets – how to try to advance one's personal goals through the purchase of goods and services. And it applies to learning the 'grammars' of the institutional systems which add cognitive and behavioural structure to allow the system to work: property, contract, human rights, authority, markets, tournaments and hierarchies.

Learned institutional arrangements are associated with two special properties apparently unique to the social sciences: *arranged predictability* and *partial dedication*.

2.1 Arranged Predictability

Arranged predictability is the central purpose of institutions like property, tort (delict), human rights, contract and insurance. It contrives predictability where it would not otherwise exist. For example, property regimes, and the various environmental cues which distinguish their various classes (e.g. homes from public roads from private retail establishments) configure our behaviour in relation to space. They make it largely predictable, e.g. that people will go from one place to another by road or path rather than across my property. Of course, different cultures may have different systems of property (e.g. Banner, 1999); but these are all systems of arranged predictabilities. Arranged predictability is a central feature of social science and one which distinguishes it from investigation in the physical and life sciences, where predictabilities are discovered rather than arranged.

Such institutional arrangements are both instrumental and conflict resolving. They permit transactions to occur. They resolve conflicts over both cognitive control and the physical environment. Property rights, for example, resolves potential conflicts over the control and use of space, while also providing a precondition to exchange of value for value.

2.2 Partial Dedication

The principle of *partial dedication* addresses the role of humans as 'parts' of an economic whole – except that they are not wholly dedicated to any one organization or part of the economic system. Most human beings play many institutional roles and participate in many institutional systems in the economy – in their work, in personal transportation, in their families, in volunteer organizations, in the educational system, in amateur sports … In each case they are partially dedicated. What this means is that each sector and each role is governed by its own set of production rules, which are learned as a basis of participation. While there may be some overlaps – one might drive in connection with one's work, or use transferable social skills in several activities - the *set* of production rules for each sector is distinctive in its particular combination of elements. It is the set of individual behaviours which is the 'part' of the organizational or institutional system rather than the 'whole' human being.

The model can also explicitly account for 'learning' in the institutional roles and systems, including substitution of production rules, deletion of production rules, and addition of production rules. These can range from the individual (e.g. people starting to wear seat belts in cars) to enterprise (introduction of a new process technology) to multi-sectoral production rule change (e.g. consequent on the introduction of cell phones or just-in-time inventory systems).

2.3 Cognitive Asymmetries in Production and Consumption

A further implication of the model of the economy as learned behaviour systems is *cognitive asymmetry* between the production side and the consumption side. In Kahneman (2003) terminology, the production side is, in general, applying System 2

ratiocination while the consumption side is, in general, applying System 1 intuition, which incorporates more biases and errors against calculated self-interest. This is not, or not merely, an information asymmetry in the neoclassical sense, although it includes that. There is an imbalance, roughly that between full-time professionals and part-time amateurs in information processing and decision-making.

Suppliers, in contrast to consumers,

1. are computationally and hierarchically specialized (Rasmussen, 1986; Moray, 1997, 1999);

2. have goals, including business survival, which can be often expressed and implemented in carefully calibrated terms;

3. are frequently, if not systematically, able to influence consumer preferences by the presentation of information, sensation and choice environments (e.g. contributions to *Psychology and Marketing*; Simonson & Tverksy 1992);

4. have the advantage of making decisions on the basis of statistical distributions rather than individual or occasional occurrences;

5. within constraints imposed by individual lifestyle production rules, the behaviour of competing enterprises, and external input markets, are able to hierarchically configure instrumental economies and associated income partitions.

3. Enterprises vs. Markets as Determinants of the Structure of Economic Activity

It is an implication of the model that the principal vital organs of an economy are enterprises in an environment of markets rather than markets. It is in enterprises rather than markets where key information processing occurs – construction of mental models, selection and configuration of instrumental economies, the substantial determination of incomes.

Most important, only enterprises can amplify variety matching, by means of the introduction, implementation or extension of instrumental economies. Markets and tournaments can only attenuate variety on one side or other of the matching process. The process of generating matching failures is an important one for the adaptation of the system. However, it is generating a feedback signal; it is not the primary process.

Input-output captures the central performance and analytical role of industries and enterprises (aggregated, industries) rather than markets. This includes the introduction of new enterprises (expansion of existing industries) or new products (which may become new industries, i.e. new rows and columns); and the removal of ‘old’ ones.

There is perhaps an illustrative contrast with genetics and natural selection. Genetics, as the etymological root implies, is generative. Natural selection is eliminative: it attenuates some possibilities while permitting others to survive and prosper. In economic systems, it is enterprises as groups of human beings which are generative, and markets and tournaments which are selective.

However, enterprise systems, like the human species, do not take the environment in which they function as unalterable. In fact, they take steps to actively shape it.

The mechanism by which enterprises do this is expressions in the grammar of instrumental economies, i.e. combinations of such expressions which, as imparted features, are recognized by individual lifestyle production sets. These expressions can be 'physical' –such as the design of products or the furnishing of retail facilities and displays; or they can be primarily communicative – such as advertising and packaging. The structuring of the environment is strongly oriented to capturing people's attention. Indeed, human attention is perhaps the most important scarce resource in the economic system. When attention is captured, it can be mobilized to attempt to teach lifestyle production rules favourable to selling enterprises; or to provide an immediate, and favourable, decision-making frame.

Enterprises do not, however, universally amplify variety, i.e. instrumental economies. The will often use their 'power' to attenuate, for example to implement tournaments in internal labour markets; or to configure external environments to attenuate choice, e.g. by compatibility requirements, or to take advantage of short term intuitive natural assessments which drive individual decision-making, e.g. framing of default choices.

'Markets' may or may not provide corrective feedback signals. Where there are excluded varieties which lend themselves to matching with configurations of instrumental economies by other enterprises, they may well. Henry Ford's classic attenuation assertion that you could have any colour of Ford you liked as long as it was black is a famous example which greatly benefited his competitors. However, goods with important complements (e.g. print cartridges for printers) or network effects (personal computer operating systems and software) may not be effectively corrected by 'free markets', i.e. entry or actions of others.

4. Methodological Interdependence vs. Methodological Individualism

4.1 Smith and Locke: Individualism vs. Interdependence

The model suggests that certain intellectual legacies of, respectively, Adam Smith and John Locke should be reconsidered.

Smith (1776) said that production of goods and services depends on self-interest rather than goodwill. This is not so much false, as a false dichotomy. The key element is not motivation but organization – institutions, enterprises, instrumental economies. Applied

human motivation is in plentiful supply. It is more a case of channeling and organizing varied motivations than eliciting them; patterns of human learning, communications and information processing are central to both the understanding and the operations of economic systems.

Ultimately an economy consists solely of people's behaviour as producers and consumers, the *organized* presence and absence of specific behaviour sets. Instrumental economies – getting more through coordinated action – are the basis for exchange to achieve outcomes which one cannot achieve alone. Coordinated action, instrumentally and institutionally, implies interdependence. This means that Locke's (1690) assertion that we should each own the fruits of our own labour is unachievable. Virtually all outcomes are joint in a specialized economy.

Institutions like property and contract will not work unless they are widely – almost universally – learned and applied. Shared cognitive and behavioural interdependence is at the core of these and other basic social institutions.

The interdependence character of instrumental economies is somewhat different. In a specialized economy, everyone is doing something different. Indeed, in industrialized societies we have abandoned the ability to self-provide even basic necessities such as food and clean water. We believe instead that all we require, and all we might want, will be readily accessible through exchange. Not only that, we are accustomed to a standard of living which depends

1. on a production system which can only function by means of the direct and indirect specialization of outputs of many, many people;

2. on a human skills production system which involves many others in delivering education, training and on-the-job experience; and

3. on the extensive use of repetition economies, i.e. in which many others have a similar consumption stake (antecedent term in lifestyle production rule).

This *methodological interdependence* is in contrast to *methodological individualism*: it is the *organization of interdependence* expressed as production rules – lifestyle production rules, instrumental economies, and institutional arrangements – which determines economic performance; rather than the projection and reconciliation of rational self-interest and profit maximization. The former is, in any case, a cognitive impossibility.

4.2 Efficiency, Equity and Choice

How, then, is economic performance expressed and appraised, e.g. in terms of 'efficency' or 'equity'?

An economy can be looked at in the aggregate, or in terms of delivery of patterns of results at the local level, such as households or individuals. The model presented can, in

principle, display both simultaneously: there is no disconnect between micro- and macro-analytical levels.

Arising from the structure of the model, the objective of an economy can be specified as the *production and presentation of choice*. This implies the systematic local delivery of choice, or the failure to deliver such choice. For any system of instrumental economies, the level of its achievement can be specified both psychologically (definition of frames), and economically (accessible choice sets by level of income). However, it is a discrete logical specification rather than an economic aggregate.

It is an implicit feature of the model that what is *not* chosen, or *not* available for choice, locally or systemically, can be as important as what is chosen or available. If something is not in the information system, it cannot be chosen

For example, unemployment of those unable to find reasonably satisfactory work occurs where the economic system ‘chooses’ not to employ them. This may be because there is more ‘flexibility’ in the shedding of obsolescent skills than in their replacement with new ones – because long lead times are required to provide the education and experience basis for specialized skills.

An ideal economy would tend toward maximum deployment of instrumental economies, particularly specialization. However, there would correspondingly be tendencies toward greater income equality as skill specialization increased and differences in bargaining power narrowed. If skill requirements were perfectly forecast, and the forecasts were implemented by the educational system and the job experience training system, and instrumental skill economies were maximized, all labour markets would be tight because the varieties (in the technical sense (Ashby, 1961) including quantities) of skills would perfectly match production needs to meet lifestyle production rule sets at those equipetal, (tending to equality) incomes.

This has important analytical as well as methodological implications. If an economy is specified with this objective and in this model, it is a property of efficiency in the production and distribution of choice that tendencies toward ‘equity’ (income equality) and efficiency are mutually reinforcing. This would overcome the main difficulties with the Pareto criterion: that it is indifferent to the distribution of incomes or endowments, and thus specifies that equity can only be achieved at the expense of efficiency; that it is based on psychologically disconfirmed assumptions; and that the organization of the economy it appraises is based on only a single institutional form, the bilateral contract.

In a specialized economy, not everyone can do each task – that is self-contradictory. However, in principle, a participant in a specialized economy ought to be able to convert through exchange her or his skills and effort into the skills and efforts of others, through the intermediation of money and the production of goods and services. In section 8, Partitions, Vectors and Matrices, a notional analytical table was presented: the relative cost of one hour of each person’s time to each other person, in which enterprises as well as markets play the role of intermediary. (Note that this requires input-output data in both

time and money units (Stahmer, 1999.) The results could be displayed as a matrix of coefficients in which the diagonal is self-production, i.e. the exchange ratio is 1 : 1.

Were the coefficients between individuals all 1, this would imply that each person could exchange an hour of her or his skills for an hour of embodied skills of each other person. At that 1:1 ratio, money is purely instrumental; it does not recalibrate different relative values of different skills. This is advanced as an analytical tendency of an economy, rather than an expected outcome.

Moreover, an ideal economy would tend toward maximum deployment of instrumental economies, i.e. maximum specialization, so that 'economic development' can be defined as an increasing density of instrumental economies in the organization of economic activity.

Of course, both the present model and the neoclassically based Pareto model may elicit philosophical preferences which cannot be resolved on a scientific basis. A tendency of an economy to income equality is not universally seen as a good thing – which is why, for example, tournaments with skewed reward structures are a common feature of many economic systems. Even in societies which proclaim 'equality', many seek status above (as distinguished from division of labour among) their fellow human beings. These philosophical differences are an important contrast between methodological interdependence and methodological individualism.

5. Operationalization of the Model

This paper outlines the model and the tools and methods proposed for this analytical framework. Implementation of the model will require computer programming.

Given today's computing power, the demands or parsimony are considerably attenuated. So, for example, it is possible to calculate, or simulate the impacts on input-output relations of changes in the underlying production rules, or their grammars (e.g. markets as opposed to hierarchies as opposed to tournaments).

Thus, there is a broad range of potential predictive power, for example, in terms of the direct and indirect impacts of grammatical changes, efficient or inefficient processing of economic information, and many other aspects, which can be empirically tested.

The ACT-R model of cognition is enabled in LISP (Anderson & Lebiere, 1998; http://act-r.psy.cmu.edu/.) This suggests itself as a starting point for level 2 of the methodology, i.e. production rule systems, including goal stacks. The results in terms of production of equivalence relations can then be translated as partitions into input-output frameworks. Consideration is also being given to implementing the model on a less expensive platform, e.g. Mathematica.

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