Sim-I-Space: An Agent-Based Modeling Approach To Knowledge Management Processes

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Acknowledgement: The authors would like to thank Wharton-SMU Research Center of Singapore Management University for their financial support in carrying out this research

Introduction

In this paper we offer a verbal description of the Sim-I-Space simulation model. The model is designed to operationalise some of the main features of the Information Space or I-Space (Boisot, 1995, 1998).

The paper is structured into two main parts as follows. In the first part we look at the overall architecture of Sim-I-Space that brings together three components: 1) agents, 2) knowledge assets, 3) agent interactions. In the second part we examine in more detail each of the model components. There are two appendices. In appendix 1 we describe the variables used in the model and identify the input parameters used in the model. In Appendix 2 we provide a more detailed specification of the model, with illustrative examples.

1.Model Architecture

Sim-I-Space is a multi-agent simulation characterized by mixture of competition and collaboration. Although built in part on a Swarm platform, in the limited number of time periods it runs, and given that agents make their decisions at random – i.e., they do not learn - it only exhibits limited elements of evolutionary behavior. Survival is the aim of individual agents in the simulation. The rents that agents earn provide them with the means to survive. If agents run out of money they are 'cropped'. They can quit while they are still ahead. The overall value of a given simulation run is the sum of the rents earned by all agents during the run. The social welfare generated by the simulation is sum total of all knowledge created in the course of the simulation and then diffused out to 'society'. Note that 'society' is located outside the simulation. The price paid by 'society' for this social welfare is the cumulative rent earned by the agents inside the simulation – ie, the price paid by 'society' turns out to be the value of the simulation.

How does Sim-I-Space implement and embody the concepts of the I-Space? The I-Space is a conceptual framework for analyzing the nature of information flows between agents as a function of how far such flows have been structured through processes of codification and abstraction. Such flows, over time, give rise to the creation and exchange of knowledge assets. Where given types of exchange are recurrent, they will form transactional patterns that can be institutionalized. In Sim-I-Space, we focus on the creation and exchange of knowledge assets alone without concerning ourselves with the phenomenon of recurrence and institutionalization. In later versions of the model, recurrence will become our central concern.

Sim-I-Space is populated with agents that carry knowledge assets in their heads. Each of these knowledge assets has a location in the I-Space that changes over time as a function of diffusion and obsolescence processes as well as of what agents decide to do with them. These have the possibility of exchanging their knowledge assets in whole or in part with other agents through different types of dealing arrangements.

Natural selection is at work in Sim-I-Space at two levels. At one level, agents survive by learning to make good use of their knowledge assets. They can make use of these assets directly to earn rents, or they can make indirect use of these assets by entering into trades with other agents who will then use them directly. Agents that fail to make good direct or indirect use of such assets in a timely fashion fail to earn the minimum rent required to survive and are selected out of the simulation – i.e., they are "cropped". At another level, knowledge assets, in turn, and somewhat like Dawkins' "memes' (Dawkins, 1982), survive by inhabiting the heads of many agents. If they fail to occupy at least one agent's head, they die out and the knowledge associated with the asset disappears from the simulation as a resource.

Existing agents have the option of quitting the simulation while they are ahead and before they are cropped. Conversely, new agents can be drawn into the simulation if the environment becomes sufficiently rich in opportunities for earning rents.

The rate of entry and exit of new agents into the simulation are based on the difference in mean rents between between two periods. The rate of entry and exit is a parameter that is set at the beginning of the simulation for every % change in mean rents. Change in the entry and exit rates is a function of % change in mean rents. In this way one can control the level of market turbulence – of creative destruction, if you will – that is generated by the performance of existing players.

We start by discussing the agents and then turn to a discussion of the nature of their knowledge assets. This is followed by a brief discussion of agent interactions.

1.1 Agents:

Sim-I-Space operates through a number of agents that, taken together, make up the diffusion dimension of the I-Space. In the model as developed, agents are intended to represent organizations – firms or other types of information-driven organizations – within an industrial sector. It would be quite feasible, however, with suitable parameter settings, to have the agents represent individual employees within a single firm and hence to simulate the behavior of individual organizations. It would also be possible to have an individual agent representing the behavior of a strategic business unit within a single firm. Conversely, one could run Sim-I-Space above the firm level and simulate knowledge flows within a population of industries.

As we have already seen, agents can enter or exit Sim-I-Space according to circumstances and can also be cropped from the simulation if their performance falls below a certain threshold. Agent entry and exit is an important source of variation within the simulation. Clearly, the population that is located along the diffusion dimension of the I-Space will vary in size at different moments in the simulation.

Agents aim to survive within the simulation and to maximize their wealth over the periods of the simulation. Wealth here is taken to be the sum of rent streams and of rent-generating knowledge assets. The first accumulate in a financial fund that is used to cover the expenses incurred in meeting and transacting with other agents. The second accumulates in an experience fund that is used to finance the creation of new knowledge assets by moving existing ones in the I-Space. In sum, agents modify their wealth either by trading in knowledge assets they possess with other agents thereby enlarging or shrinking their asset base, or by creating new knowledge assets. They do this by moving around the I-Space in a learning process and by adding and then linking new knowledge assets to their existing stock

(Boisot, 1998). In this way they enhance their rent-generating potential. The details of how this is done are given under the heading of 'agent interaction'.

From the financial and experience funds, agents draw meetings and knowledge-investment budgets. Money that is not spent in a given period gets put back into the relevant fund where it accumulates. An agent's financial funds correspond to its tangible assets whereas its experience funds correspond to its non-fungible intangible assets. Each fund, or both, can be switched off with a toggle. The program can thus be made to behave in a modular fashion with agents surviving either through trading and collaboration with other agents alone, or through knowledge creation alone. An agent's preference for using one type of fund or for another – i.e., for trading in existing knowledge or for investing in knowledge creation - is set at the beginning of the simulation for all agents.

1.2 Knowledge Assets:

In Sim-I-Space, knowledge assets are represented in network form. A knowledge network consists of a collection of elements and of relations between elements. We shall refer to the elements of the network as *nodes* and to the relations between elements as *links*. Nodes and links can be combined with certain probabilities[1] called *linkage probabilities*. A knowledge asset, then, can either be a node, a link between two nodes, or a set of interlinked nodes that can vary in size and complexity. Each node and each link varies in how far it has been codified, made abstract, or has been diffused to other agents. Thus each node and link has a unique location in the I-Space that determines its value to the agent and hence it's rents-generating potential. The more codified and abstract a knowledge asset in the I-Space, the greater its utility and hence the greater its value. Also, the less diffused a knowledge asset in the I-Space, the scarcer it is and hence, again, the greater its value. Different locations in the I-Space thus offer different rental potential to agents. These can be calibrated to reflect a variety of industry conditions – rates of knowledge obsolescence, tendencies to spillovers, etc. Agents can enhance the value of their knowledge assets – and hence their rents-generating potential – in two ways: 1) by investments in the Social Learning Cycle (SLC)

[1] Since in Sim-I-Space we do not specify the contents of nodes or links, we do not face the problem of establishing the *coherence* of networks created in this way. Future developments of the model will address this issue.

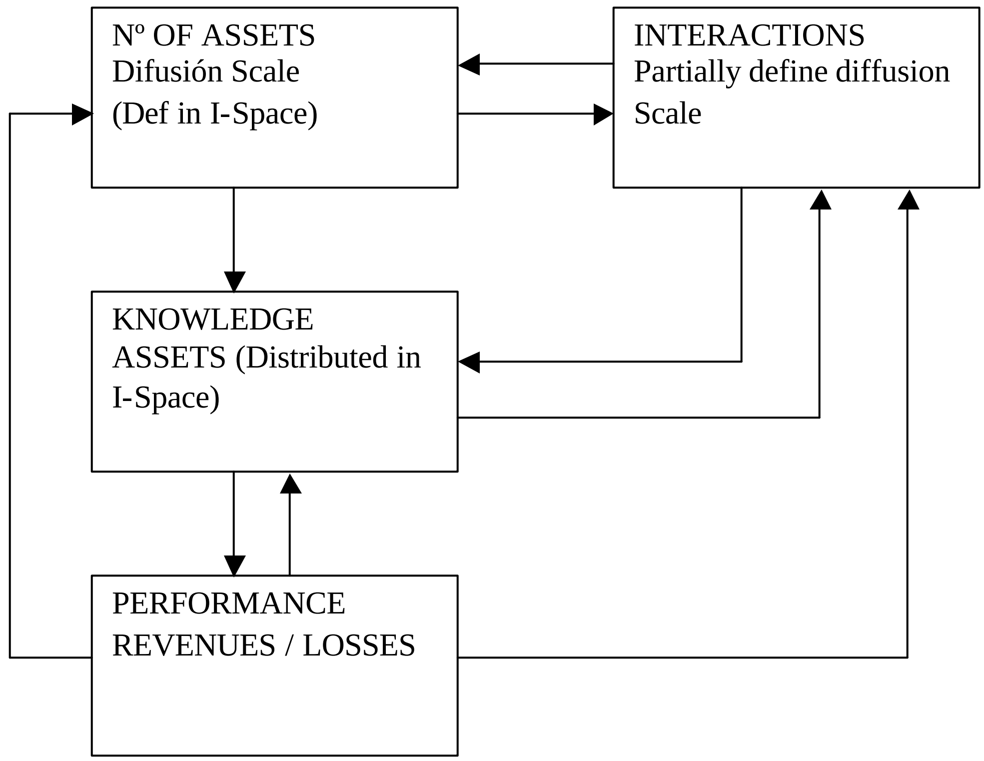

Figure 1: Sim I-Space

that offer the possibility of changing the location of knowledge assets in the I-Space; 2) by combining nodes and links into networks that can be *nested* and in this way building up more complex knowledge assets.

1.3 Agent Interactions:

Agents meet each other throughout the simulation. The frequency of encounters can be varied. They can ignore each other or they can attempt to engage in different types of transactions. In the second case, they need to be able to inspect each other's knowledge assets in order to establish whether a transaction is worth pursuing. Having established that it is, they can either: 1) engage in straight buying as selling of knowledge assets; 2) license other agents to use their knowledge assets; 3) enter into a joint-venture with another agent by creating a new agent that is jointly owned; 4) acquire another agent and convert it into a wholly-owned subsidiary; 5) merge with another agent, thus reducing the number of agents in the simulation.

The way that the simulation model maps onto the I-Space architecture is indicated by the flowchart of Figure 1. Having described the general architecture of Sim-I-Space, we now examine each of its components in more detail.

2.Model Components

In this section, we briefly describe the components of Sim-I-Space's architecture and show how I-Space elements and relationships are expressed in the model. We shall use the same basic headings to describe the components as we did to describe the model's overall architecture, namely, agent characteristics, agent knowledge, and agent interactions.

2.1 The Components of Agent Characteristics

Agent ID: a unique ID that is allocated sequentially identifies Agents in the model. No two Agents will have the same ID - Agent 0 is the first Agent created, Agent 1 is the second, and so on.

The Financial Fund and the Experience Fund: Agents possess resources that are used to cover their operating expenses. These resources are of two kinds: financial and experiential. Agents manage their resources by allocating rents to either a Financial or to an Experience fund, and by setting Financial and Experience Budgets. Speaking loosely, financial funds correspond to tangible assets such as cash in the real world whereas experience funds correspond to intangible assets such as know how. In effect, in the model, financial funds covers the costs of overt behaviors involving interactions between agents, whereas experience funds covers the costs of implicit agent behaviors associated with activities such as thinking and learning. Although in the real world overt and implicit behaviors are intimately intertwined, we can associate the first type of behavior with *operations* and the second with *development*. Specifically:

- *Financial Funds and Financial Budget*: Financial Funds correspond to tangible resources, such as cash, that are used to meet operating expenses, including the cost of meeting other Agents, trading for Assets, and paying out dividends. The Financial Budget is set by the Agent for each period to limit the amount of the Financial Funds that the Agent intends to expend each period.

- *Experience Funds and Experience Budget*: Experience Funds correspond to intangible resources, such as the experience gained from learning-by-doing, that are used to manipulate Assets – to increase/decrease their degree of Abstraction or Codification, or to combine Assets to create new Assets. The Experience Budget is set by the Agent to limit the amount of the Experience Funds that the Agent intends to expend each period.

Although Agents can survive without Experience Funds, they must not run out of financial funds otherwise they get cropped

Active, Passive and Trading Sets: Agents have a finite memory and because of this, storing knowledge carries a cost. Agents manage the scarce resource that is their memory either by holding knowledge assets in one of two sets, or by discarding them altogether. The two sets are:

- *The active set*: an Agent's active set contains all the knowledge assets that are being actively utilized by the agent and that are generating rents in the period.

- *The passive set*: an agent's passive set contains all the knowledge assets held by an Agent that are not being actively utilized by the agent or generating rents in the period. Maintaining knowledge assets in the passive set reduces the cost of carrying them yet keeps them available for direct use or for trading purposes in later periods – i.e., they are held for their option value.

When agents meet, not all of their knowledge assets will necessarily be available for trading. When two agents meet for the first time, for example, the transaction costs associated with inspecting each other's knowledge assets – presentation, examination, evaluation, etc - will limit the process to the most abstract and codified of these assets. This much we established in our earlier discussion of the I-Space in chapter 4. Over time and with recurrent meetings, the degree of familiarity between any two Agents may increase and as a result the cost of inspecting each other's knowledge assets will decrease. The agents will then be able to inspect each other's more concrete and less codified knowledge assets, thus increasing the number of assets available for trading.

- *The Trading Set*: a trading set is a set of knowledge assets that an agent makes available for transactions with other agents. An agent will have more than one trading set and will present different trading sets to the different agents it meets according to the degree of prior familiarity with them.

Clearly, the more one agent is familiar with another, the less codified and abstract will be the assets that it presents for inspection and hence the larger the trading set it will present. Also, and by implication, the longer the time that will be allocated to the interaction.

Agent Memory: Agent memory stores the frequency of the historical encounters with other Agents. Based on this memory, an agent "decides" whether or not to interact with a given agent, something that is reflected in the probability of interaction between the two agents.

2.2 The Components of Agent Knowledge

Asset ID and Type: knowledge assets ("Assets") are either *nodes* or *links*. A unique ID number that is allocated sequentially identifies each Asset, i.e. no two Assets (nodes or links) will have the same ID. The first Asset will have ID 0, the second Asset will have ID 1, and so on.

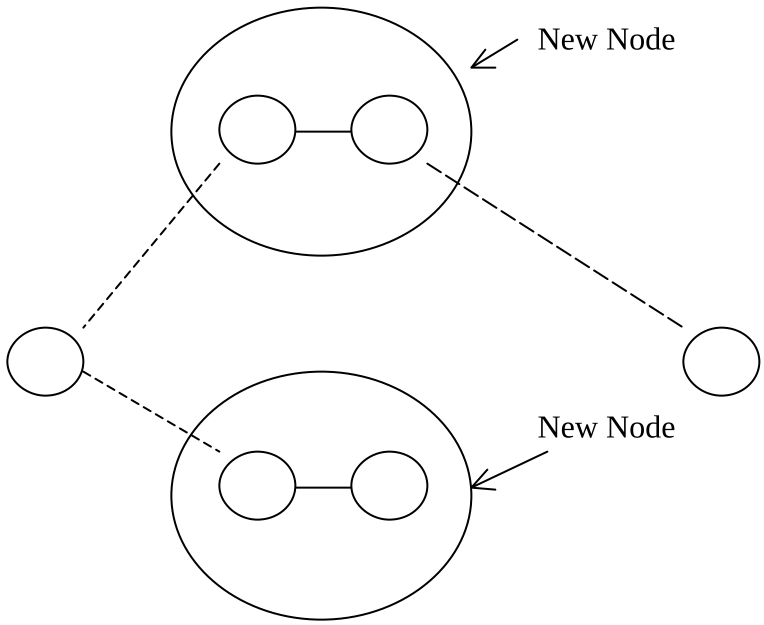

Figure 2: Nested Nodes

Abstraction and Codification: Knowledge assets vary in how far they are codified and abstract. In Sim-I-Space, each Asset is given a discrete value for Abstraction and Codification that begins at 2 (respectively representing concrete and uncodified Assets), and goes up to 10. Users have to decide for themselves what meaning to give to these different levels of codification and abstraction.

Diffusion: Diffusion measures the number of agents in Sim-I-Space who have access to a given knowledge asset. Reflecting different degrees of codification and abstraction, each knowledge asset – in line with what is claimed by the I-Space - varies in the extent to which it is diffused among the agents in the model. Diffusion ranges from 0 to 3. Users have to decide for themselves what percentage of a given Agent population corresponds to these different levels of diffusion. It must be borne in mind that the size of the Agent population will keep on varying throughout the simulation.

Complexity: We saw earlier that knowledge could be represented as a network of interlinked nodes. Such networks vary in complexity depending on the number of nodes and the density of links between them. When parts of the network are tightly integrated with each other, they will themselves be represented by a node (see Figure 2). Given the network that 'nests' in such a node, it becomes a complex entity. This complex node can in turn participate in a higher-level network that is also capable of getting nested. We can thus represent the complexity of any network by counting the degree of nesting that takes place within its nodes. Such complexity begins at 0 – i.e., no nesting takes place within the Assets - and has no upper limit – i.e., a potentially infinite amount of nesting is possible. In the simulation, Assets can only combine with Assets of equal levels of complexity, and if nesting takes place at that level, the resulting Asset is of one larger complexity. Users have to decide for themselves what meaning to give to these different levels of complexity.

Base Rental Potential: Knowledge assets earn rents that vary with their position in the I-Space. The more closely they are located to the region of maximum value in the space – where codification and abstraction are at a maximum and where diffusion is at a minimum– the higher the rents that they can earn. The Base Rental Potential reflects the fundamental relationship between rents and the three attributes of abstraction, codification and diffusion possessed by a given knowledge asset. Thus, each I-Space location in the I-Space is associated with a Base Rental Potential that is applied to all Assets residing in that location.

Rental Multiplier: Actual rental levels will be a function of what, specifically, is being simulated in Sim-I-Space. Bread baking, for example, does not generate the same volumes of rents as biotechnology; no matter how asymmetrically distributed the knowledge assets might be. The Base Rental Potential is thus subject to a rental multiplier that determines the difference between the Rental Potential of two Assets of equal degrees of Abstraction, Codification, and Diffusion but used in two different industries. The Rental Multiplier is the link between the Base Rental Potential - a function of where a given Asset is located in the I-Space - and the actual rents earned per unit time in a given type of simulation. The Rental Multiplier takes into account a variety of factors such as complexity (increasing dramatically as Complexity increases[2]), obsolescence (decreasing over time subject to the Obsolescence decay function described below), and the “jackpot effects” (extraordinary random increases in rents resulting from particular asset combinations). The rental multiplier applies to individual assets. It is a summary measure of how specific characteristics affect that asset’s rents.

The effect of diffusion on the rental value of the Asset is non-linear – the loss in value from one additional Agent coming into possession of the Asset varies greatly depending on whether there was originally only one agent who owned the Asset, or if there were 100 agents who owned the Asset. In the former case, there is a sharp loss in value, and in the latter case, there will be only a marginal loss in value. To reconcile this difference there are two relevant values of Diffusion: 1) Nominal Diffusion (a continuous variable that measures the actual number of Agents that own the Asset that has no upper bound), and 2) Model Diffusion, a discrete variable derived from Nominal Diffusion and that is used in the I-Space Model to calculate the Rents Multiplier of the Asset. Model diffusion has an upper bound that is specified in the model to give varying degrees of granularity. For example, in a situation where Model Diffusion takes on the values of 0~3, it might be determined as shown in Table 1 below:

Table 1 – Nominal Diffusion & Model Diffusion

Model Diffusion	**Nominal Diffusion (I.e. # of Agents that own the Asset)**
0	1 ~ 2
1	3 ~ 8
2	9 ~ 26
3	27 +

[2] By combining Assets, Agents create new Assets of higher Complexity (and Rents Multiplier). By doing so, Agents can reduce Carrying Costs, and usage of Agent memory (by replacing original Assets with the new combined Asset), while retaining some of the value of the original Assets as rental generators.

In the above example, it makes no difference in the Rents Multiplier whether 1 or 2 Agents own the Asset, but when a 3rd Agent owns the Asset, the Rents Multiplier suddenly decreases and then remains steady until the Asset diffuses to the 9th Agent, etc.

Carrying Costs: Maintaining Assets in a usable form imposes carrying costs on Agents. These are an exponential function both of the Assets' level of Complexity[3], as well as of their degree of codification and abstraction. The higher a given knowledge asset's degree of codification and abstraction, the lower the level of entropy associated with it and hence the lower its carrying cost. However, we do not need to represent this second component of carrying costs as it is already reflected in the base rents potential. The main function of carrying costs in the simulation is to affect the choice of what assets will be placed in the active and passive trading sets. Carrying costs will be higher in the active set than in the passive set.

Creating New Assets: New Assets are created either through *moves* in the I-Space – i.e., through increases in codification, abstraction, impacting or absorption - or through the probabilistic *combination* of existing nodes and links (see Linkage Probability Matrix below). In the first case, new knowledge assets are created through a process of differentiation; in the second, through a process of integration. In either case, the "parents" of a new Asset are the nodes and/or links from which this Asset was derived. The Assets that agents are initially endowed with at the beginning of a Smart Asset run have no "parents".

The processes of codification, abstraction, impacting and absorption – four of the six steps in the Social Learning Cycle - are those through which new knowledge assets are created in the I-Space. These are processes of *differentiation*. As the links between assets so created themselves increase in codification, so linked nodes can be nested and then collapsed into single nodes. These are processes of *integration*. We first discuss differentiation and then integration:

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[3] Increasing Complexity thus has two conflicting effects – increasing both the Rental Multiplier, and the Carrying Cost.

2.2.1 Differentiation

Codification: Codification of an Asset creates a new Asset of the same type and Complexity with the next higher Codification value. The new Asset inherits the Linkage Probabilities of its predecessor, with a random increase in all the existing non-zero values in the corresponding row (for Links) or column (for Nodes) in the Linkage Probability matrix. In this way, codification increases the linkage probabilities of a given knowledge asset's *existing* links

Abstraction: Abstraction of an Asset creates a new Asset of the same type and Complexity with the next higher Abstraction value. The new Asset inherits the Linkage Probabilities of its predecessor, but with an increase in the number of non-zero values randomly distributed in the corresponding row (for Links), or column (for Nodes) in the Linkage Probability matrix. In this way, abstraction extends a given knowledge asset's linkage probabilities to *new* links.

Absorption: Absorption of an Asset creates a new Asset of the same type and Complexity with the next lower Codification value. The new Asset inherits the Linkage Probabilities of its predecessor, with a random decrease in the all the existing non-zero values in the corresponding row (for Links) or column (for Nodes) in the Linkage Probability matrix. In this way, absorption *decreases* the linkage probabilities of a given knowledge asset's existing links

Impacting: Impacting of an Asset a new Asset of the same type and Complexity with the next lower Abstraction value. The new Asset inherits the original Linkage Probabilities of its predecessor, but with a decrease in the number of non-zero values randomly distributed in the corresponding row (for Links), or column (for Nodes) in the Linkage Probability matrix. In this way, abstraction *reduces* a given knowledge asset's linkage probabilities to new links.

There are several ways in which a given Asset can be codified, abstracted, absorbed or impacted, so that each Asset maintains memory of what are the possible results of the abstracting, codifying, impacting or absorbing process. Furthermore, the processes of abstraction, codification, impacting and absorption vary in their idiosyncrasy so that some

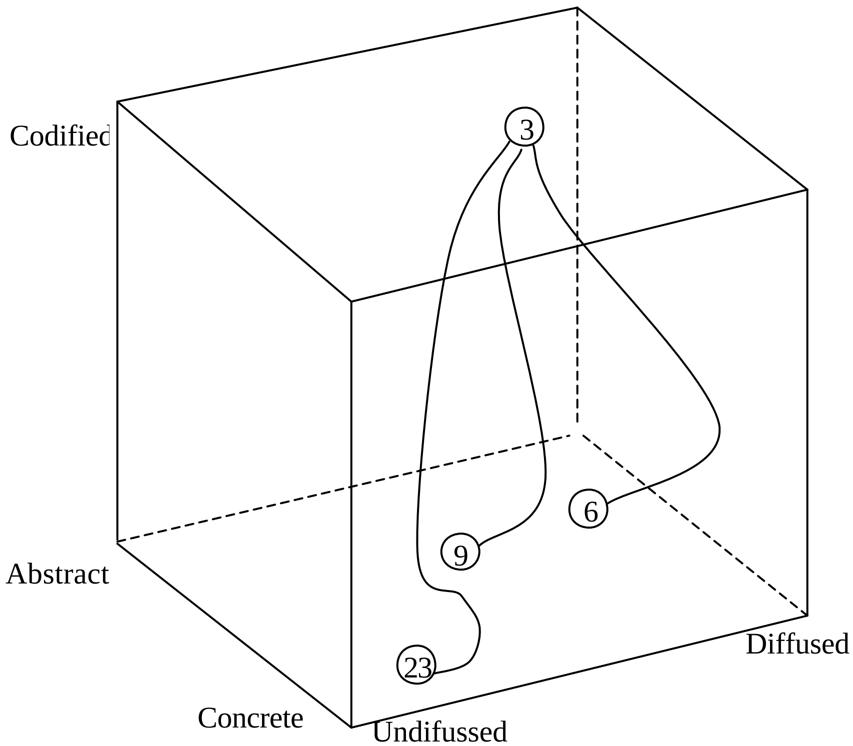

Figure 3: Differential absorption and Impacting in the I-

results will be more widely diffused than others. In Figure 3 for example, it may be that the absorption of Node 3 – i.e., its embedding and interpretation - will yield Node 6, Node 9 as well as Node 23. But, as indicated in the figure, 50% of the Agents who successfully absorb Node 3 will create Node 6, 33% will create Node 9, and the remaining 17% will create Node 23. Clearly what we are dealing with here are three quite distinct interpretative schemas some of which are more idiosyncratic than others. The same argument applies to impacting, codification and abstraction

<u>2.2.2 Integration</u>

Integration relates one asset to another via links. The best way to visualize this is via a matrix representation of the I-Space.

<u>The I-Space Matrix and I-Space Locations</u>: The I-Space Matrix is a three-dimensional matrix representation of the I-Space whose axes stand respectively for abstraction, codification and diffusion. The I-Space Matrix is made up of discrete I-Space locations or 'cells' in which Assets reside. Each I-Space location is uniquely described by discrete values of abstraction, codification and diffusion, and can contain any number of Assets. Each I-Space Location in the I-Space Matrix is also associated with a Base Rental Potential (see above).

<u>The Linkage Probability Matrix</u>: New knowledge can be created in Sim-I-Space either by creating new links and nodes – this can be done by investing in the abstraction, codification, impacting and absorption of existing nodes and links - or by combining existing links and nodes in new configurations. In the latter case, nodes and links are brought together to create new knowledge assets by increasing the probabilities of linking them together. The linkage probability reflects the uncertainties associated with new knowledge creation. The linkage probabilities between a given node and a given link is indicated by their intersection on a Linkage Probability Matrix which lists all links on one side of the matrix and all nodes on the other. When an agent decides to increase its investment in new knowledge creation, this has the effect of either increasing the probability of creating individual nodes or links, or of increasing the linkage probabilities associated with a given link-node cell. Thus investing in a given knowledge asset does not guarantee that new knowledge will actually be created, but it increases the chances that such creation will take place.

Thus, aside from creating new knowledge assets through abstraction, codification, impacting and absorption, another way in which new assets are created in the simulation model is when the Linkage Probabilities between (a) a Node and a Link of equal Complexity; and (b) that same Link with another Node of equal Complexity, are sufficiently high. When the Linkage Probabilities in such a Node-Link-Node chain exceeds a specified threshold, a new Asset is created. Linkage Probability thus measures the propensity for an Asset to combine with Assets of the same level of Complexity but of the complementary type – i.e., nodes with links, and links with nodes. Every possible Node-Link pair of the same level of complexity has some linkage probability even if this turns out to be zero.

Each Agent that owns the necessary constituent Assets and that has made the necessary investment, will discover the new Asset once the appropriate probability threshold has been crossed. The resulting asset will necessarily be more complex than its constituent elements. In the model, the new Asset will have a level of Complexity that is 1 notch further up on the complexity scale than its constituent Assets.[4]

2.2.3 Background Processes

Two background processes, Obsolescence decay and Diffusion decay, shape the environment in which the simulation takes place:

Obsolescence Decay**:** Obsolescence decay measures the loss of value of existing knowledge assets due to their obsolescence over time. Obsolescence is represented as the shrinking of the Rents Multiplier of existing Assets over time. The rate of decrease is a function of an industry-specific factor.

Diffusion Decay**:** Diffusion decay is the loss of value of existing knowledge assets due to the unintended diffusion – the 'spillovers' - of these assets**.** This is represented as the random distribution of Assets to a greater number of Agents both within and outside the model. Each Agent coming into the possession of these new Assets will make an independent decision as to whether it will incorporate them into its Active or Passive sets, or whether it will ignore them (if the agent is fully laden). The probability and rate at which a given Asset will diffuse will be a function of:

- Its degree of abstraction, and codification – in accordance with the tenets of the I-Space
- An industry-specific factor.

Blocking Diffusion Decay: Blocking diffusion decay is in the hands of an agent. Agents are initialized to block or not to block diffusion decay. Investments in diffusion decay will be a percentage cost of the rents potential of the asset and proportional to diffusion.

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[4] Note that only Assets of equal Complexity have any Linkage Probability, thus all constituent Assets will have the same level of Complexity.

2.3 The Components of Agent Interactions

Agent Meetings**:** Agent meetings can be either arranged or random.

- *Arranged meetings*: At the beginning of each period, Agents will identify Agents they wish to meet. Arranging to meet an Agent imposes an Arrangement cost. Arranged meetings can occur between any numbers of Agents, and only take place when all parties involved arrange to meet all the other Agents involved. I.e. a 3-party meeting only takes place when all 3 participating Agents choose to meet the other 2 Agents in the same period.

- *Random meetings:* Aside from arranged meetings, random meetings can occur between any two Agents. Random meetings do not incur any arrangement costs. The users of the simulation are free to specify the frequency with which agents will meet in each period.

Meeting Costs**:** Agent meetings impose four different kinds of costs on participants – arrangement costs, fixed costs, presentation costs and inspection costs. *All* meeting costs are Financial Costs – they are set against the Financial Budget allocated for the period and thus consume Financial Funds.

- *Arrangement cost*: The arrangement cost is levied on the Agent for each Agent he attempts to arrange a meeting with – regardless of whether a meeting results from the attempt. This cost only applies to attempts to arrange meetings and does not apply when meetings are random. The arrangement cost of a meeting does not vary as a function of the history of past transactions.

- *Fixed cost*: The fixed cost of a meeting is levied on all participants of a meeting, regardless of size.[5] The fixed cost of a meeting does not vary as a function of the history of past transactions.

- *Presentation costs*: Presentation costs are the costs of making available the agent's Trading Set for inspection. They are imposed once for each meeting that the agent attends.[6] Presentation costs increase with the number of knowledge assets that the agent presents, and decrease both with the degree of abstraction and codification of these assets – in line with I-Space thinking - as well as with the degree of recurrence of transactions with a given agent or group of agents.

- *Inspection cost*: The inspection cost is the cost of an Agent inspecting the Trading Set that has been offered for its examination, and is levied once for each Trading Set that the Agent inspects. Each Trading Set imposes an Inspection cost that increases with the number of Assets in the Trading Set, and decreases with the Abstraction and Codification of those Assets,[7] as well as decreasing with recurrence.

Transactional options**:** Agent meetings can result in the following transactions taking place between agents:

- *The trading of knowledge assets*: In a trade, agents exchange knowledge assets for Financial Funds. There is no change in the level of diffusion of the assets traded since the selling agent relinquishes all rights to the assets in exchange for a stock of Financial Funds received.

- *The licensing of knowledge assets*: In licensing, agents share their knowledge assets in return for Financial Funds. Nominal Diffusion (see above) increases since the agent who grants the license to the Asset retains its rights to use it. In return for the right to

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[5] A benefit of a large meeting is that Agents amortize the fixed cost over a greater number of potential transactional partners.

[6] A second benefit of a large meeting is that Agents amortize the presentation cost over a greater number of potential transaction partners.

[7] Inspection cost forms the limiting factor to the size of multi-agent meetings. As the number of potential transaction partners increase, the cost of attending such a meeting increases.

use the Asset, the agent receiving the license (the licensee) pays the agent granting the license (the licensor) a continuous flow of Financial Funds.

- *Joint Ventures*: In a joint venture, agents come together to create a new agent that is jointly owned. The new agent receives an injection of Financial Funds, Experience Funds and Assets from its "parent" agents. The parents continue to exist as independent agents while receiving a variable flow of Financial Funds from the Agent created as a result of the joint venture. The flow will be proportional both to the rents and to their respective investments in the joint venture.

- *Mergers*: In a merger, Agents come together to create a new Agent, by pooling all their Assets, Financial Funds and Experience Funds. The original Agents cease to exist as independent Agents and will instead be represented by this new Agent. Thus, in a merger, the total number of agents in the simulation actually decreases.

- *The creation of subsidiaries*: In creating a subsidiary, one agent unilaterally creates a new Agent, which receives an injection of Financial Funds, Experience Funds and Assets from the "parent" Agent. The original Agent continues to exist independently, and earns a variable flow of Financial Funds dependent on the success of the subsidiary. [8]

While all transactions can take place regardless of the number of participants at a meeting, all transactions are bilateral transactions. I.e. In a meeting with five Agents, the decision to trade an Asset still takes place between two participants who have presented and inspected each other's Trading Set - ditto for licensing, joint ventures and mergers. Thus meetings with more than two Agents serve the primary function of efficiently bringing more Agents together, but do not, of themselves, constitute new transactional options. The situation is summarized in Table 2 below:

[8] An Agent that finds itself with far too many unrelated Assets may carve off portions of it into subsidiaries.

Table. 2 – Multi-Agent Meetings & 2-Agent Meetings

	N-Party Meeting (Arranged)	**2-Party Meeting (Arranged/Random)**
Trading Set Presented	Based on lowest degree of recurrence with all (N-1) other Agents.	Based on degree of recurrence with the other participating Agent.
Arrangement Costs	Pays arrangement cost for (N-1) Agents that each Agent elects to meet.	If the meeting is arranged, the Agent pays the arrangement cost.
Presentation Costs	Each Agent presents once at each meeting, and pays the presentation cost for the Trading Set it presents once for each meeting it attends.	
Inspection Costs	Each Agent inspects (N-1) Trading Sets, and pays the associated inspection costs	Each Agent inspects the other's Trading Set, and pays the associated inspection costs
Fixed Costs	Each Agent pays the Fixed cost of a Meeting once for each Meeting it attends.	

References

Boisot, M., (1998) *Knowledge Assets: Securing Competitive Advantage in the Information Economy*, Oxford: Oxford University Press.

Appendix 1: Description of variables

We offer a summary description of the Sim-I-Space variables below together with their settings for a typical run:

	Input Parameters

GLOBAL SWITCHES

ASSET_MANAGEMENT
- This activates the asset management module.
- When it is a true, mod_discovery and mod_research methods will run, if either of them is true.

MOD_DISCOVERY
- In the I-space world each agent discovers Nodes and Links to generate new Nodes or Links, after checking the linkage probability between Nodes and a Link.
- If the Mode of Discovery sets to 0(TRUE), then the 'generateDiscovery' Method is activated. Otherwise, it will be disabled.

MOD_RESEARCH
- Each agent moves a Node or a Link to create new Node or Link in the I-space.
- If the Mode of Research sets to 0(TRUE), then the 'generateResearch' Method is activated. Otherwise, it will be disabled.

AGENT_INTERACTION
- The module that activates encounters and interactions among agents can be switched on or off.
- If the AGENT_INTERACTION sets to 0(TRUE), then the 'generateMeetings' Method is activated. Otherwise, it will be disabled.

MOD_OBSOLESCENCE
- This constitutes an end-of-Period functions.
- The module for generating Obsolescence Decay for each node or link can be switched on or off.
- If the MOD_OBSOLESCENCE sets to 0(TRUE), then the 'generateObsolescenceDecay' Method is activated.
  Otherwise, it will be disabled

MOD_DIFFUSION
- This constitutes an end-of-Period functions.
- The module for generating Diffusion Decay for each node or link can be switched on or off.
- If the MOD_DIFFUSION sets to 0(TRUE), then the 'generateDiffusionDecay' Method is activated.
  Otherwise, it will be disabled

Input Parameters

MAIN VARIABLES

INIT_AGENT_NUM
- Number of Agents at the start of the simulation
- What an Agent is depends on the nature of the simulation - it could be a firm, an employee within a firm, or something intermediate like an SBU or a department within a firm. The key requirement is that Agents be endowed with both data-processing and decision-making powers and that they be homogeneous with respect to the attribute that defines them as an Agent.
- Possible range (current): 1 - 50 (20)

INIT_NODE_NUM
- Number of distinct knowledge Nodes at the start of the simulation
- The initial number of Nodes will be distributed randomly to individual Agents
- Knowledge Nodes are identifiable pieces of knowledge that can stand on their own when generating revenue. They can themselves be made up of nested networks of knowledge Nodes and Links
- Possible range (current): 1 - 50 (25)

INIT_LINK_NUM
- Number of distinct knowledge Links at the start of the simulation
- The initial number of Links will be distributed randomly to individual Agents
- Knowledge Links establish relationships between knowledge Nodes. They constitute identifiable pieces of knowledge that help to integrate knowledge assets together.
- Possible range (current): 1 - 30 (15)

MODEL_PERIODS
- Number of periods that the simulation will run for
- Possible range (current): 1 - 200 (200)

	MAX_AGENT_NUM • Maximum number of Agents allowed during the simulation • Possible range (current): 50 - 300 (50)
	MAX_NODE_NUM • Maximum number of distinct knowledge Nodes allowed during the simulation • Possible range (current): 100 - 5000 (300)
	MAX_LINK_NUM • Maximum number of distinct knowledge Links allowed during the simulation • Possible range (current): 100 - 3000 (200)

	Input Parameters
ASSET VARIABLES	**MAX_COMPLEXITY** • Maximum level of Complexity of Assets allowed in the simulation • Derived from the "maximum" levels of Complexity perceivable by agents in the simulation. • Possible range (current): 1 - 10 (7)
	COMPLEXITY_COST • Rate at which holding Assets of increasing Complexity increase their carrying cost • Derived from MAX_COMPLEXITY (see above) such that MAX_COMPLEXITY is the level at which a fully Abstract, Codified and Diffused knowledge Asset remains economically viable. • Possible range (current): 0.00 - 1.00 (0.001)
	NEW_LINK_PROB • The probability that a new Asset generated by combining two Nodes and a Link is a Link • When Agents research the creation of a new Asset via the combination of existing Nodes/Link, the resulting new Asset can be either a Node or a Link, and NEW_LINK_PROB determines the ratio of Nodes to Links among new Assets. • Possible range (current): 0.00 - 0.50 (0.20)
	MOVE_POSSIBILITIES • Number of possibilities for each type of movement in I-Space for each Asset • Movement in I-Space creates new knowledge Assets, and for each existing knowledge Asset there is a finite number of possible new Assets locations available in I-Space. • Possible range (current): 1 - 5 (2)
	PASSIVE_CARRY_MULT • The carrying cost of knowledge Assets in the Passive set relative to that of knowledge Assets in the Active set • Knowledge Assets in the Passive set cost less to maintain as they are not being actively managed in the I-Space to generate Revenue. • Possible range (current): 0.00 - 1.00 (0.50)

	Input Parameters
I-SPACE WORLD VARIABLES	**BASE_REV_MULT** • A multiplier that determines the allocation of Base Revenue Potential within the I-Space • Base Revenue Potential in the I-Space is proportional to the degree of Abstraction and Codification, and is inversely proportional to the degree of Diffusion. • Possible range (current): 0.00 - 2.00 (1.00)
	ASSET_SHARE_PROB • The probability that a given Agent at the start of the simulation gets initially allocated a given Asset. • The initial portfolio of Assets is distributed among such Agents based on this probability. Each Agent will have ASSET_SHARE_PROB probability of getting each Asset. This is a measure of the initial homogeneity knowledge in the simulation at the beginning of the game. • Possible range (current): 0.00 - 1.00 (0.20)
	OBSOLESCENCE_DECAY • Factor controlling the rate at which Assets become obsolete over the course of the simulation • The rate at which the Revenue Multiplier of Assets decays per period due to obsolescence is proportional both to OBSOLESCENCE_DECAY and the total number of new knowledge Assets that have been created in that period. What is being measured here is the "creative destruction" that goes on within an industry. Dynamic fast-moving industries are subject to much higher rates of obsolescence decay than slower moving ones. • Possible range (current): 0.00 - 0.50 (0.001)
	DIFFUSION_DECAY • Factor controlling the rate at which Assets are diffused • The rate at which Assets diffuse to a broader population each period is proportional to DIFFUSION_DECAY and the degree of Abstraction and Codification of the Asset • There are two forms of Diffusion Decay: 1) diffusion of Assets to Agents *within* the simulation increases the degree of Diffusion of Assets - as measured by the simulation metrics; 2) diffusion of Assets to a population *outside* the simulation does not increase the degree of Diffusion of the Asset - as measured by the simulation metrics - but decreases the Revenue Multiplier of the Asset directly. • Possible range (current): 0.00 - 0.05 (0.001)
	DIFFBLOCK_COST_MULT • This is a factor controlling the rate at which the cost of blocking the diffusion of assets is set. • The formula for calculating the cost of blocking the diffusion is as follows: The diffusion block cost = DIFFBLOCK_COST_MULT * Abstract * Codify * Diffuse. • Possible range (current): 0.00 - 0.20 (0.001)
	AGENT_ENTRY_THRESHOLD • Threshold of mean Agent revenues above which new Agents are attracted into the simulation • The number of new Agents is based on an estimate of the number of Agents the current "market" can support • Possible range (current): 1.00 - 5.00 (1.25)
	AGENT_ENTRY_RATE • The Agent Entry Rate is the number Agents entering per percent change in revenues between this period and the last period. • For example, setting AGENT_ENTRY_RATE to 0.25 means that for every percent increase in revenues, 0.25 Agents will be attracted into the game, translating into a simple number of a 1 agent for every 4% increase this period. N.B. Although this would be unlikely, one could conceivably have a negative Agent Entry Rate, i.e. at -0.25, this means that 1 agent is attracted into the game for every 4% decrease during this period. • Possible range (current): 0.01 - 1.00 (0.25)

	AGENT_EXIT_THRESHOLD • Agents exit is controlled by two variables - an Agent Exit Threshold and an Agent Exit Probability variable. Thus an Agent may decide to exit depending on how much financial funds it has managed to amass, and depending on the current trend of its revenues. • The Agent Exit Threshold determines the current level of financial funds that the Agent must achieve before it will consider exiting. This in essence sets the level at which an Agent feels that it is sufficiently "ahead" of the game to choose to quit while it is ahead. • Possible range (current): 5.00 - 50.00 (12.50)
	AGENT_EXIT_PROB • The Agent Exit Probability is the probability of any one Agent exiting per % change in that Agent's revenues between this period and the last period. This function works in both directions, depending on the value – i.e., setting AGENT_EXIT_PROB to 0.01 means that for every % increase in revenues, each Agent has a 0.01 (or 1%) chance of deciding to exit. • Similarly, setting this variable to -0.02 means that for every % decrease in revenues, each Agent has a 0.02 (2% chance of deciding exit). Thus by playing with the positive and negative values for this, you can have Agents that decide to leave when revenues are increasing, or Agents that leave when revenues are declining. • Possible range (current): -0.007 ~ +0.007 (-0.005)
	MAX_AGENT_ENTRIES • Maximum number of new Agents that will enter per period • Possible range (current): 1 - 10 (5)

	Input Parameters
I-SPACE MATRIX VARIABLES	**ABSTRACT_DIM_SIZE** • Size of the Abstraction dimension • This establishes the number of discrete intervals in the Abstraction dimension • Possible range (current): 2 - 10 (5)
	CODIFY_DIM_SIZE • Size of the Codification dimension • This establishes the number of discrete intervals in the Codification dimension • Possible range (current): 2 - 10 (5)
	DIFFUSE_DIM_SIZE • Size of the Diffusion dimension • This establishes the number of discrete intervals in the Diffusion dimension • Possible range (current): 2 - 10 (4)
	DIFFUSE_FACTOR • Factor which determines rate at which model Diffusion increases with increases in nominal Diffusion (see text for further details) • This variable establishes how to convert nominal Diffusion (the number of Agents in the simulation that own the Asset) into model Diffusion (the measure of Diffusion which directly impacts the location of the Asset in discrete I-Space. The DIFFUSE_FACTOR essentially converts a linear discrete model Diffusion into a logarithmic scale. • Possible range (current): 2 - 5 (2)

	Input Parameters
LINKAGE PROBABILITY VARIABLES	**ABS_NONZERO_VAL** • The value that is given by increasing abstraction to particular cell in the Linkage Probability matrix – prior to increasing abstraction its value was set at zero. • Possible range (current): 0.00 to 0.50 (0.20)
	COD_INCREASE_VAL • The increase in the Linkage Probability value that occurs following an increase in codification in a cell with a prior non-zero value. • Possible range (current): 0.00 to 0.50 (0.20)
	ABS_NONZERO_PROB • The degree to which an increase in the degree of Abstraction translates into an increase in the number of non-zero linkage probability entries in the Linkage Probability matrix • Abstraction is measured by the number of non-zero entries in the respective rows or columns in the Linkage Probability matrix. The larger the number of non-zero entries, the wider the range of potential linkages – ie, applications - a given Node or Link has. • As increasing Abstraction increases the number of non-zero linkage probability entries in the Linkage Probability matrix, so decreasing Abstraction increases the number of zero linkage probability entries in the matrix. • Possible range (current): 0.00 to 0.25 (0.05)
	NEW_ASSET_THRESHOLD • The complexity threshold beyond which a given Node-Link-Node chain creates a new knowledge Asset of greater Complexity. • Possible range (current): 0.50 to 1.00 (0.50)
	NEW_ASSET_PROB • Base probability of successfully achieving the new Asset combination made possible by a given Node-Link-Node chain whose Linkage Probability values exceed NEW_ASSET_THRESHOLD • Possible range (current): 0.00 - 3.00 (1.00)

	Input Parameters
AGENT VARIABLES	**INIT_FINANCIAL_FUNDS** • The initial endowment of Financial Funds for initial Agents • Possible range (current): 1.0 - 50.0 (10.0)
	INIT_EXPERIENCE_FUNDS • The initial endowment of Experience Funds for initial Agents • Possible range (current): 1.0 - 50.0 (10.0)
	FINANCIAL_ALLOCATION • The ratio of financial funds allocated from revenue and costs. • For example, 0.2 means that 20% of the revenue (cost) is allocated to financial funds (expense). • Possible range (current): 0.0 - 1.0 (0.5)
	ACTIVE_SET • The size of the Active set • Possible range (current): 1 - 50 (10)
	PASSIVE_SET • The size of the Passive set • Possible range (current): 1 - 50 (10)
	ISPACE_MOVE_PROB • The probability of successfully moving an Asset inside I-Space • The probability of successfully moving an Asset in I-Space is proportional to the Asset's Abstraction and Codification. • Possible range (current): 0.01 - 0.10 (0.03)
	ISPACE_MOVE_COST • A factor which determines the cost of moving an Asset in I-Space • The cost of moving an Asset in I-Space is proportional to the Asset's Abstraction and Codification. • Possible range (current): 0.01 - 0.10 (0.03)
	JOINT_VENTURE_RETURN • The proportion of a Joint Venture Agent's net income that is returned to parent Agents • Possible range (current): 0.01 - 1.00 (0.10) •
	SUBSIDIARY_RETURN • The proportion of a Subsidiary Agent's net income that is returned to parent Agents • Possible range (current): 0.01 - 1.00 (0.20)
	PAR_FUND_THRESHOLD • The financial fund threshold required of a parent company that allows it to create a subsidiary company • Possible range (current): 1 - 1000 (15)
	PAR_ASSET_THRESHOLD • The asset threshold required of a parent company that allows it to create a subsidiary company • Possible range (current): 0.01 - 1.00 (0.80)

	Input Parameters
AGENT MEETING VARIABLES	**MEETING_ARRANGE_COST** • The cost of attempting to schedule a meeting with an Agent • Possible range (current): 0.00 - 0.10 (0.005)
	MEETING_FIXED_COST • The fixed cost of attending a meeting - irrespective of size • Possible range (current): 0.00 - 0.10 (0.005)
	PRESENT_COST_MULT • The factor that sets the cost of presenting an Asset at a meeting • The cost of presenting an Asset is proportional to the Asset's Abstraction and Codification. • Possible range (current): 0.01 - 0.10 (0.005)
	EXAMINE_COST_MULT • The factor that sets the cost of inspecting an Asset at a meeting • The cost of inspecting an Asset is proportional to the Asset's Abstraction and Codification. • Possible range (current): 0.01 - 0.10 (0.005)
	TRADE_VALUE_MULT • The multiplier that is used to determine the tradeable value of an Asset • Possible range (current): 1.00 - 5.00 (1.75)
	LICENSE_VALUE _MULT • The multiplier that is used to determine the licensing value of an Asset • Possible range (current): 0.01 - 2.00 (0.25)

	Input Parameters
MEETINGSPACE VARIABLES	**PROB_RANDOM_MEETINGS** • The probability of random meetings per Agent per period • Possible range (current): 0.0 – 1.0 (0.25)
	MAX_RANDOM_MEETINGS • The maximum number of random meetings per Agent per period • Possible range (current): 0 - 10 (5)
	TRADING_SET_RATIO • The factor that is used to determine size of the Trading Set that an agent will deploy. This is based on the number of prior meetings that the focal agent has had with a given Agent • Possible range (current): 1 - 5 (2)

	Input Parameters
DM VARIABLES	**MIN_PREFERENCE_LEVEL** • The minimum preference that a given agent can display for abstraction, codification, impacting, and absorption. • Possible range (current): 0.0 – 1 (1)
	MAX_ PREFERENCE_LEVEL • The maximum preference that a given agent can display for abstraction, codification, impacting, and absorption. • Possible range (current): 0 - 10 (5)

	Input Parameters
RESEARCH DM VAR	**PROB_MOVE** • The probability that an Agent will attempt to move a given knowledge Asset in I-Space • Possible range (current): 0.00 - 1.00 (0.20)

	Input Parameters
MEETINGDMVARIABLES	**PROB_POSITIVE** • The base probability of a focal agent adopting a positive disposition towards a given Agent • Possible range (current): 0.00 - 0.50 (0.10)
	PROB_NEGATIVE • The base probability of a focal agent adopting a negative disposition towards a given Agent • The probability of having a neutral disposition is thus 100% - PROB_POSITIVE - PROB_NEGATIVE. • Possible range (current): 0.00 - 0.50 (0.20)
	HIGH_COOP_MULT • The multiplier used to determine the level of cooperation among agents. • Possible range (current): 0.00 – 0.10 (0.50)
	PROB_TRADE (UNUSED) • The probability of a given agent offering a Trade during a meeting with another Agent • Possible range (current): 0.00 - 1.00 (0.25)
	PROB_VARIABILITY (UNUSED) • Possible range (current): 0.00 - 1.00 (0.05)

	JOINT_VENTURE_INVEST • The rate of the investment for a joint venture • Possible range (current): 0.00 - 1.00 (0.25)
	SUBSIDIARY_INVEST • The rate of the investment for a subsidiary • Possible range (current): 0.00 - 1.00 (0.25)

Appendix 2: Detailed Model specification with example

STRUCTURE OF THE SIM-I-SPACE MODEL:

1) <u>Assets</u>

a) <u>Asset ID and Type</u>: Knowledge Assets ("Assets") are either Nodes or Links. Each Asset is identified by a unique ID number that is allocated sequentially, i.e. no two Assets (Node or Link) will have the same ID, and the first Asset will have ID 0, and the next Asset will have ID 1, and so on.

b) <u>Abstraction and Codification</u>: Each Asset has discrete attributes of Abstraction and Codification, which represent the degree each Asset is abstract or codified respectively. Values for Abstraction and Codification begin at 0 (respectively representing concrete and uncodified Assets), and have an upper bound that is specified in the model to give varying degrees of granularity.

c) <u>Diffusion</u>: The attribute of Diffusion represents the degree each Asset is diffused among the Agents in the model. The effect of Diffusion on the value of the Asset is non-linear – the loss in value from one additional Agent coming into possession of the Asset varies greatly depending on whether there was originally only one Agent who owned the Asset, or if there were 100 Agents who owned the Asset. In the former case, there is a sharp loss in value, and in the latter case, there may be almost no loss in value. To reconcile this difference there are two relevant values of Diffusion.

i) <u>Nominal Diffusion</u>: Nominal Diffusion is a continuous variable that measures the actual number of Agents that own the Asset. Nominal Diffusion has no upper bound.

ii) <u>Model Diffusion</u>: Model Diffusion is a discrete variable derived from nominal Diffusion that is used in the I-Space Model to calculate the Base Revenue Potential of the Asset. Model Diffusion has an upper bound specified in the model to give varying degrees of granularity.

E.g., in a model with model Diffusion values of 0~3, model Diffusion may be determined as follows:

Fig. 1 – Nominal Diffusion & Model Diffusion

Model Diffusion	Nominal Diffusion (i.e. # of Agents that own the Asset)
0	1 ~ 2
1	3 ~ 8
2	9 ~ 26
3	27 +

In this example, there is no difference in the Base Revenue Potential if 1 or 2 Agents own the Asset, but when a 3rd Agent owns the Asset, the Base Revenue Potential decreases. Base Revenue Potential then remains steady until the Asset diffuses to the 9th Agent, etc.

d) Complexity: Complexity describes the complexity of the knowledge structure represented by the Asset. Complexity begins at 0 (basic Assets) and has no upper bound. Assets combine with Assets of equal Complexity, and the resulting Asset is of one larger Complexity.

e) Revenue Multiplier: The Revenue Multiplier is the link between Base Revenue Potential (a function of where the Asset is in the I-Space) and actual revenue earned per unit time. The Revenue Multiplier accounts for a variety of factors, including Complexity (increasing as Complexity increases[9]), obsolescence (decreasing over time subject to the Obsolescence decay function), and "jackpot effects" (random extraordinary increases to the payout from combining Assets).

f) Carry Cost: Maintaining Assets impose a Carry Cost on Agents. The Carry Cost is a function of the Asset's Complexity[10].

g) Node/Link Parents: New Assets can be created as a result of the process of abstraction, codification, impacting and absorption, or by the combination of a chain of Node/Link/Node of sufficiently high Linkage Probability. The "parents" of an Asset are thus Nodes and/or Link from which this Asset was derived from. For initial/basic Assets, they have no "parents".

h) Possible new Assets due to "movement": The processes of abstraction, codification, impacting and absorption yield new Assets. However, there are only a finite number of ways in which any given Asset can be abstracted, codified, impacted or absorbed – thus each Asset maintains memory of what are the possible results of abstracting, codifying, impacting or absorbing itself. Furthermore, the process of abstraction, codification, impacting and absorption is idiosyncratic – thus some of the results will be more common than others. E.g., it may be that the absorption of Node 3, will yield only Node 6, Node 9 or Node 23. However, 50% of the Agents who succesfully absorb

[9] By combining Assets, Agents create new Assets of higher Complexity (and Revenue Multiplier). By doing so, Agents can offset Carry Costs, and usage of Agent memory (by replacing original Assets with the new combined Asset), while retaining some of the value of the original Assets as revenue generators.
[10] Increasing Complexity thus has two conflicting effects – increasing both the Revenue Multiplier, and the Carry Cost.

Node 3 will discover Node 6, 33% will discover Node 9, and the remaining 17% discover Node 23.

2) I-Space Matrix and I-Space Locations

a) I-Space Matrix and I-Space Locations: The I-Space Matrix is a three-dimensional matrix representation of the I-Space, with axes for Abstraction, Codification and Diffusion. The I-Space Matrix is made up of I-Space Locations - discrete locations in the I-Space Matrix where Assets reside. Each I-Space Location is uniquely described by discrete values of Abstraction, Codification and Diffusion, and can contain any number of Assets. Each I-Space Location in the I-Space Matrix is associated with some Base Revenue Potential.

b) Base Revenue Potential: The Base Revenue Potential reflects the fundamental relationship between Revenue and the three attributes of Abstraction, Codification and Diffusion. Thus, each I-Space Location in the I-Space Matrix is associated with a Base Revenue Potential that is used for all Assets residing in that location. The Base Revenue Potential is further subject to an Industry Multiplier that determines the difference between the Base Revenue Potential of two Assets of equal Abstraction, Codification, and Diffusion in two different industries.[11]

3) Linkage Probability Matrix

a) Linkage Probability: Linkage Probability measures the affinity for an Asset to combine with Assets of the same Complexity, but of the alternate type (Nodes with Links, and Links with Nodes). Every possible Node-Link pair with the same Complexity has some Linkage Probability (although this Linkage Probability may be zero).

b) Linkage Probability Matrix: The Linkage Probability Matrix is a two-dimensional matrix that exists for each level of Complexity. Each column in the matrix represents one of every existing Node of the given level of Complexity, and each row a Link. Thus the entry in row i, and column j, is the Linkage Probability between the Link in row i, and the Node in column j.

4) Agent

a) Agent ID: Agents in the model are identified by a unique ID that is allocated sequentially, i.e. no two Agents will have the same ID, and Agent 0 was the first Agent created, while Agent 1 was the next, and so on.

b) Financial Funds and Experience Funds: Agents possess resources that are used to cover their operating expenses. These resources, and

[11] Base Revenue Potential should not be confused with Revenue Potential - the former is invariant over time in each simulation run, while the latter is the realized revenue per period generated by each Asset, varying over time.

associated expenses, fall into two categories – Financial and Experience. Agents manage their resources by allocating revenues into either Financial or Experience funds, and setting Financial and Experience Budgets.

i) Financial Funds and Financial Budget: Financial Funds correspond tangible resources, such as cash, that are used to meet operating expenses, including the cost of meeting other Agents, trading for Assets, and paying out dividends. The Financial Budget is set by the Agent each period to limit the amount of the Financial Funds that the Agent intends to expend each period.

ii) Experience Funds and Experience Budget: Experience Funds correspond to more intangible resources, such as the experience from learning-by-doing, that are used to manipulate Assets – to increase/decrease their Abstraction or Codification, or to combine Assets to create new Assets. The Experience Budget is set by the Agent as a limit on the amount of the Experience Funds that the Agent is intending to expend each period.

c) Active set and Passive set: Agents have a finite memory that is separated into two sets – an Active set and a Passive set. Assets can be held in either of these sets, although storing Assets invoke Carry Costs. Agents manage their memory by choosing to hold Assets in either of the two sets, or discarding them altogether.

i) Active set: The Active set contains all Assets being actively utilized by the Agent, and generating revenue.

ii) Passive set: The Passive set contains all Assets that the Agent possesses, but are not utilized, and not generating revenue. Maintaining Assets in the Passive set alleviate some of the Carry Cost associated with the Assets.

d) Trading Set: Trading Sets are sets of Assets that an Agent makes available for transactions with other Agents. When two Agents meet, not all of their Assets may be available for transactions. In the first meeting, the cost of presenting Assets will limit the sharing to only the most Abstract and Codified Assets. Over time, as the degree of familiarity between two Agents increase with recurrent meetings, the cost of presenting Assets will decrease, and Agents will be able to share more concrete and uncodified Assets (thus increasing the size of the set of Assets available for transactions). Agents thus have more than one Trading Set, and it presents different Trading Sets to different Agents it meets depending on the degree of familiarity (i.e. history of meetings).

e) Agent Memory: Agent memory stores the frequency of the historical encounters with other Agents.

ASSET EVOLUTION IN THE MODEL:

5) Movement/Creation of Assets: The processes of abstraction, codification, impacting and absorption are the processes by which Assets evolve within I-Space.

a) Abstraction: Abstraction of an Asset creates a new Asset of the same type and Complexity with the next higher Abstraction value. The new Asset inherits the Linkage Probabilities of its predecessor, with an increase in the number Assets it can link with – i.e. an increase in the number of non-zero values in the corresponding row (for Links), or column (for Nodes) in the Linkage Probability matrix.

b) Codification: Codification of an Asset creates a new Asset of the same type and Complexity with the next higher Codification value. The new Asset inherits the Linkage Probabilities of its predecessor, with an increase in its ability to link with Assets – i.e. an increase in existing non-zero values in the corresponding row (for Links) or column (for Nodes) in the Linkage Probability matrix.

c) Impacting: Impacting of an Asset, a new Asset of the same type and Complexity with the next lower Abstraction value. The new Asset inherits the original Linkage Probabilities of its predecessor, with a decrease in the number Assets it can link with – i.e. a decrease in the number of non-zero values in the corresponding row (for Links), or column (for Nodes) in the Linkage Probability matrix.

d) Absorption: Absorption of an Asset creates a new Asset of the same type and Complexity with the next lower Codification value. The new Asset inherits the Linkage Probabilities of its predecessor, with a decrease in its ability to link with Assets – i.e. a decrease in existing non-zero values in the corresponding row (for Links) or column (for Nodes) in the Linkage Probability matrix.

6) Creation of new Assets: Aside from abstraction, codification, impacting and absorption, another way in which new Assets are created in the model is when the Linkage Probabilities between a Node (N_x) and a Link (L_y) of equal Complexity; and that same Link (L_y) and another Node (N_z) of equal Complexity are sufficiently high. When the Linkage Probabilities in such a Node-Link-Node chain exceeds a specified threshold, an Agent can attempt to research the creation of a new Asset.

a) New Asset: The result of combining a given set of Node-Link-Node can either be a Node or a Link. However, the result of combination is unique (?) – i.e. every Agent that owns the necessary constituent Assets that successfully research the creation of a new Asset from this will discover the same new Asset. The new Asset is also necessarily more complex than its constituents, and in the model, the new Asset has Complexity 1 larger than the Complexity of the constituent Assets.[12]

AGENT INTERACTION IN THE MODEL

[12] Note that only Assets of equal Complexity have any Linkage Probability, thus all constituent Assets will have the same Complexity.

7) **Agent Meetings:** Agent meetings can take place between two Agents (bilateral) or between a larger number of Agents (multilateral). To ensure that meetings remain manageable, there is a cap on the largest possible size for a multilateral meeting. In order for a meeting to occur, participants in a meeting must have either arranged to meet the other Agent(s), or have met the Agent(s) in a random encounter.

a) Arranged Meetings**:** At the beginning of each period, Agents will define their disposition towards other Agents in the game. This disposition can either be:

i) strong desire for meeting – an Agent who registers such a disposition will actively seek to arrange a meeting with the subject Agent, and will agree to a meeting arranged by the subject Agent;

ii) amenable to meeting – an Agent with this disposition will not seek to arrange a meeting with the subject Agent, but will agree to a meeting arranged by the subject Agent; or

iii) no desire for a meeting – an Agent with this disposition will neither seek to arrange a meeting with the subject Agent, nor will it be likely to agree to a meeting arranged by the subject Agent.

b) Random Meetings: Aside from arranged meetings, random meetings can occur between any two Agents. Random meetings do not incur any cost to arrange, but Agents do not have control over the Agents they encounter.

Based on the result of the attempts to arrange meetings, as well as the random encounters in each period, Agent meetings are generated.

In the model, Agents are aware of the economies of scale present in multi-Agent meetings, and thus have a default preference for attending the largest possible multi-Agent meetings (meetings with more than 2 Agents), but are however limited to attending only one multi-Agent meeting each period.

8) **Presentation and Inspection:** Agents attending meetings will present their Trading Set for inspection, as well as inspecting the Trading Set of other Agents attending the meeting. In a multi-Agent meeting, an Agent will present only one Trading Set. However, as it will have varying degrees of familiarity with the other Agents attending the meeting, it will restrict itself to the smallest Trading Set among all the Trading Sets it would present if it had met all the participants in bilateral transaction. E.g., if Agent X attends a meeting with Agent Y and Agent Z, Agents that it has met 9 times and 4 times before respectively, the Trading Set Agent X presents to the group will be the same as the Trading Set it would have presented to Agent Z (the Agent with which it has the lowest degree of familiarity).

9) **Meeting Costs:** Agent meetings impose four different kind of costs on participants – arrangement costs, fixed costs, presentation costs and inspection costs. All meeting costs are Financial Costs – they are set

against the Financial Budget allocated for the period and consume Financial Funds.

a) Arrangement cost: The arrangement cost is levied on the Agent for each Agent he attempts to arrange a meeting with – regardless of whether a meeting results from the attempt. This cost only applies to attempts to arrange meetings and does not apply when meetings are random. The arrangement cost of a meeting is invariant regardless of the history of past transactions.

b) Fixed cost: The fixed cost of a meeting is levied on all participants of a meeting, regardless of size.[13] The fixed cost of a meeting is invariant regardless of the history of past transactions.

c) Presentation cost: The presentation cost is the cost of making available the Agent's Trading Set for inspection, and is levied once for each meeting that the Agent attends.[14] Presentation cost increases with the number of Assets the Agent presents, and decreases with the Abstraction and Codification of the Assets (i.e. varies depending on the Trading set presented), as well as decreasing with recurrence.

d) Inspection cost: The inspection cost is the cost of an Agent inspecting the Trading Set that has been offered for its examination, and is levied once for each Trading Set that the Agent inspects. Each Trading Set imposes an Inspection cost that increases with the number of Assets in the Trading Set, and decreases with the Abstraction and Codification of those Assets,[15] as well as decreasing with recurrence.

10) Meeting Transactions: The following transactions can occur in an Agent meeting:

a) Trading of Assets: Trading is a bilateral transaction in which Agents exchange Assets for Financial Funds. There is no change in Diffusion as the selling Agent relinquishes all rights to the Assets in exchange for a stock of Financial Funds received.

b) Licensing of Assets: Licensing is a bilateral transaction where Agents share Assets for Financial Funds. Nominal Diffusion increases as the Agent who grants the license to the Asset retains its rights to use the Asset. In return for the right to use the Asset, the Agent receiving the license pays the first Agent a continuous flow of Financial Funds.

c) Joint Ventures: Joint ventures can occur in either a multilateral meeting or in a bilateral meeting. In a joint venture, Agents come together to create a new Agent. The new Agent receives an injection of Financial Funds, Experience Funds and Assets from the "parent" Agents. The founding Agents continue to exist independently, while

[13] A benefit of a large meeting is that Agents amortize the fixed cost over a greater number of potential transactional partners.
[14] A second benefit of a large meeting is that Agents amortize the presentation cost over a greater number of potential transaction partners.
[15] Inspection cost forms the limiting factor to the size of multi-agent meetings. As the number of potential transaction partners increase, the cost of attending such a meeting increases.

receiving a variable flow (proportional to their investment in the joint venture) of Financial Funds from the Agent created as a result of the joint venture.

d) Mergers: Mergers can occur in either a multilateral meeting or in a bilateral meeting. In a merger, Agents come together to create a new Agent, by pooling all their Assets, Financial Funds and Experience Funds. The original Agents cease to exist as independent Agents, and will instead be represented by this new Agent.

e) Subsidiaries: The creation of subsidiaries is a transaction undertaken by an Agent alone. In creating a subsidiary, one Agent unilaterally creates a new Agent, which receives an injection of Financial Funds, Experience Funds and Assets from the "parent" Agent. The original Agent continues to exist independently, and earns a variable flow of Financial Funds dependent on the success of the subsidiary.[16]

In a multi-Agent meeting, after the presentation of Trading Sets, the participants first decide if they wish to form a Merger, or create a Joint Venture. If they choose not to do so, the meeting will break up into a sequence of bilateral meetings. The difference is that Agents in these subsequent bilateral meetings no longer need to pay meeting costs, but are free to transact.

Fig. 2 – Multi-Agent Meetings & 2-Agent Meetings

	Multi-Agent Meeting	**2-Agent Meeting**
Arrangement Cost	Pays arrangement cost for (N-1) Agents that each Agent elects to meet.	If the meeting is arranged, the Agent pays the arrangement cost.
Presentation Cost	Each Agent presents once at each meeting, and pays the presentation cost for the Trading Set it presents once for each meeting it attends.	
Inspection Cost	Each Agent inspects (N-1) Trading Sets, and pays the inspection cost for inspecting the (N-1) Trading Sets.	Each Agent inspects one other Trading Set, and pays the inspection cost for inspecting that one Trading Set.
Fixed Cost	Each Agent pays the Fixed cost of a meeting once for each meeting it attends.	
Trading Set Presented	Based on lowest degree of recurrence with all (N-1) other Agents.	Based on degree of recurrence with the other participating Agent.

[16] An Agent that finds itself with far too many unrelated Assets may carve off portions of it into subsidiaries.

BACKGROUND ACTIVITY IN THE MODEL

11) **Obsolescence Decay:** Obsolescence decay is the loss of value of existing Assets due to obsolescence over time. This is represented as the shrinking of the Revenue Multiplier of existing Assets over time. The rate of decrease is a function of the number of new Assets generated this period.

12) **Diffusion Decay:** Diffusion decay is the loss of value of existing Assets due to the unintended diffusion of these Assets**.** There are two aspects to this diffusion – diffusion to Agents within the model, and diffusion to parties outside the model. .

a) Diffusion Decay to Agents: Diffusion of Assets to Agents within the model allows beneficiary Agents to use the Assets competitively. This form of decay is represented as the random distribution of Assets within the model to a greater number of Agents. Each Agent coming into the possession of these new Assets will make independent decisions whether to incorporate it into its Active or Passive sets, or to ignore it (if it is fully laden);

b) Diffusion Decay to World: Diffusion of Assets to parties outside the model causes the beneficiaries to reduce their demand for the Asset in the model. This reduced demand is represented as a random decrease in the Revenue Multiplier of the Asset.

The probability and rate at which Assets will diffuse is a function of its Abstraction, and Codification.

AN EXAMPLE

Structure of the Model

For this example we use a 5x5x4 I-Space Matrix, i.e. 5 levels of each Abstraction (A), and Codification (C), and 4 levels of Diffusion (D). In this case, 0 is the minimum Abstraction, Codification, and Diffusion; 3 is the maximum level of Diffusion; and 4 is the maximum level of Abstraction and Codification.

In this model, the corresponding Base Revenue Potential for each location in I-Space is calculated as ((A+1) * (C+1)) / ((D+1) * 25).

Fig. 3 shows the I-Space Matrix, and the associated Base Revenue Potentials for each location in the I-Space. In order to show the I-Space Matrix – which is a 3-dimensional matrix, we will view the I-Space Matrix in 2-dimensional slices, where each slice represents a different level of Diffusion.

Fig. 3 – I-Space Matrix: Base Revenue Potential View

(Diffusion=0)

Cod \ Abs	0	1	2	3	4
4	0.20	0.40	0.60	0.80	1.00
3	0.16	0.32	0.48	0.64	0.80
2	0.12	0.24	0.36	0.48	0.60
1	0.08	0.16	0.24	0.32	0.40
0	0.04	0.08	0.12	0.16	0.20

(Diffusion=1)

Cod \ Abs	0	1	2	3	4
4	0.10	0.20	0.30	0.40	0.50
3	0.08	0.16	0.24	0.32	0.40
2	0.06	0.12	0.18	0.24	0.30
1	0.04	0.08	0.12	0.16	0.20
0	0.02	0.04	0.06	0.08	0.10

(Diffusion=2)

Cod \ Abs	0	1	2	3	4
4	0.07	0.13	0.20	0.27	0.33
3	0.05	0.11	0.16	0.21	0.27
2	0.04	0.08	0.12	0.16	0.20
1	0.03	0.05	0.08	0.11	0.13
0	0.01	0.03	0.04	0.05	0.07

(Diffusion=3)

Cod \ Abs	0	1	2	3	4
4	0.05	0.10	0.15	0.20	0.25
3	0.04	0.08	0.12	0.16	0.20
2	0.03	0.06	0.09	0.12	0.15
1	0.02	0.04	0.06	0.08	0.10
0	0.01	0.02	0.03	0.04	0.05

The I-Space Matrix above represents the underlying structure, showing how revenue is distributed within I-Space.

We now look at the individual Agents participating in this I-space. Each Agent will have its own set of Nodes and Links that reside in various locations in the I-Space matrix. For instance, Agent 1 might have a distribution of Nodes (N_x) and Links (L_y) that looks like Fig. 4.

Fig. 4 – I-Space Matrix: Agent Asset Distribution View

(Diffusion=0)

Cod \ Abs	0	1	2	3	4
4			N_1	N_2	N_3,N_4
3					
2					
1		L_1			
0					

(Diffusion=1)

Cod \ Abs	0	1	2	3	4
4					
3		L_2	N_5,L_3		
2					
1		N_6		N_7	
0					

(Diffusion=2)

Cod \ Abs	0	1	2	3	4
4					
3			L_4	L_5	
2					L_6
1		N_8			
0			N_9		

(Diffusion=3)

Cod \ Abs	0	1	2	3	4
4				L_7	
3				L_8	L_9,L_{10}
2					
1	N_{10}				
0					

From this view, we see that Agent 1 has 10 Nodes and 10 Links. The general distribution indicates its Links are mostly Abstract and Codified and Diffused, while its Nodes are mostly Abstract, Codified and unDiffused.

Combining the information from Fig. 3 and Fig. 4, we can thus tell, for instance, that Node #7 is fairly Abstract (3), fairly unCodified (1), fairly unDiffused(1) and will generate a Base Revenue of 0.24 units per unit time. If Node #7 were a basic Node, it would have a Revenue Multiplier of 1 (barring Obsolescence), and would generate revenue of 0.24 units per unit time.

Beyond the I-Space, at any point in time, a global Linkage Probability Matrix exists which maintains the Linkage Probabilities between all existing Node-Link pairs.

From the perspective of an Agent who has limited memory, only a subset is relevant. In this case, where an Agent has an Active Set size of 5 of each type, the relevant subset of the Linkage Probability Matrix might look like Fig. 5.

Fig. 5 – Linkage Probability Matrix: Agent Subset

		Active Node					Passive Node				
		N_2	N_3	N_4	N_8	N_{10}	N_1	N_5	N_6	N_7	N_8
Active Links	L_1	0.22	0.30	-	0.16	0.20	-	-	0.14	-	-
	L_3	-	-	0.23	0.25	0.26	-	-	-	0.15	-
	L_4	0.24	0.23	-	0.17	0.18	-	-	0.14	-	0.17
	L_6	-	-	0.28	0.23	0.18	-	-	0.15	-	0.13
	L_{10}	0.22	0.21	-	0.20	0.28	-	0.13	-	-	-
Passive Links	L_2	0.11	0.14	0.14	-	-	0.13	0.12	-	0.16	0.15
	L_5	-	-	-	0.14	-	-	0.20	0.18	0.16	-
	L_7	-	-	0.23	-	0.13	0.20	-	-	0.16	0.15
	L_8	-	-	-	-	-	-	0.18	0.20	0.16	0.14
	L_9	-	-	-	-	-	-	0.17	0.15	-	0.17

The above indicates that for instance, Link #1 has fair Linkage Probability with Node #3, and the Node #10 has a fairly high Linkage Probability with Link #10. As a whole, we also see that Agent 1 appears to have chosen a set of Nodes and Links that have higher than average mutual Linkage Probabilities and placed them in the Active Set.

The Linkage Probability Matrix also shows implied relationships between Assets of the same type. Node #2 is a direct competitor with Node #3, because for every Link that Node #2 has some non-zero Linkage Probability with, Node #3 has a non-zero Linkage Probability as well.

On the other hand Node #4 is completely unrelated to Node #2 and Node #3, because for every Link that Node #2 and Node #3 have some non-zero Linkage Probability with, Node #4 has Linkage Probability of zero, and vice versa.

Asset Evolution in the Example

Over time, an Agent's portfolio of Assets may change. If we return to Agent 1 after one time period, its portfolio may have been updated to look like Fig. 6 (changes in **bold**):

Fig. 6 – I-Space Matrix: Agent Asset Distribution View (One Period Later)

(Diffusion=0)

Cod \ Abs	0	1	2	3	4
4			N_1	N_2	N_3
3					
2					
1	**N_{12}**	L_1			
0					

(Diffusion=1)

Cod \ Abs	0	1	2	3	4
4					**N_4**
3		L_2	N_5,L_3		
2		**N_{11}**			
1		**N_6 -**		N_7	
0					

(Diffusion=2)

Cod \ Abs	0	1	2	3	4
4					
3			L_4	**L_5 ®**	**L_{11}**
2					L_6
1		N_8			
0			N_9		

(Diffusion=3)

Cod \ Abs	0	1	2	3	4
4				L_7	
3				L_8	L_9,L_{10}
2					
1	N_{10}				
0					

In this updated view, we see that Node #4 has increased in Diffusion, Node #6 has been codified, and Link #5 has been abstracted. In addition, a new Node #12 has appeared.

The increase in Diffusion for Node #4 could have come about in a variety of ways. It might have been the result of Licensing by Agent #1, or it might have been the impact of Diffusion Decay.

Furthermore we have new Node #11 – the result of codifying Node #6, and a new Link #11 – the result of abstracting Link #5.

Finally we have Node #12 – a new Node that has not been created as a result of any of the "moves" in I-Space. There exists two possibilities for the existence of Node #12, it can either be the result of:

a) creation of a new Asset from a set of Nodes and Links that have sufficiently high mutual Linkage Probability; or
b) Agent 1 being the beneficiary of some form of Diffusion, whether intended (through Trading) or unintended (through Diffusion Decay).

In this case, if Node #12 were the result of (a), and the threshold Linkage Probability for creating new Nodes was 0.25, we can examine the earlier Linkage Probability Matrix to see what are the likely constituents of this Node #12.

Revisiting our original Linkage Probability Matrix (Fig. 5) – we find that only the chain of Nodes #8, #10 and Link #3, have Linkage Probabilities that meet this requirement, are thus likely to be the constituents of Node #12.

In this new time period, the Linkage Probability Matrix will also have changed as Agent 1 makes its own decisions to include/exclude new Assets. A possibility might look like Fig. 7 below (changes in **bold**).

Fig. 7 – Linkage Probability Matrix: Agent 1 Subset (One Period Later)

		Active Node					Passive Node				
		N_2	N_3	N_4	N_8	N_{10}	N_1	N_5	**N_{11}**	N_7	N_8
Active Links	L_1	0.22	0.30	-	0.16	0.20	-	-	**0.17**	-	-
	L_3	-	-	0.23	0.25	0.26	-	-	**-**	0.15	-
	L_4	0.24	0.23	-	0.17	0.18	-	-	**0.14**	-	0.17
	L_6	-	-	0.28	0.23	0.18	-	-	**0.20**	-	0.13
	L_{10}	0.22	0.21	-	0.20	0.28	-	0.13	**-**	-	-
Passive Link	L_2	0.11	0.14	0.14	-	-	0.13	0.12	**-**	0.16	0.15
	L_{11}	**-**	**0.15**	**-**	**0.14**	**-**	**0.16**	**0.20**	**0.18**	**0.16**	**-**
	L_7	-	-	0.23	-	0.13	0.20	-	**-**	0.16	0.15
	L_8	-	-	-	-	-	-	0.18	**0.23**	0.16	0.14
	L_9	-	-	-	-	-	-	0.17	**-**	0.15	0.17

Among the Nodes, Node #6 was codified to create Node #11. Therefore, by definition, Node #11's Linkage Probabilities are derived from Node #6's, with higher non-zero Linkage Probabilities as a result of codification. As Node #11 is superior to Node #6, the Agent has chosen the former to replace the latter in its Passive set.

Similarly, among the set of Links, Link #5 was abstracted to create Link #11, and for similar reasons, the latter has replaced the former in the Agent's Passive set. As defined, Link #11's Linkage Probabilities are essentially those of Link #5, with more non-zero Linkage Probabilities as a result of abstraction.

Finally, aside from the changes listed above, other changes will be taking place in the background. Among others, Obsolescence Decay will have set in, and the various Nodes and Links that existed will now generate less revenue per unit time. Diffusion Decay will also have occurred, and we saw a possible effect of Diffusion Decay on Node #4 earlier (although this increase in Diffusion might have also been the result of sharing).

Agent Interaction in the Example

Stepping back from the Agent 1, we look at the I-Space world that Agent 1 resides in. In this example, there are seven other Agents in Agent 1's world (Agent 1, Agent 2... Agent 8).

If this is the very first period in the simulation, Agent 1 will not have met any other Agent. However, if we visit Agent 1 some time into the simulation, Agent 1 will have developed a history of interactions with other Agents, and will have established a set of preferences as to which Agent it would like to interact with. Similarly for other Agents, each of them will have their own list of Agents they would prefer to interact with.

At the beginning of a period, each Agent will update its disposition to other Agents. A possible scenario is shown below, each row is an Agent's disposition to the Agents in the columns, i.e. the entry in row i, and column j, indicates Agent i's disposition towards Agent j – where "2" indicates a strong desire for meeting; "1" amenable to meeting; and "0" no desire for a meeting at all.

Fig. 8 – Agent Meetings: Arranging Meetings

	Agent 1	Agent 2	Agent 3	Agent 4	Agent 5	Agent 6	Agent 7	Agent 8
Agent 1		1	2	0	1	1	1	1
Agent 2	1		0	1	1	2	1	2
Agent 3	1	0		0	1	1	1	0
Agent 4	2	1	1		0	0	1	2
Agent 5	1	1	1	0		0	0	1
Agent 6	1	0	1	1	1		1	1
Agent 7	0	0	2	0	1	1		2
Agent 8	0	0	0	1	2	0	0	

?

In this example, Agent 1 does not wish to meet Agent 4, but is amenable to a meeting if arranged b Agents 2, 5, 6, 7, and 8. In addition, it has a strong desire to meet Agent 3, and will thus attempt to arrange a meeting with Agent 3.

Because Agent 3 is amenable to a meeting with Agent 1, it will respond favorably to Agent 1's invitation.

On the other hand, Agent 2 will similarly try to engage Agent 6 in a meeting, but as Agent 6 has no desire to meet Agent 2, no meeting will occur between Agent 2 and Agent 6.

In addition to arranged meetings, random encounters may give rise to meetings as well. The figure below shows the meetings of Agents, after taking into account Agent disposition that leads to meetings being arranged, as well as random encounters that lead to Agents meeting other Agents. A "?" in row i, and column j, indicates that Agent i will meet Agent j in a meeting. At this point, the type and size of meeting is undetermined because Agents will aggregate as many as possible meetings with other Agents to reap economies of scale in multi-Agent meeting.

Fig. 9 – Agent Meetings: Actual Meetings

	Agent 1	Agent 2	Agent 3	Agent 4	Agent 5	Agent 6	Agent 7	Agent 8
Agent 1		?	?	?		?		?
Agent 2								
Agent 3					?		?	
Agent 4						?		?
Agent 5							?	?
Agent 6								?
Agent 7								?
Agent 8								

?

Based on the matrix, a 4-Agent meeting is possible between Agent 1, Agent 4, Agent 6 and Agent 8.

At the same time, a 3-Agent meeting is possible for Agent 3, Agent 5 and Agent 7. Or for Agent 5, Agent 7 and Agent 8.

Because Agents want to attend the largest possible meeting, Agent 8 will eschew the 3-Agent meeting in favor of the 4-Agent meeting.

Looking at the 4-Agent meeting between Agent 1, Agent 4, Agent 6 and Agent 8. Of the four Agents participating, the meeting between Agent 4 and Agent 8 was arranged by Agent 4 – thus Agent 4 has incurred Arrangement cost for this meeting. When the four agents do meet, they pay the Fixed cost of the meeting. All this is before the Agents even have had the chance to present their Trading Sets or inspect the other Agents' Trading Sets.

Finally, when the Agents meet, each Agent will make available its Trading Set. For Agent 1, it has a total of 10 Nodes and 10 Links available. In our model, with Abstraction/Codification values of 0~4, Trading Sets are defined as follows:

Fig. 10 – Agent Meetings: Trading Sets

Trading Set	# Previous Meetings	Characteristics of Assets in Trading Set	Asset in Agent 1's Trading Set
0	0 ~ 1	Abstraction & Codification =4	N_3, N_4
1	2 ~ 4	Both Abstraction & Codification >=3	All above + N_2, L_7, L_8, L_9, L_{10}, L_{11}
2	4 ~ 7	Both Abstraction & Codification >=2	All above + N_1, N_5, L_3, L_4, L_6
3	8 ~ 12	Both Abstraction & Codification >=1	All above + N_7, N_8, N_{11} ,L_1, L_2
4	13 ~ 18	All Assets	All above + N_9, N_{10}

In our example, Agent 1 has met Agent 4 six times before, Agent 6 and Agent 8 nine times before. Now if Agent 1 had met Agent 4, Agent 6 and Agent 8 separately, it would present Trading Set 2 to Agent 4, and Trading Set 3 to Agent 6 and Agent 8 respectively. However in the context of a multi-party interaction however, it will present the Trading Set based on the Agent with which it has had the least history – in this case Agent 4.

Thus at the Meeting Agent 1 will only make available Trading Set 2 for inspection. Agent 4, Agent 6 and Agent 8 will also present their Trading Sets. Additional costs are then incurred - Agent 1 incurs a Presentation cost based on presenting Trading Set 2, and it incurs an Inspection cost based on inspecting the Trading Sets of Agent 4, Agent 6 and Agent 8.

After Agents have inspected the Trading Sets of all participants, the meeting has the opportunity to decide if it wishes to combine in a Merger, or create a Joint Venture. If they choose not to do so, the Agents are then free to engage in bilateral transactions with the participants. The bonus of the multi-Agent meeting is that because they have all paid their presentation and inspection costs, they will be able to engage in three separate bilateral meetings, having only paid the presentation cost once.

Note that there is no requirement for Agent 1 to collaborate with either Agent 4, Agent 6 or Agent 8, it can do so, with all of them, some of them or none of them. The multi-Agent meeting only serves to amortize to cost of presentation over a larger audience, and really only becomes effective when all parties have a similar history of collaboration/meetings (otherwise the Agent can only present the most Abstract and Codified Assets and is unable to collaborate with its more concrete and uncodified Assets).