SIMULATING ENTREPRENEURIAL STRATEGIES IN A GLOBAL KNOWLEDGE ECONOMY

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ABSTRACT

In seeking to better understand strategic entrepreneurship in the 21st Century, this paper develops an agent-based simulation model that allows researchers to study different opportunity recognition strategies in a globalized knowledge economy. The simulation takes account of international knowledge spillovers and shows the comparative payoffs of each entrepreneurial strategy, with distinctive knowledge progression and financial performance profiles. In addition, the societal level effects that arise from competitive agent behavior can be analyzed.

INTRODUCTION

Looking at the literature on opportunity recognition, one can easily get the impression that we are dealing with only one player: that classical hero of entrepreneurship – the innovator that single-handedly conceives and develops an entrepreneurial enterprise. However, Ihrig (2010) argues that there are also other valuable strategies for recognizing and realizing opportunities, especially those that involve imitative behavior. He introduces a framework that distinguishes between four distinct entrepreneurial strategies: innovating, inventing, imitating, and copying. He goes on to describe an agent-based simulation that models those strategies, enabling researchers to study their associated financial payoffs and their knowledge creation potentials under different environmental conditions.

As Ihrig and zu Knyphausen-Aufseß (2009) point out, it is important to analyze the opportunity recognition process in an *international* context. Therefore, the goal of this paper is to extend Ihrig's (2010) simulation model, which places its entrepreneurs in a single 'national' economy, and to develop a model that takes account of the global knowledge economy and *international* knowledge spillovers. For this, we first briefly review Ihrig's (2010) framework and describe his original simulation model. We then present the model extensions that help implement the international dimension and show results of virtual experiments that highlight the distinct modeling capabilities of the simulation.

THE BASIC CONCEPTUAL FRAMEWORKS

Understanding entrepreneurial opportunities and their formation is at the heart of entrepreneurship research (Alvarez & Barney, 2008a; Alvarez & Barney, 2008b). Ihrig (2010) argues that there are very different ways in which entrepreneurs pursue opportunity. The model he puts forward differentiates between the *origination* of a new venture idea and its *development*. The first step is where entrepreneurs obtain their new venture ideas, and the second where they further develop and refine them. This distinction results in the following two by two matrix (Figure 1).

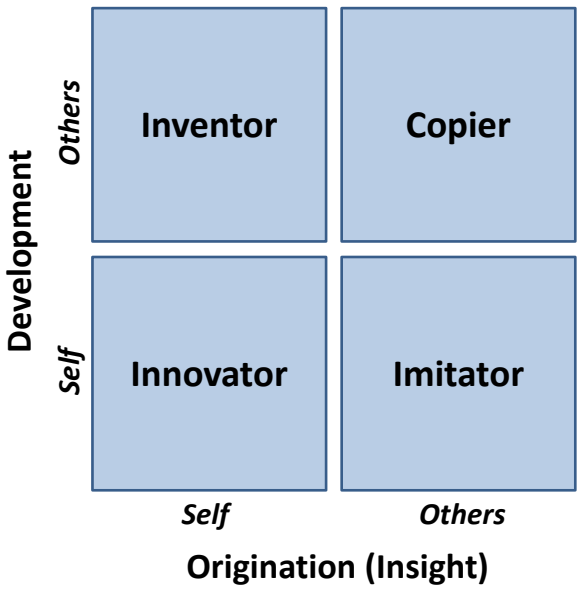

Figure 1: Four Different Entrepreneurial Strategies

Entrepreneurs can either conceive a new venture idea by themselves or gain the insight from somewhere else. Similarly, the development of a new venture idea can either be done independently or by drawing on others' expertise. The model results in four different entrepreneurial roles or strategies: innovating, inventing, imitating, and copying.

Ihrig (2010) takes a knowledge-based approach when studying how entrepreneurs obtain their new venture ideas and develop them (Ihrig, zu Knyphausen-Aufseß, & O'Gorman, 2006). Based on Austrian economics (Kirzner, 1997), he considers knowledge, and in particular its appropriation, development and exploitation, as the basis for new venture creation. This is why he uses the knowledge-based simulation

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environment *SimISpace* (Ihrig & Abrahams, 2007) to model the different entrepreneurial strategies and the contexts in which they take place. *SimISpace* is an agent-based graphical simulation environment designed to simulate strategic knowledge management processes, in particular knowledge flows and knowledge-based agent interactions. The simulation engine's conceptual foundation is provided by Boisot's (1995; 1998) work on the Information Space or *I-Space*. The *I-Space* is a conceptual framework that facilitates the study of knowledge flows in diverse populations of agents – individuals, groups, firms, industries, alliances, governments, and nations. It relates the degree of structure of knowledge (i.e. its level of codification and abstraction) to its diffusibility as that knowledge develops. Tacit, highly unstructured knowledge flows very slowly between agents and often only in face-to-face situations. Highly structured knowledge by contrast, which has been codified and abstracted, can diffuse rapidly and impersonally throughout a population, whether such diffusion is desired or not. As shown in Figure 2, knowledge is unstructured and undiffused at point A whereas at point B, it is both structured and diffused. Over time, knowledge that starts off at point A gradually gets structured and diffused to end up at point B.

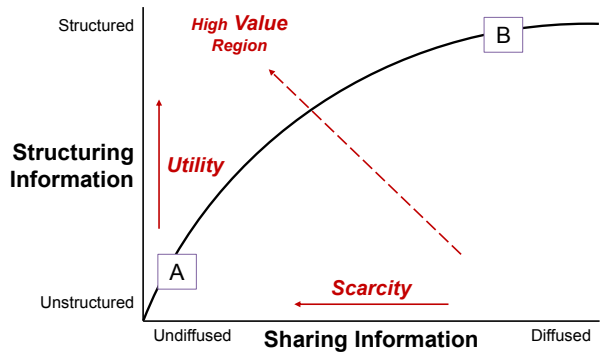

Figure 2: The Information-Space

THE SIMULATION SOFTWARE *SIMISPACE*

Ihrig and Abrahams (2007) offer a comprehensive description of the entire *SimISpace* environment and explain the technical details. Before showing how Ihrig (2010) builds the application-specific model – *SimOpp* – to operationalize his theoretical concepts and the processes behind them, we must review some of the basics of the *SimISpace* simulation software.

Two major forms of entities can be modeled with *SimISpace*: agents and knowledge assets. When setting up the simulation, the user defines agent groups and knowledge groups with distinct properties. Individually definable distributions can be assigned to each property of each group (uniform, normal, triangular, exponential, or constant distribution). The simulation then assigns the individual group members (agents and knowledge items) characteristics in accordance with the distribution specified for the corresponding property for the group of which they are a member.

Knowledge in the simulation environment is defined as a 'global proposition'. The basic entities are *knowledge items*. Based on the *knowledge group* they belong to, those knowledge items have certain characteristics. All knowledge items together make up the *knowledge ocean* – a global pool of knowledge. Agents can access the knowledge ocean, pick up knowledge items, and deposit them in knowledge stores through the *scanning* action. A *knowledge store* is an agent's personal storage place for a knowledge item. Each knowledge store is local to an agent, i.e. possessed by a single agent. As containers, knowledge stores *hold* knowledge items as their contents. Stores and their items together constitute *knowledge assets*. Examples of knowledge stores include books, files, tools, diskettes, and sections of a person's brain. There is only one knowledge item per knowledge store, i.e. each knowledge item that an agent possesses has its own knowledge store. If an agent gets a new knowledge item (whether directly from the knowledge ocean or from other agents' knowledge stores), a new knowledge store for that item is generated to hold it.

The concept of a knowledge item has been separated from the concept of a knowledge store to render knowledge traceable. If knowledge items are drawn from a common pool and stored in the knowledge stores of different agents, it becomes possible to see when two (or more) agents possess the same knowledge, a useful property for tracking the diffusion of knowledge.

The separation between a global pool of knowledge items and local knowledge stores is particularly important when it comes to codification and abstraction (these only apply to knowledge stores, not to knowledge items). Knowledge items are held by multiple agents, and one agent's investment in codification or abstraction does not influence the codification and abstraction level of the same knowledge item held by another agent. Agents possess knowledge stores at a particular level of codification and abstraction. If the agent codifies its knowledge and makes it more abstract, the properties of the knowledge item itself – i.e., its *content* – are not changed, but it gets moved to a new knowledge store with higher degrees of codification and abstraction – i.e., its *form* changes.

SimISpace also features a special kind of knowledge: a DTI (knowledge *Discovered Through Investment*) is a composite knowledge item that cannot be discovered through scanning from the global pool of knowledge items, but only by integrating its constituent knowledge items into a coherent pattern. The software user determines which knowledge items will act as the constituent components of a DTI; and the only way for an agent to discover a DTI is to successfully scan and appropriate its constituent components and then to codify and/or abstract them beyond user-specified threshold values to achieve the required level of integration. Once these values are reached, the agent automatically obtains the DTI (via a *discover* occurrence triggered by the simulation software). Investing in its constituent components – i.e. scanning,

codifying and abstracting them – is the main means of discovering a DTI. Specifying the values of different DTIs allows the user to indirectly determine the values of the networks of knowledge items that produce DTIs. Once an agent has discovered a DTI item, it is treated like a regular knowledge item, i.e. other agents are then able to also scan it from the agent that possesses it (without the process of having to discover its child constituents).

To keep the model and the resulting analyses simple, Ihrig (2010) uses only six of the twenty actions featured in the *SimISpace* environment: relocate, scan, codify, discover, learn, exploit. The virtual agents use those actions in each period of a run to accumulate new knowledge and develop it so as to discover DTIs. Agents can increase their financial funds by capitalizing on the knowledge they possess, in particular DTIs. Agents' financial funds act as a measure of their success – the better the knowledge appropriation, development and exploitation strategy, the higher the funds will be. (Agents with zero financial funds 'die'.) Based on different agent group behaviors, the increases in agents' individual financial funds and stocks of knowledge occur at different rates. Whereas all agents in the simulation will try to *learn* and *exploit* their knowledge (and thereby to grow their financial funds), agents will differ in their approaches to obtaining and developing knowledge in the first place. What follows is a concise review of the critical actions assigned for modeling entrepreneurial knowledge appropriation and development.

Scanning. An agent can scan for knowledge, randomly picking up knowledge items, either from the knowledge ocean or from other agents' knowledge stores. The probability of picking from the knowledge ocean (vs. from other agents) can be specified at the agent-group-level. While an agent can scan any knowledge item in the knowledge ocean, it can only scan knowledge items from the knowledge stores of other agents that fall within its *vision*. *SimISpace* agents populate a physical, two-dimensional space (called *SimWorld*), and the vision property determines how far the agent can 'see', defined as being within a certain spatial radius from its current location.

A knowledge item that is successfully scanned is placed in a new knowledge store possessed by the agent, which picks up its codification and abstraction levels either from the knowledge group that the knowledge item belongs to in the knowledge ocean, or from those of the knowledge store where the agent found the item. Agents will only try to scan knowledge items they do not already possess, or not at that level of codification and abstraction.

The ease with which a knowledge item is scanned from another agent's knowledge store is some positive function of the store's degree of codification and abstraction. Knowledge items in knowledge stores with higher codification and abstraction have a higher probability of being scanned.

Relocating. An agent can relocate within a certain distance of its position on the 100 by 100 *SimWorld* grid, with the distance moved being governed by the *distance* setting for the relocate action of its agent group. Relocating implies moving either closer to or further away from other agents or knowledge stores, and is thus relevant to scanning as it affects which other agents and knowledge stores the agent can see from its new position. As agents can only scan within the radius of their vision, they are only able to pick up knowledge from different areas by moving. Relocating agents leave their knowledge stores behind in the original location, but still retain access to them. (N.B.: When a new knowledge store is created, it is always assigned the same location as the agent that possesses it.)

Structuring Knowledge (Codifying and Abstracting). Codification and abstraction are separate actions that affect the knowledge stores (form) in which a given knowledge item (content) is held, although the agent must first possess a knowledge item in a store before it can perform these actions. Agents can create new knowledge stores at different codification and abstraction levels within the 0 to 1 range. The codification or abstraction levels of a newly created knowledge store are increased incrementally beyond those of existing stores. The knowledge item in the new knowledge store always remains the same – it is only the level of codification and abstraction of the knowledge store that changes. Stores with higher levels of codification and abstraction are both more likely to be scanned by other agents, and more valuable when exploited: however, the more diffused knowledge becomes, the less value agents can extract from it (see description of exploiting occurrence below).

Learning. Before a knowledge item can be exploited, it has to register with an agent though a learning process. This can only apply to a knowledge item that an agent possesses. Its chances of successfully learning increase with the levels of codification of the knowledge store that holds it.

Exploiting. Agents can generate value for themselves by capitalizing on their knowledge, but only after it has been registered and internalized through learning. The exploiting agent's financial funds are increased by the value of the exploiting actions the agent undertakes, with the *exploit amount* calculation based on the user-set *base value* of the knowledge item involved. This takes account of the levels of codification and abstraction of the knowledge store holding the knowledge item, and of the level of diffusion of the knowledge item (the percentage of agents that possess the particular piece of knowledge in that period). The user can define an industry-specific table of revenue multipliers based on abstraction and codification levels. In the *I-Space* (Boisot, 1998), the value of knowledge is some positive function of both its utility (the level of codification and abstraction) and of its scarcity (the level of diffusion). Therefore, typically, the higher the levels of codification and abstraction, the higher the revenue multiplier, i.e. more codified and abstract

knowledge is worth more. More codified and abstract knowledge, however, is also more likely to be diffused, which erodes the value of knowledge. The calculations also allow for the effects of obsolescence, which also erodes value: obsolete knowledge is worthless. Whereas revenue multipliers depend on the codification and abstraction characteristics of a knowledge *store*, obsolescence depends solely on the properties of the knowledge *item* the store contains.

THE SIMULATION MODEL *SIMOPP*

We can now describe the *SimISpace* model designed and built for the opportunity recognition context (*SimOpp*) and present the properties of the participating agent and knowledge groups as outlined by Ihrig (2010).

Agents

In line with the conceptual framework explained above, four *agent groups* are created. The following matrix (Figure 3) shows the four agent groups and the relevant *SimISpace* actions that distinguish them from one another.

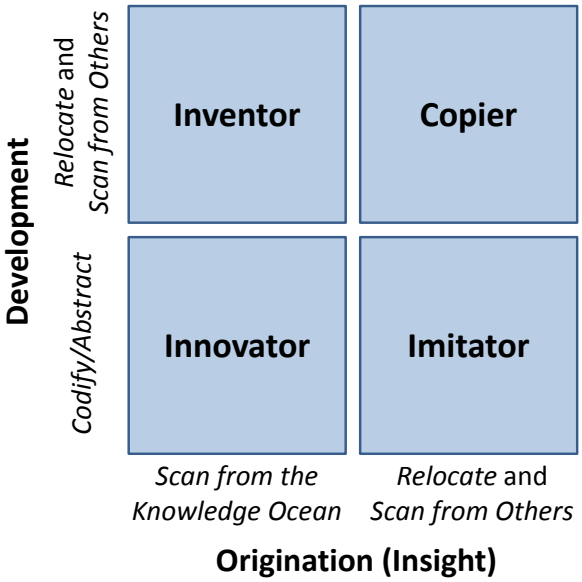

Figure 3: The Four Entrepreneurial Groups in *SimOpp*

The propensities to engage in (probabilities to choose and perform) particular actions vary from group to group based on the conceptual distinctions made. In total, agents engage in four activities (one activity being one or more individual *SimISpace* actions/occurrences). One activity (1) is assigned for implementing *origination* (either *self* or *others*) and another activity (2) for implementing *development* (either *self* or *others*). For the first (*origination*) activity, agents coming to an insight themselves is implemented through the 'Scan from the Knowledge Ocean' action, whereas agents obtaining insights from a third party is implemented through the 'Relocate' and the 'Scan from Others' actions (since agents can move through the *SimWorld* and scan knowledge assets from other agents).

When it comes to *development* (activity 2), agents developing themselves is implemented with the 'Codify/Abstract' actions, agents developing by drawing on others' resources is again implemented via the 'Relocate' and 'Scan from Others' actions. There are two other relevant activities which all agents must perform if they are to be able to capitalize on their knowledge: those are implemented with the 'Learn' and 'Exploit' actions (activities 3 and 4 respectively). Note that the numbering of the activities does not necessarily imply a particular order in which the actions are conducted in the simulation. Knowledge can only be learned once it has been obtained and can only be exploited once it has been learned. Which of the possible actions an agent chooses is determined randomly each period by the simulation software based on the distributions assigned for the propensities to engage in an action.

Looking at each agent group in turn and based on the description above, we can see what actions and properties agents have in common and what distinguishes them. The specific values of the constant distributions that are assigned to determine the group's propensities to engage in particular actions are displayed in brackets.

Innovator. Innovators perform four actions; they *scan* (1) and they *codify* (1), and (as all the other groups) they *learn* (1) and *exploit* (1). They can only scan from the knowledge ocean.

Imitator. Imitators can perform five actions; they *scan* (0.5), *relocate* (0.5), *codify* (1), *learn* (1) and *exploit* (1). In contrast to the Innovators, Imitators only scan from the agents surrounding them (and not from the knowledge ocean).

Inventor. Inventors perform four actions – scan (1.5) and relocate (0.5), and learn (1) and exploit (1), but they do not codify. They can scan from both the knowledge ocean and from other agents.

Copier. Copiers perform the same four actions – scan (1) and relocate (1), and learn (1) and exploit (1), but not codify. In contrast to the Inventors, they only scan from other agents, but *not* from the knowledge ocean.

There are ten agents in each agent group, and all agents start with financial funds of 100. The *relocate distance* and *vision* property are the same for all groups, but they can be changed to model differential access to competitive knowledge reflecting for example distinct technological contingencies (Ihrig, MacMillan, Zu Knyphausen-Aufseß, & Boisot, 2010). Imitators, Inventors, and Copiers are randomly spread out in the *SimWorld* (uniform distribution 0-100 for x and y location); Innovators are clustered together at the center (uniform distribution 45-55 for x and y location) – centrally located for when the other agents move around the *SimWorld* in the 1000 period runs.

Knowledge

The *SimOpp* model uses both *SimISpace*'s basic and higher-level DTI knowledge types. There are three

distinct basic knowledge groups: *Local*, *Entrepreneurial*, and *New Venture Idea Knowledge*.

Local Knowledge. Local Knowledge represents an agent's understanding of the local market and its culture. It starts at a high level of codification and abstraction (0.7) and has a base value of 5. As described above, a knowledge item's intrinsic *base value* is the starting point for calculating the *exploit amount* – the increase in an agent's financial funds after it has successfully performed an exploit action on a knowledge asset.

Entrepreneurial Knowledge. Entrepreneurial Knowledge represents 'Know-How' (Ryle, 1949). Abilities like those to "sell, bargain, lead, plan, make decisions, solve problems, organize a firm and communicate" (Shane, 2003: 94) are examples of knowledge items in this group. To this belongs a 'creating the initial transactions' (Venkataraman & Van de Ven, 1998) set of skills like writing business plans, initiating sales, creating initial products and services, securing initial stakeholders and finances. Knowledge from this knowledge group starts at medium codification/abstraction levels (0.5) and has a base value of 10.

New Venture Idea Knowledge. New Venture Idea Knowledge represents the 'Know-*What'*. Knowledge items in this group are insights about a particular potential service or product offering. Knowledge from this knowledge group starts at low levels of codification and abstraction (0.3) but has a base value of 20.

There are ten knowledge items in each knowledge group, all of which have *obsolescence rates* of zero, *codification* and *abstraction increments* of 0.1, and no *per period carrying gain or cost*. All agent groups are endowed with Local Knowledge and Entrepreneurial Knowledge (i.e. every agent in the simulation possesses all knowledge items from these groups), but they do not possess New Venture Idea Knowledge.

As with the settings for agent groups, it is important to start with simple assumptions, switching certain settings off, and to only increase complexity slowly. This enables the researcher to gain a better understanding of the fundamental dynamics of the simulation, as it is easier to analyze results. Future research efforts can then test and explore the whole parameter space of *SimISpace*.

Opportunities

DTI knowledge is used to model opportunities. Once an agent possesses a knowledge item each from the Local Knowledge, Entrepreneurial Knowledge and New Venture Idea Knowledge groups, in knowledge stores with codification levels equal or greater than 0.6, it gains the corresponding DTI, i.e. the agent 'discovers' an opportunity. There are ten DTIs, each based on a combination of the nth items of each basic knowledge group. For example, the underlying knowledge items for DTI 1, are knowledge item 1 of Local Knowledge, knowledge item 1 of Entrepreneurial Knowledge, and knowledge item 1 of New Venture Idea Knowledge. DTI knowledge items have high *starting levels of codification* and *abstraction* (0.8), high (compared to base knowledge) *base values* of 2500, *obsolescence rates* of zero, *codification* and *abstraction increments* of 0.1, and no *per period carrying gain or cost*.

Agents obtain opportunities in different ways. The dynamics of this simulation mean that there are three.

Opportunity Construction. The classical way is to construct an opportunity. The occurrence type triggered in the simulation is called *discovery*, but this term is not used here, because of the particular connotation it carries in the entrepreneurship literature. An agent obtains all underlying knowledge items, structures them up to the specified codification threshold, and then gains the relevant DTI, i.e. the opportunity. As their prior stocks of knowledge, agents already possess Local Knowledge and Entrepreneurial Knowledge from the start of the run, and can obtain the missing New Venture Idea Knowledge item either directly from the knowledge ocean (*self*) or from another agent's knowledge store (*others*). They then reach the required threshold either by codifying the knowledge themselves or by scanning it from another agent that already holds it at the required level (or, in the case of the imitator, by a combination of both).

Opportunity Acquisition. Agents can not only scan others' basic knowledge items, but also their DTIs. So, as well as being able to construct opportunities themselves, agents can acquire the knowledge about an opportunity directly by scanning it from another agent that carries the DTI in its knowledge store.

Opportunity Amplification. Agents can also develop and structure their opportunities further, either by increasing the codification levels of their DTIs themselves, or by scanning from other agents that possess higher codified stores of that DTI.

THE NEW, INTERNATIONAL OPPORTUNITY RECOGNITION SIMULATION MODEL

As described by Ihrig (2010), *SimOpp* enables researchers to study opportunity recognition strategies and their outcomes under different environmental conditions and to analyze associated micro and macro effects dynamically. The simulation shows the comparative payoffs of each strategy in different environments, with distinctive knowledge progression and financial performance profiles. In addition, the societal level effects that arise from competitive agent behavior are displayed. Face validity was established by showing that "the critical characteristics of the process being explored are adequately modeled and that the model is able to generate results that capture known canonical behavior" (Carley, 2002: 262). Ihrig, MacMillan, zu Knyphausen-Aufseß and Boisot (2010) build on the simulation model, further exploring theoretical and practical implications and investigating the differential impact of two types of technological advances that facilitate access to competitive knowledge: advances in *Information and*

Communication Technologies (ICT) versus advances in *Geographical Mobility* (Mobility). What has not yet been done is to look at the international transfer of knowledge in an increasingly global world. Ihrig and zu Knyphausen-Aufseß (2009) argue that the entrepreneurial strategy of creative imitation is particularly relevant in the international context. To see whether this is true, we now construct a variant of *SimOpp* to simulate an international scenario.

Modeling the international scenario

For this purpose, we must introduce an additional agent group – 'National Innovators' – and an additional knowledge group – 'Local Knowledge II'. National Innovators are our lead entrepreneurs from abroad. They were the first worldwide to have discovered a particular opportunity and implemented it in their country. Their label indicates that they are 'leading entrepreneurs' from the national setting where the knowledge originated. With a couple of exceptions, the National Innovator group has the same simulation properties as the 'Innovator' group in the basic model (see Table 1).

Table 1: Settings for 'National Innovator' Agent Group (differences to 'Innovator' group in bold)

National Innovator: agent group that represents 'lead entrepreneurs from abroad'

Knowledge agents possess:
- **Local II Knowledge**
- Entrepreneurial Knowledge
- New Venture Idea Knowledge

[all knowledge groups are prior stock]

Actions agents perform:
- **Abstract**
- Learn
- Exploit

As they are from a market, country or geographical region different to that of our four original groups, they have drawn on a different range of local knowledge in first constructing their opportunities – 'Local Knowledge II' (which has the same simulation properties as 'Local Knowledge'). Since National Innovators are already 'ahead' in the entrepreneurial development process, and have already obtained all the required underlying knowledge, they are endowed with all knowledge groups from the start of the simulation: not only 'Entrepreneurial Knowledge' and 'Local Knowledge II', but also 'New Venture Idea Knowledge'. Since they already possess all relevant knowledge, the 'scanning' action is disabled for them. Coming from a different location and culture, National Innovators also have different cognitive predispositions, different ways of structuring knowledge. Therefore, we implement their knowledge structuring process with the 'abstraction' action rather than the 'codification' action. Note that in our model, we use codification and abstraction as two different ways of structuring knowledge, based on the region or culture the agent group is from. For this particular application, we do not make the conceptual distinctions between the two activities as described in Boisot (1998).

When it comes to the opportunity construction process, National Innovators obtain their own set of ten DTIs 'abroad' (by combining knowledge items from the 'Entrepreneurial Knowledge', 'New Venture Idea Knowledge', and 'Local Knowledge II' groups, and bringing them to an abstraction level of 0.6). This set of DTIs, called *DTI II* (as opposed to *DTI I* in the 'home' economy), cannot be constructed by our initial four groups, as their cognitive predispositions are different (they use the codification action, not the abstraction action to structure their knowledge). However, they can acquire *DTI II* items through scanning. Once scanned, they are in a position to capitalize on them, but the base value (of the *DTI II* items) is set to 20 and not to 2500 (the base value of *DTI I* items), since 'opportunities from abroad' do not (directly) constitute opportunities in the market of our four initial agent groups, so they are treated as additional new venture ideas instead (and are given the same base value of 20). To convert them into a 'real' opportunity, *DTI II*s have to be adapted to the local region or market by combining them with the respective knowledge item of a 'Local Knowledge' group. This gives our four groups of entrepreneurs access to another set of ten DTIs – localized opportunities from abroad (*DTI II in I*) – which is given a base value of 2500 to reflect the special value of such opportunities. The opportunity construction processes are summarized in Figure 4.

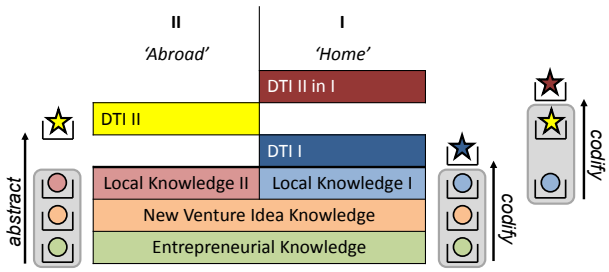

Figure 4: Opportunity Construction: obtaining DTIs 'Home' vs. 'Abroad'

The *vision* and *relocate distance* settings for all agents remain at 5 (as in the base model). We do not use the 100 by 100 *SimWorld* grid to model the international case, but implement the international dimension differently, by having two different cognitive predispositions or ways of structuring knowledge, by introducing an additional local knowledge group, and by adding new sets of DTIs. In line with Ihrig et al. (2010), we use the vision and relocate distance properties in a more generic way, as in moving closer to or further away from knowledge sources, which may or may not be interpreted in terms of space/geography.

The base-line scenario

Before running this new model, we have to establish a base-line set of outputs with which to compare the results of the simulation that incorporates the international dimension. We cannot just take the financial funds graph Ihrig (2010) produces, because adding more agents and knowledge to the simulation will cause dilution effects, and an adjusted base scenario has to be created in order to later parse out the effect we are interested in, namely the effect of the availability of knowledge about opportunities from abroad. We make the following two adjustments. First, we run the base scenario of the original *SimOpp* model with ten more (inactive) agents in order to account for the diffusion effect. The diffusion of a knowledge item, an important parameter that is part of the calculation of the exploit amount, is calculated by the number of agents that possess a knowledge item divided by the *total number* of agents. If we introduce our new 'National Innovator' group with ten agents, the increase in the total number of agents will have a direct, positive effect on the financial funds. Adding more agents in the simulation will increase the financial funds because knowledge is less diffused and thereby more valuable. Therefore, we take care of this effect in an adjusted base version. Second, we run the base scenario again with the 'Local Knowledge II' group and its ten additional knowledge items that we need for modeling the international context already added in. Increasing the numbers of knowledge items to be scanned, codified, learned and exploited also has a direct effect on the financial funds. The more knowledge items there are in the system, the longer it takes agents to reach the same amount of funds. It takes the agents more time to deal with the base knowledge before they can discover and exploit the more valuable DTIs, and therefore the financial funds graphs will shift to the right. The *vision* and *relocate distance* settings for all agents are set to 5.

EXPLORING INTERNATIONAL OPPORTUNITY RECOGNITION

Ihrig (2010) runs each scenario for 60 runs, each of 1000 periods. We analyze 2000 periods to allow us to highlight certain trajectories. Because of the complexities of our simulation, the data storage and processing capacities required are extremely high. Adding more knowledge and agents and running the simulation for 2000 periods instead of 1000 limited us to only 18 runs (rather than 60) for the adjusted base scenario and the international scenario. However, running all the scenarios described by Ihrig (2010) with only 18 instead of 60 runs showed no apparent difference between the results.

One period in the simulation is supposed to represent a particular length of 'real-world' time: the approximate conversion factor depends on the particular industry or environment being analyzed, although it could be estimated by looking, for example, at the particular duration of a specific process in the real world (e.g., it took x amount of years until Starbuck's business idea had been widely recognized in market y), and then identifying a graph that represents this process in the simulation (e.g., the knowledge diffusion curve) and checking on how many periods that run took.

Figure 5 displays the financial funds profiles of our four agent groups (in a *closed* economy) in the adjusted base scenario. The graph shows the average across all runs and also displays the standard deviation to indicate the significant difference between the individual lines. The outcome is consistent with Ihrig's (2010) base scenario. We can distinguish the different groups – based on the distinct opportunity recognition strategies of the four entrepreneurial types. Innovators perform better than Imitators, and they both outperform Copiers and Inventors, whose financial profiles overlap.

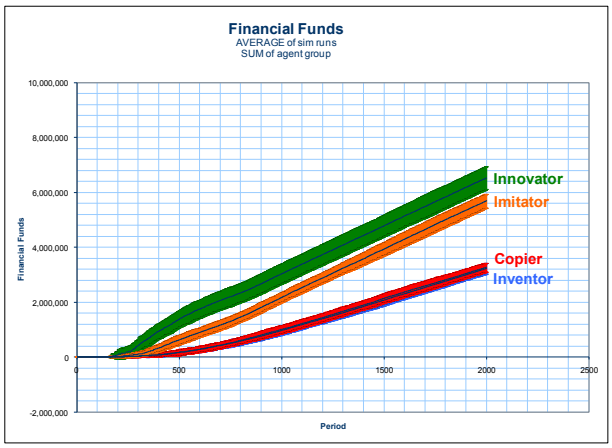

Figure 5: Financial Funds *Adjusted Base* Scenario (closed economy)

The four entrepreneurial strategies in an international environment

Having the adjusted base scenario in place, we can run our international case, which is now influenced by our lead innovator (the 'National Innovator'), the additional knowledge group ('Local Knowledge II'), and the two more sets of DTIs. Based on the distributions we have assigned to specify the properties of the four agent groups, we know their different general knowledge appropriation and development behaviors, and we tested them in a closed economy (Figure 5). How those different behaviors or strategies will play out in a population of agents in an international knowledge environment, however, we do not know. We cannot predict the specific effects this will have on the financial funds. We need the simulation to dynamically model the complex relationships among knowledge and agents across time to see how successful or not the different agent groups will be in terms of growing their financial funds and knowledge portfolios.

Individual level analysis

The financial performance of our four groups of entrepreneurial agents in an *international world* is displayed in Figure 6. The financial performance of the National Innovator group is not displayed, because we

are only interested in the effects on the original 'Home' market and its participating entrepreneurs.

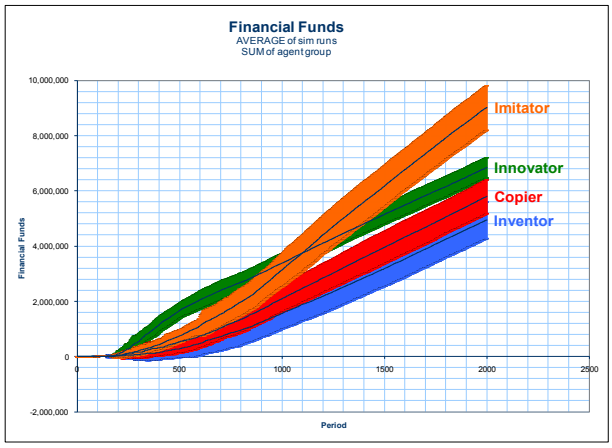

Figure 6: Financial Funds *International* Scenario

All agents gain (suggesting open markets are good), although the Innovators gain least, and the Imitators most. Whereas in the base scenario both Innovators and Imitators run in parallel (Figure 5), in the international case the Imitator group overtakes the Innovator group by period 1100 (Figure 6); and in the long run, the Imitators trump the Innovators in terms of financial funds. Ihrig (2010) already highlighted the Imitators, who are different from the Copiers and challenge the Innovators; but when the international dimension is introduced, we see the important role creative imitation plays even stronger, i.e. we see how valuable it can be to be inspired by certain preexisting ideas and further developing them. The simulation experiment thus gives evidence that the opportunity recognition strategy of the Imitator pays off especially well in a globalized knowledge economy. If the entrepreneurs of a developing country cannot follow an *innovation* or *imitation* strategy because of resource constraints, *copying* presents itself as a viable alternative. Interestingly, the standard deviations of the Copier, Inventor and Imitator groups are larger than in the base scenario, indicating higher volatility in the market associated with the entry of the international element.

Insight 1: In an international setting, when knowledge about opportunities is accessible from abroad, the financial performance of creative imitators will surpass those of classic innovators.

Societal level analysis

An advantage of using simulation methods is that, in addition to performing analyses at the micro level – looking at individual agents and agent group behaviors – users also explore effects at the macro level. Not only can we assess the financial performance of different groups of entrepreneurial agents, but we can also see the societal (whole population) effects of their actions.

In terms of societal benefits the international scenario produces a higher total financial output (GDP). As a basic measure of the population's performance, we treat the total financial funds per period (the sum of all agent groups) as a proxy for GDP. Conceptually, it can be viewed as the market value of all final goods and services made within the *SimWorld* based on the exploitation of the agents' knowledge assets.

Society at large is interested in the 'outgrowth of entrepreneurial opportunities', in growth in the number of new products or services on the market. So the most important result is that the international environment leads to an influx of new opportunities to the market, which constitutes the basis for new innovation and employment as displayed in Figure 7.

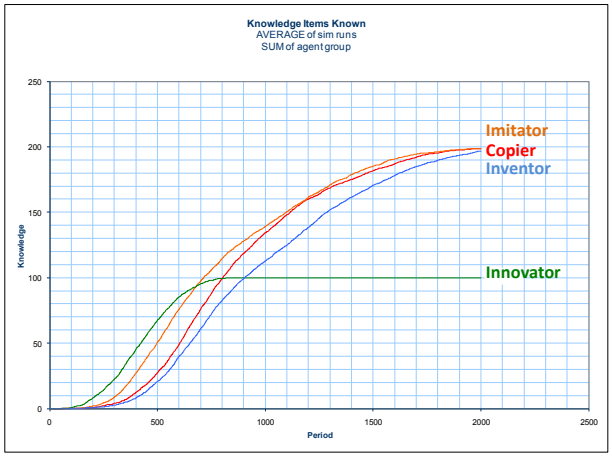

Figure 7: DTIs Known International Scenario

Note that although Imitators, Copiers, and Inventors all have access to the knowledge about opportunities from abroad (in contrast to Innovators, who just have 100 DTIs vs. 100 + 100 DTIs) and follow a similar knowledge trajectory in Figure 7, it is only the Imitators that outperform the Innovators financially (Figure 6). Overall, we can say that the international knowledge diffusion can be an important foundation for growth and continuing wealth creation, for both society as a whole and for its future entrepreneurs, who together, in virtuous cycles, build further their new insights to discover new sets of opportunities through continuous learning (Boisot, 1998).

Insight 2: In an international setting, all types of entrepreneurs in the 'home economy' benefit from exposure to knowledge from other arenas, as will society as a whole.

The international scenario lends itself to 'spatial' or geographic interpretations that have implications for regional policy initiatives and the individual strategies of transnational intra- and entrepreneurs. However, our new model also allows us to analyze industry dynamics, so that, instead of saying 'Local Knowledge' and 'Local Knowledge II' represent different cultures and regions, we characterize particular industries. Using ideas and opportunities from different industries can enable a company to outperform its competitors, but only if it is skilled at the entrepreneurial strategy of creative imitation. Again, *SimOpp* can help analyze the particular entrepreneurial actions required to succeed in different competitive environments. So we can add to

Ihrig's (2010) list of distinct simulation and modeling capabilities.

SimOpp Simulation & Modeling Capability: The extension of *SimOpp* allows one to model and simulate knowledge exchange between different cultural, spatial, and industry arenas and its resulting micro and macro effects.

CONCLUSION

Based on Ihrig (2010), we used the *SimISpace* software to develop a model that can simulate the opportunity recognition process and competitive agent behavior in a global world with international knowledge spillovers, and the respective financial payoffs associated with different entrepreneurial strategies. It allows the researcher to simulate knowledge exchange between different cultural, spatial and industry arenas and analyze both the resulting micro and macro level effects. In seeking to better understand strategic entrepreneurship in the 21st Century, we were able to analyze the four entrepreneurial strategies developed by Ihrig (2010) in an international setting and suggested real-world implications. Additional virtual experiments can now be conducted, and also other researchers that explore international entrepreneurship issues can use this *SimISpace* model to derive theory-driven hypotheses that are empirically testable.

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