

WHU-Forschungspapier Nr. 56E  
(August 1998 / translated October 1999)

**Basic Model of a Dynamic Theory  
of Economic Agents**

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# Basic Model of a Dynamic Theory of Economic Agents

WHU Research Paper Nr. 56 / August 1998

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## 1 PURPOSE OF THE MODEL

This paper aims to present the nucleus of a dynamic theory of economic agents (more specifically, the firm). Those elements of the model that are necessary and sufficient to understand and emulate the actions of and between economic agents in varying structures are described in respect of their terminology and their interactions. The discussion is based on a sequential construction of arguments and can be described in brief, i.e. it is of low complexity.<sup>1</sup>

Links to existing publications on the theory of the corporation are evident. These links are to be comprehensively analysed and integrated in later phases. Therefore, a check on the originality of the approach presented here is neither possible nor intended at this stage.

## 2 BASIC ELEMENTS OF THE MODEL

The model presented below intends to explain complex structures based on the actions of and between economic agents. Therefore, agents and actions are its basic elements.

### 2.1 Agents

#### 2.1.1 Basic properties

For the purpose of the model, agents are accorded the following sufficient, fundamental properties which determine their individuality (ref. diagram 1).

Abilities of the agent (individual „Können“, i.e. capability) may be differentiated in a first step between those of anticipation and those of realisation.

Anticipatory ability may be described as the ability to anticipate changes in the action space. It is further divided into perceptory, prognostical, and evaluatory ability:

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<sup>1</sup> The paper is based on an earlier research paper by Weber/Brettel/Schäffer (1996) as well as on the doctoral theses of Schäffer (1996), Brettel (1997), Grothe (1997), and Bach (1998), which were written at the RWE Chair of Logistics and Controlling at the WHU Otto Beisheim Graduate School of Management. The process of assimilating and reducing to the core the various models on which previous publications were based proved to be surprisingly lengthy, but also highly fascinating and fruitful. This paper, which – no longer surprisingly for us – had no precedent in the individual models of the participating agents (ref. p.8), is the result.

- Perceptory ability: This consists of the agents' ability to perceive relevant aspects of their environments as well as themselves, and to enable them to process the data thus gathered.<sup>2</sup>
- Prognostical ability: is taken to describe the ability to predict changes in the agent's action space, or – in other words – to formulate corresponding expectations with a high probability of realisation.<sup>3</sup>
- Evaluatory ability: is defined as the ability to compare relevant<sup>4</sup> conditions in the action space in terms of their value<sup>5</sup>.

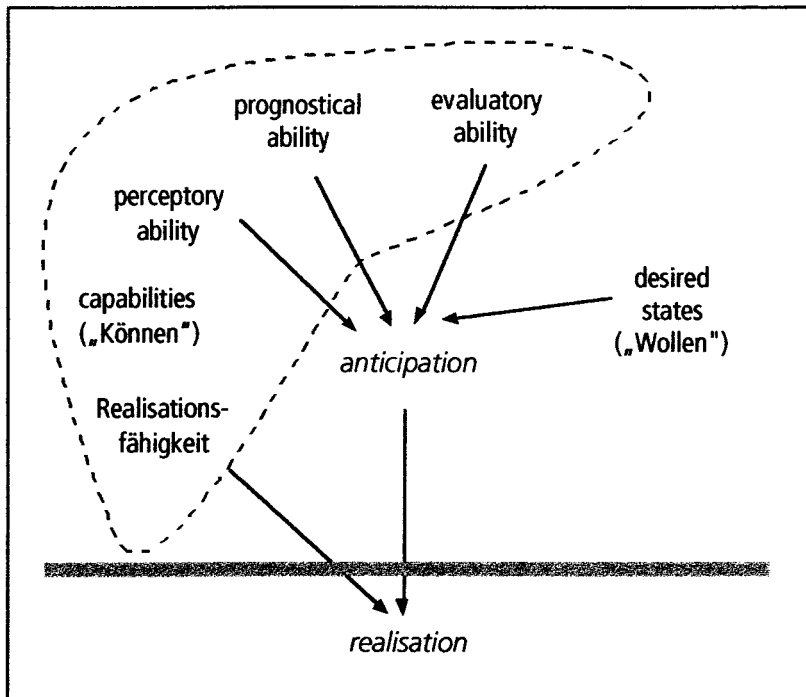


Diagram 1: Modelled properties of an acting agent

Anticipatory abilities are complemented by the ability of realisation. This is an expression of the agent's ability to realise actual changes in the action space (in relation to the state of the action space resulting from an agent's non-action)<sup>6</sup>.

Both abilities of anticipation and of realisation are limited per agent. These limits refer to qualitative elements of the respective ability<sup>7</sup> as well as to their quantitative extent<sup>8</sup>.

<sup>2</sup> Findings of cognitive sciences indicate that processing occurs quasi simultaneously as data become available.

<sup>3</sup> „Formulation of expectations“ is the explicit or implicit formulation of if-then hypotheses with which an agent depicts spatially, temporally or functionally displaced conditions.

<sup>4</sup> „Relevant“ refers to conditions which are potentially action initiating or action directing for the agent.

<sup>5</sup> „Evaluation“ in this context means giving utility values to predicted alternatives or the comparison of these values with desired end-states (ref. 2.1.2). Differing propensities to accept risk are included in this form of evaluation.

<sup>6</sup> „Realisation“ is an action (sequence) that leads to desired changes in the action space.

<sup>7</sup> In relation to a machine tooling process, for example, restrictions of the ability of realisation might become apparent in limited manual dexterity, while restrictions of the ability of anticipation might show up in limitations regarding knowledge of the part or of the machines.

Owing to their abilities, agents have a potential action space. Individual direction results from the existence of desired states (individual „Wollen“, i.e. desire / volition / intent). Several desired states may compete. It is axiomatically assumed that desired states are unlimited a priori.

The realisation of desired states is described as utility. Axiomatically, it is assumed that the higher utility that corresponds to a higher degree of realisation is preferred over a lower utility.

Desired states determine individual goal definition, while abilities provide the agent with the means to achieve the goal.

With these two impulses, the foundation for the dynamics of the approach presented in this paper has been laid: insofar as no impulse permanently dominates the other, expansive desires in competition with limiting abilities result in the dynamic development of agent-based actions.

### *2.1.2 Interactions between basic properties*

Agents are induced to search for basic patterns and connections which contain numerous units of information in a compressed form. This results from the fact that agents may not be able to process all the details of their environment because of limited abilities, and that environmental states – notwithstanding optimal abilities - cannot always be perceived because they may be out of spatial, temporal or functional range relative to the observer's position (range restriction).

The agent seeks support from auxiliary constructs that enable the anticipation of actions in spite of limited abilities. In this way, internal models are introduced to the basic model. They emerge from the interaction between desired states and individual mental abilities.

Complexity is reduced through a combination of hypothesis construction and clustering. Internal models thus appear as an instrument that enables agents to counteract limitations on their abilities, albeit at the cost of having to formulate error-prone hypotheses on the one hand and generalisations on the other. Hypotheses of this type are abstractions from individual circumstances and form the basis for the anticipation of an action by an agent. Thus, they also form the link between the abilities of the agent, which earlier on were depicted as being independent of each other.

Consequently, an internal model of relevant action types („Weltausschnitte“, the agent's perception of relevant sections of the world or environment) consists of two parts. First, it contains assumptions regarding the agent's own abilities and their subsidiary conditions („Selbstbild“, image of self); second, expectations regarding objects in the environment with which a relationship exists, and expectations concerning the consequences of varying action sequences („Weltbild“, image of the world or environment). In other words, an internal model may be described as a sorting pattern that enables a reduction of complexity in respect of an action complex by means of specialisation and standardisation.

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<sup>8</sup> For instance, the maximum rotation speed of a grinder or the cognitive limitations of a decision maker.

Internal models are formed over time based on agents' own experiences<sup>9</sup> or on knowledge gained from the experiences of others<sup>10</sup>. They can act on action complexes exclusively or in competition with other internal models.

## **2.2 Actions**

Actions as the second constitutive component of the model are defined here as productive factor combination processes that can potentially lead to a desired result. In this manner, actions are based on the characteristics of individual agents described earlier: desire motivates them to improve their individual and current utility position directly or indirectly. This undertaking is limited<sup>11</sup> by their individual capabilities in the specific context situation<sup>12</sup>.

Agents' actions are interdependent: a previous action modifies the action space and thereby influences the following actions (of the specific agent and of other agents). Ideally, two action types may be differentiated in respect of the modelling intent:

- First, an action that is completed solely for the purpose of anticipating one or several other actions, in other words, that precludes anticipating the following actions. Preclusion may occur directly (e.g. in the form of programming) or indirectly (e.g. by modifying the availability of resources).
- Second, an action that is completed in order to enhance the agent's utility position directly.

To summarise: individual agents act in order to increase their utility in the framework of and while using their individual properties. The capacity of these properties (in the context of the environment) constitutes the set of possible actions.

## **3 EXTENSIONS TO THE BASIC MODEL**

Two extensions to the basic model will be made in the following: First, an individual agent's action history is observed; second, her interaction with other agents will be described.

### **3.1 Learning**

As shown above, agents utilise hypotheses to reduce the consequences of their limited abilities. Hypotheses are error-prone, and they abstract. Therefore, agents try to collect experiences relating to the hypotheses. In order to do that, they note the effects of their actions. Given a high correlation between anticipation and realisation, the hypothesis is maintained or reinforced. If anticipation and realisation correspond to a lesser degree, the hypothesis is maintained, adapted, or discarded. In all these cases, agents continually develop their internal model. They learn. This concept is shown in the right-hand part of diagram 2. The diagram also shows that in addition to the development of

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<sup>9</sup> For instance, through a successive trial-and-error process.

<sup>10</sup> For example, the adoption of parents' behaviour patterns by children.

<sup>11</sup> This implies that two aspects are decisive for the crystallisation of a specific action: on the one hand, a chosen action obtains importance through the attached utility function, on the other, the agent's set of abilities may offer less support for alternative actions.

<sup>12</sup> The degree to which agents can actually utilise their individual abilities is of decisive importance for the context situation (e.g. the availability of necessary resources).

the internal model, an influence on the agent's abilities of realisation exists (realisatory learning).

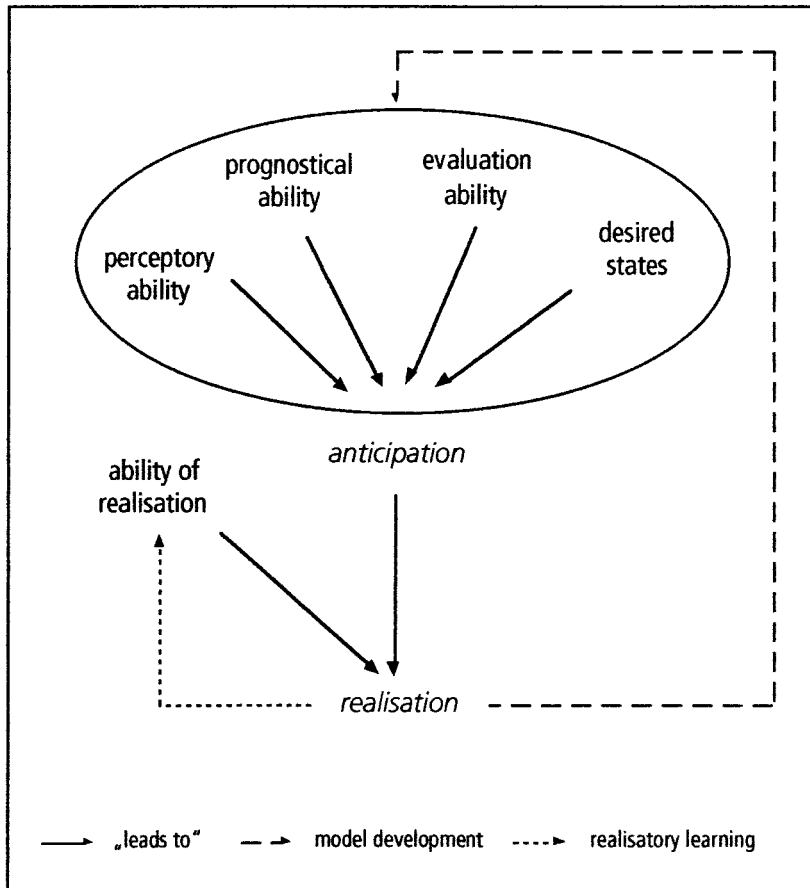


Diagram 2: Basic scheme of learning

Furthermore, agents gather experience regarding the formation of experiences, i.e. they learn to learn (second degree learning).

### 3.2 Higher order agents

The degree of improvement of agents' utility positions is dependent on their abilities of realisation and their internal models. If these so strongly influence the action generation of the individual, then the description and prognosis of the abilities of realisation and internal models of other agents gain immediate importance. In this way, the individual agent can formulate much more precise expectations regarding the actions of other agents. This implies that the internal models of other agents are significant as a context for individual anticipation.

Beyond the individual significance, the indirect<sup>13</sup> interaction between anticipation and realisation creates the potential for the endogenous creation of higher order agents<sup>14</sup>.

### 3.2.1 Concept of the higher order agent

A majority of agents is defined as a higher order agent when the potential or actual<sup>15</sup> co-operation of the agents under consideration leads to an increase in their expected utility. This may be based on shared elements of property dimensions – in the sense of a reinforcement<sup>16</sup> – or on differences in property dimensions (complementary relations)<sup>17</sup>. Cases of utility enhancement through competition (second degree reinforcements) are to be distinguished from cases where utility is enhanced through co-operation, as described previously: competition can mutually increase the levels of ability of the agents under consideration and thereby lead to different ability levels in relation with other agents<sup>18</sup>. The intuitive or reflective perception of these utility enhancing properties indicates to individual agents their potential belonging to an agent majority, i.e. to a higher order agent.

The multidimensionality of potential utility enhancing properties elucidates that individual agents may belong to several higher order agents, whose memberships in turn may overlap.

The possibility of mutual utility enhancement can lead to co-operative actions which are based on common abilities. Such linkage effects form the foundation of properties which cannot be described solely on the basis of individual actors. These co-operative actions and group abilities thus constitute higher order agents.

The concept of an acting agent is in this way not limited to a specific level of abstraction. For instance, from the perspective of a business sector as a higher order agent, companies would correspond to individual lower order agents; within a company, this role would be played by business units or divisions; within these, an individual employee would be the lower order agent. Each unit on the same abstraction level is characterised by the same properties<sup>19</sup>. In this sense, one may speak of the utility function of an organisation (e.g. corporate goals) or of „organisational knowledge“.<sup>20</sup>

Utility enhancement by means of perceived internal models and abilities of realisation accommodates the interactive forming of expectations in the group (“common

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<sup>13</sup> The „indirectness“ of this interaction is caused by the filter of individual perception, which applies to any internal model, precludes direct transparency or transformation and thus characterises the interaction between several agents.

<sup>14</sup> A lowest order agent is understood to be a single acting human being in this context.

<sup>15</sup> For instance, the competitiveness of a firm may on occasion be safeguarded even in the absence of competitive actions by third parties when the firm has to assume that a potential competitor might enter into competition without advance warning.

<sup>16</sup> Scale effects are an economically relevant example of this.

<sup>17</sup> For instance, these enable specialisation to occur.

<sup>18</sup> A special form of competition are so-called „hunter-prey systems“, which dynamically dampen undesirable fluctuations caused by inhibiting and reinforcing forces.

<sup>19</sup> N.B. that – as described – such a statement must always be based on relevant and mutual utility enhancements that are effective in a specific context. For many discussion / analysis purposes, a company *cannot* be seen as a collection of organisational units.

<sup>20</sup> „No individual nowadays disposes of the knowledge necessary to construct a modern computer, a car, or an aeroplane. However, organisations are ‘able’ to do so. And it is exactly in this sense that complex organisations nowadays are more intelligent than any human.“ (Wilke 1995, p. 297).

knowledge", „to know how things are done around here"). With these perceived advantages, binding forces are reinforced.

The independence from abstraction levels described above allows the basic model to be of a low order of complexity; at the same time, it allows the representation of any level of complexity.

### 3.2.2 *Genesis and change of higher order agents*

#### 3.2.2.1 Causes

Higher order agents emerge and change through mutual utility enhancement. Their activation can principally be linked back to two causes:

- First, a higher order agent can be created or changed through the dominance of one agent in relation to others. Such a form of co-ordination through instructions by an „authority" over other agents is described as vertical or exogenous co-ordination. The higher order agent is strongly characterised by the dominating individual agent, who generally possesses advantages regarding abilities, albeit not in every case. Vertical co-ordination can be used to co-ordinate similar („hierarchy") or different („coercion") purposes of agents. In this model, the application of coercion is (normatively) excluded.<sup>21</sup>
- Second, common structures may be created and changed through endogenous phenomena. Such patterns of adaptation may be described as horizontal co-ordination. In this way, an order may appear through mutual adjustment, which is similar in the end to an intended structure, but can be more stable and differentiated because of stronger overall bonding. The lack of exogenous instruction as a reference point emphasises the importance of individual abilities and utility functions. Horizontal co-ordination can co-ordinate similar („network") or different („market") purposes. In this process of adjustment, solutions can be found which have no precedent in the individual models of specific agents. Thus, an endogenously growing structure can be described as a discovery process that leads to new knowledge.

#### 3.2.2.2 Forms

Changes in the abilities of agents and changes in the agent constellations (integration or exclusion of agents on specific abstraction levels) can lead to changes in the utility enhancement of individual actors. In this way, they are subjected to a continuous pressure to change. The resulting change can principally occur in two forms:

- If the previously described properties of agents are subject to continuous change processes, this is described as alteration of agents, who maintain their individuality.
- If the properties of agents change abruptly or radically, this is described as complete transformation. This may lead to the termination of agents in their previous identity, but does not necessarily have to. Simultaneously, a new individuality of agents,

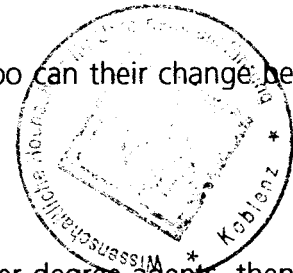
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<sup>21</sup> This assumption can, however, easily be challenged, as numerous historical examples show, and is in this way based on a certain system of norms and values.



which is determined by their parameters and events, has to be determined after the transformation.<sup>22</sup>

As was the case with the genesis of higher degree agents, so too can their change be either modelled consciously or emerge endogenously.



### 3.2.2.3 Interaction between reinforcement and inhibition

When searching for the common mechanism of genesis of higher degree agents, then the following interaction of two impulses may be distinguished on an adequate level of abstraction:

- In both cases, the reinforcement of a practice is the result: this is obvious in the case of instruction, while in the case of mutual adjustment, such a reinforcement is typically preceded by competition between alternative approaches within a group of agents.
- The second impulse becomes apparent: next to reinforcement, the inhibition of alternative solutions is necessary. In the first case, this is based on the clarity with which an agent obtains authority (through power or through expertise) as well as which instruction is relevant – all instructions thus excluded are not to be heeded. In the second case, it becomes clear that inhibition is a development process: the solution that endogenously came into existence has by definition proved to be dominant.

In this context, the genesis of a higher order agent can easily be traced to the basic forms of co-operation and competition. It also becomes apparent that the structures which can be derived from the basic elements become increasingly multi-layered and differentiated and therefore require more extensive description: they achieve high complexity.

## 4 SUMMARY

In conclusion, actions resulting from desired states and abilities of individual agents as well as the genesis and change of higher order agents can be reduced to the same abstract foundation: the interaction of reinforcement and inhibition. This is the nucleus of our basic model of a dynamic theory of economic agents.

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<sup>22</sup> The German language differentiates between „Wandel“, which we have here translated with „alteration“, and „Wechsel“, which we translate with „complete transformation“, as explained in the text.

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71.	Weber, Jürgen Schäffer, Utz	Controlling als Koordinationsfunktion? – Zehn Jahre nach Küpper/Weber/Zünd (Oktober 1999)

Rektorat / Oktober 1999