

Creating a conceptual framework for a deeper understanding of evolving processes in socio-technical systems.

Simone A.E. van Tongeren
Faculty of TPM, Delft University of Technology, Netherlands
Student Number: 1364758

2 April 2014

Abstract

The world around us changes, innovates and adapts to new selection pressures constantly. At a meta-level Universal Darwinism describes how processes evolve over time in a socio-technical system. But what actually gets selected and replicated in these systems is still debated. The possibilities of Universal Darwinism and institutional analyses is investigated with a literature study. The conceptual framework, that is constructed during the literature review, is a first attempt to describe evolving processes in socio-technical systems. The next steps that need to be taken are testing the framework with an agent-based model and operationalizing variety of socio-technical systems.

Keywords: Universal Darwinism, institutional analyses, Memetics, socio-technical systems, evolution.

Word count: 3,896 words

1. Introduction

'One general law, leading to advancement of all organic being, namely, multiply, vary, let the strongest live and the weakest die (Darwin, 1859)'.

This article focuses on the analysis of evolving processes in socio-technical systems¹. Darwin's theory is a theory that explains evolutionary change at a high level² (Aldrich et al. 2008; Hodgson & Knudsen 2006). What actually gets selected and replicated in socio-technical systems is still debated (Aldrich et al. 2008; Hodgson & Knudsen 2006). The research question of this article is therefore: *What conceptual framework can generate a deeper understanding of evolving processes in*

socio-technical systems? After a literature study, a conceptual framework is made that shows that the combination of Universal Darwinism³ and institutional analyses has a potential to describe evolution of processes in socio-technical systems. In this paper first the research method, lacks of insights and a theory overview is given. Followed by the core of the paper, the conceptual framework. It is concluded with a reflection, conclusions and future research.

2. Research Method

In this research the chosen methodological typology is to understand complex phenomena (Tashkkori & Teddlie 2003). The chosen research strategy is the design science strategy, because it allows a conceptual framework to be designed during the research (Bots 2007; Tashkkori & Teddlie 2003). To identify interesting literature, that covers the

¹Socio-technical systems are complex and consists of technical artifacts and heterogeneous decision making entities. These systems are guided by public policy in a multi-scale institutional context (Ghorbani 2013).

²There is nothing in Darwinism that belittles or excludes self-organization, human intentionality, or Lamarckian inheritance (Hodgson & Knudsen 2006).

³ Memetics, molecular genetics are also a part of the conceptual framework, however, the focus is on the combination is on the potential overlap between the Universal Darwinism theory and institutional analysis.

implementation of Universal Darwinism in socio-technical systems, a complete literature review was conducted, using the key words “Universal Darwinism”, “Change” and “Socio-technical system” in several search engines (Scopus, Web of Science, Google Scholar). Kasmire et al. (2011) contains all the key words. This work explores the possibility of using agent-based modelling in combination with Universal Darwinism. This work inter alia refers to Blackmore (1999), Dawkins (2007) and Dennett (1976), which are important theorists in the field of inter alia Universal Darwinism and Memetics. Furthermore, two other theorists who have worked in line with the key words are Hodgson and Knudsen (Hodgson & Knudsen 2010a; Aldrich et al. 2008; Hodgson & Knudsen 2006; Hodgson 2008; Hodgson 2010). These and other authors (Veblen 1899; Lewis & Stienmo 2012; Liagouras 2009) promote the idea of combining Universal Darwinism and institutional analyses in a social-technical sphere.

3. Lack of insights

There are two lacks of insight which should be investigated during the literature research, so that the conceptual framework can be formalized and the research question answered:

1. *How do processes in socio-technical systems evolve over time?*

To appropriately apply a Darwinian view (which comes from biology) on a socio-technical situation, the conceptual framework should at least cover:

- a. Gene-like entity and carrier, to study which form of information carrier and entity is present in a socio-technical system.
- b. Selection, variation and heredity mechanisms of a gene-like entity to study how relative stable information is adapted to the changing environment.

2. *How can processes in socio-technical systems be formalized?*

The theories should at least cover the following aspects to design appropriate decision-making behavior of the participants in the socio-technical system:

- a. Decision making of humans, to study how decisions are taken.

- b. Institutions⁴, to study what rules affect personal decisions.

4. Theory overview - scope

In this section the choice for Universal Darwinism and institutional analyses is explained.

The conceptual framework’s starting point is the theory of Universal Darwinism. This theory is the most simple theory that explains the mechanism of natural selection and evolution in biology. In other words how ancestors with the same origin could diverge and adapt to a changing environment (Darwin 1859). Inter alia Darwin himself suggested to generalize the core principles (variation, selection and heredity) to cover the evolution of all open⁵ socio-technical systems (e.g. Blackmore, 1999; Darwin, 1859; Dawkins, 1976; Hodgson & Knudsen, 2006; Stoelhorst, 2008; Veblen, 1899). Universal Darwinism is a meta-theory, which means that this theory does not explain every detail. The theories of institutional analyses and Memetics have assisted to operationalize Universal Darwinism for socio-technical systems.

The *Meme Machine* of S. Blackmore (1999) is in alignment with Darwin’s theory. She states that everything that is passed on from person to person is a meme. This includes all the words in your vocabulary, the skills and habits you have picked up from others. As with genes, memes can be tracked down through populations by their phenotypes (Blackmore 2000).

Institutional analyses assist to measure change in socio-technical systems as institutions are sets of rules that structure social behavior and interaction (Ostrom 1991; Crawford & Ostrom 1995). Furthermore, the institutional analyses incorporate the social structure and personal decision making process. However, to maintain the explanatory power of institutions, it is important to take the flexibility of decision making regarding institutions into account.

⁴ Institutions are rules which are accepted by all those involved, are used in practice and have some sort of durability (Ghorbani 2013).

⁵ An open system can be defined as system that is open to resources as in-and out- put (Stoelhorst & Huizing 2006).

5. Conceptual framework

In this section the conceptual framework is formulated to describe evolutionary change of processes in socio-technical systems. First, the lack of insight (*How do processes in socio-technical systems evolve over time?*) is discussed. To successfully apply Universal Darwinism a gene-like entity, the gene-like entity carrier and the translation of mechanisms concerning variation, selection and heredity need to be found in the socio-technical system.

The gene-like entity carrier in a socio-technical system is regarded as interactor (Hull 1988; Hodgson & Knudsen 2010a). The interactor is a relative cohesive entity that hosts gene-like entities and can interact with its environment so that it leads to changes in the population of interactors and their gene-like entities. Individuals and social organizations are candidate interactors (Hull 1988; Hodgson & Knudsen 2010a).

Memes are likely to be the gene-like entity of socio-technical systems (Blackmore 2000; Dennett 2007), as memes contain adaptive solutions to problems and guides the development of interactors (Stoelhorst & Huizing 2006). Decoding accumulated memes gives reason to repeat successful behaviors in future interactions with the environment (Stoelhorst & Huizing 2006).

Here an analogy is made between molecular genetics (which describes genes) and memes, as the same distribution is chosen. In molecular genetics there are coding genes and regulatory genes. The coding gene stands for a particular property of the entity. The regulation gene governs the coding gene, by determining where and when the property is expressed (J.B. Reece & Urry 2010; Mesoudi et al. 2006).

Accordingly, memes are divided into coding (hence forth: fact) memes and regulation memes, see Figure 1. Additionally, to specify regulation memes further, institutions (norms, values and shared strategies) are chosen to be the content of the regulatory memes. The reason for choosing institutions as content of regulatory memes is that institutions give structure to socio-technical systems, are relatively stable, durable and have a way to adapt to new situations which is transferred from interactor to interactor (Veblen 1899). In other words, the regulation meme and fact meme operate together, as the fact meme is 'guided' by the regulation meme from interactor to interactor.

The Institutional Analysis and Development (IAD) framework can help to understand the second lack of insight - *How can processes in socio-technical systems be formalized?*- as it helps to comprehend a complex social situation (Polski & Ostrom 1999; Crawford & Ostrom 1995). The IAD framework focusses, after the formulation of the (policy) problem, on the behavior in the action arena (action situation, individuals and groups who are 'routinely' involved in the situation). The goals of the IAD framework are to:

- 1) Identify the influence of physical and material conditions, rules-in-use and community attributes (like cultural values) on the behavior of an actor,
- 2) Identify and evaluate patterns of interactions, which is the behavior in the action arena and the outcomes from these interactions.

As visualized in Figure 2, people interact in an action arena and get influenced by the external pressures (of the community, institutions and the physical world) (Ghorbani 2013).

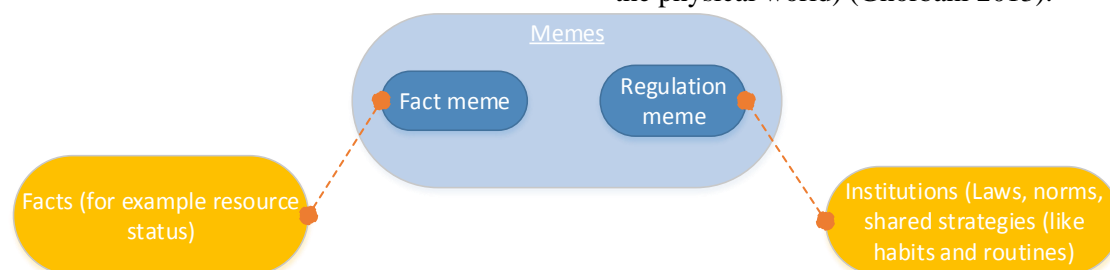


Figure 1 Memes division

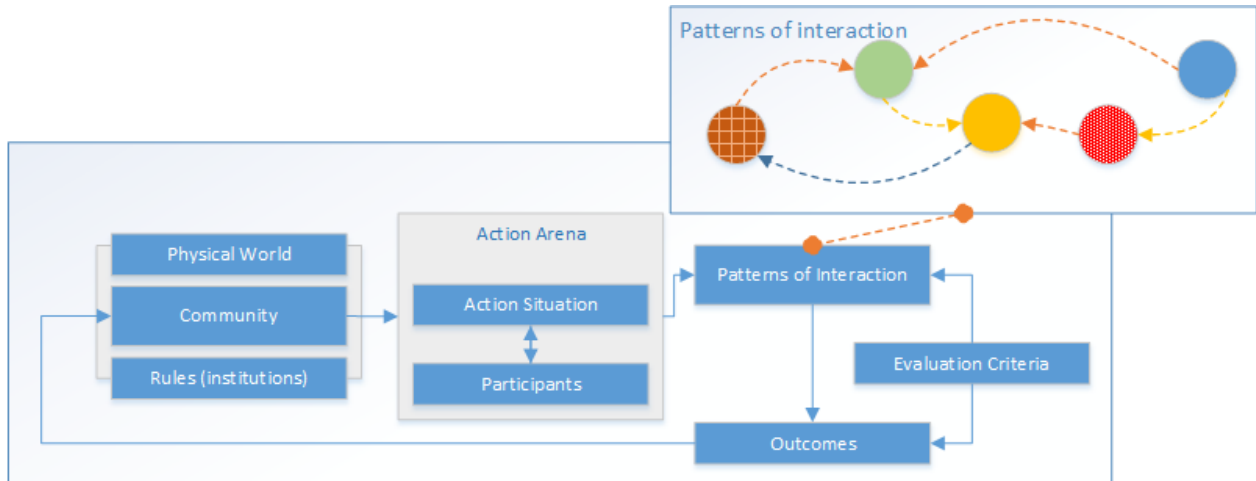


Figure 2 IAD framework (Ostrom 1991). The Patterns of interaction box, the circles are the interactor of the action arena and the arrows are the different kinds of interactions.

During a decision making process, human entities are imposed on institutions and personal priorities while making their decisions (Polski & Ostrom 1999). The priorities of the humans reflect the ability of a human to self-reflect (Bandura 1999; Blackmore 2000). In other words, an interactor’s decision making process is influenced by an internal and an external selection process (Polski & Ostrom 1999, p.22; Blackmore 2000).

The Darwinian principles are interpreted as follows. The variation mechanism in socio-technical systems is seen as the innovation and copy-errors of memes by interactors (Hodgson & Knudsen 2010b). Furthermore, variety can be of random or purposive in origin, but without variation natural selection cannot operate (Hodgson, 2008, p. 401). Geoffrey Hodgson (2002) argues that the core of the evolutionary mechanism is variation and he thereby suggests that *‘evolution can occur in any system substrate where there are mechanisms generating continued variation (Hodgson, 2002, p. 272)’*.

How and what can be varied needs to be researched. At the moment there is not much known about variation of memes in socio-technical systems (Aldrich et al. 2008). Whether a varied meme becomes the new ‘standard’ depends on the selection mechanism.

The selection mechanism entails the personal decision to replicate a particular meme, which

is dependent on a person’s personal priority, scope of memes and constraints or selection pressures memes impose (Bandura 1999; Polski & Ostrom 1999; Hodgson & Knudsen 2006).

The final Darwinian principle is heredity. It is of importance that memes are transferred and get imitated, to assure continuity of operations (Hodgson & Knudsen 2010b). Meme imitation/transfer ensures that knowledge regarding both successful and unsuccessful operations are inherited from day to day and person to person within a system (Hodgson 2013). A meme is vertically (from generation to generation) or horizontally (between a group of kids) transferred.

These three mechanisms help to study how relative stable information is adapted to the changing environment. In Table 1 an overview of the Universal Darwinism concepts’ interpretation is given.

Table 1 Summary – Universal Darwinism concepts interpretation

Concept	Concept translation
Gene-like entity	Fact and Regulatory memes
Gene-like entity carrier	Interactor
Variation	Innovation and copy errors
Heredity	Information transfer and imitation
Selection	Personal priority and memes
Environment	Fact and Regulatory memes

To identify the different foundations and variation rates of institutions, the grammar of institutions of Ostrom and Crawford (1995) and the four layer model of Williamson(1998) is incorporated in the conceptual framework.

The institutional grammar (ADICO) defines laws as ADICO, norms as ADIC and shared strategies as AIC. This grammar shows that norms in comparison to laws have no sanction (O of Or else), as *ADICO* means: Attributes: Participants, *Deontic*: Obligated/permitted/forbidden etcetera, *a/m*: Action/outcome, *Condition*: Parameters (when an ADICO statement applies), *Or else*: Sanction.

The change rate of the different kinds of institutions varies. The four layer model of Williamson (1998) describes the four social institutional levels. Starting with the informal institutions (where norms and culture are embedded), this kind of institutions changes every 100 to 1000 years. Formal rules (where laws and regulations are embedded) changes between 10 to 100 years. Agreements and contracts change between 1 and 10 years. The lowest level, operational rules, changes continuously (Williamson 1998).

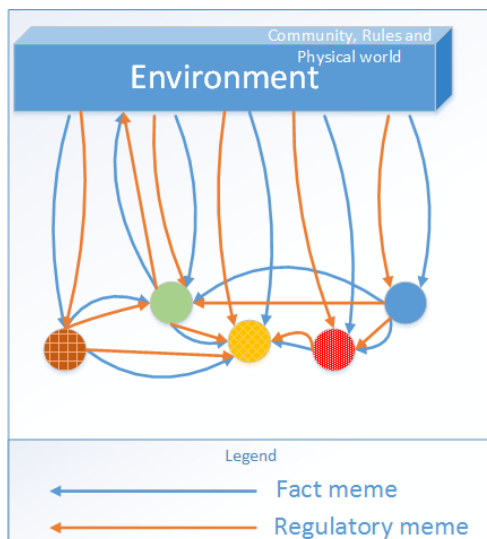


Figure 3 Visualization of the (influenced) processes on operational level

In Figure 3 the environment is (just like in the IAD framework) community, physical world and rules. The environment is dependent on

the scope of the action arena. Fact and regulation memes represent the different kinds of information streams going through the action arena.

6. Reflection

In this scientific paper a first attempt is made to compose a scientific framework that captures change of processes in socio-technical systems. In this section the benefits and complications are described.

The conceptual framework shows the overlap between the institutional analyses and the Universal Darwinism. The combination of the institutional field of theory and the Universal Darwinism seems to have potential, as the institutional analyses helps to identify:

- The 'gene-like entity' in the socio-technical system (Veblen 1899).
- The different foundations of the gene-like entity (Crawford & Ostrom 1995).
- The different change rates of existing gene-like entity (Williamson 1998).
- The network of interactors that (possibly) influences the replication of gene-like entity (Polski & Ostrom 1999).
- The human selection process of gene-like entity (Bandura 1999; Polski & Ostrom 1999, p.22).

The division between memes helped to understand processes, as a particular fact meme can stimulate the decision for a particular regulation meme. Regulatory memes help to think how an action is executed and the fact memes (together with personal priorities) define why an action is done. In other words, the meme division subscribes the different functions and foundations of information.

The definition of memes that is used in this paper is 'Everything that is passed on from person to person is a meme (Blackmore 2000)'. However, Blackmore (1998) states that not all information types are memes. Some memes are not passed on from person to person or are not imitated, for example instinctive imitation, which is inter alia yawning and laughing. This is not true imitation because humans already knew how to laugh, as people do not imitate another person's laugh. This view keeps memes away

from the many things we each learn ourselves, by ourselves and of "*anything that can be the subject of an instant of experience* (Blackmore 1998)".

It also suggests that the fact, that for example a the water tap is broken, is not in line with the definition of memes, as the water tap is not a person and the information is not imitated, as it is about an instant experience. The action, to for example call the plumber, can be imitated from person to person and can therefore be interpreted as meme. However, the conditions, under which circumstances it is appropriate to call a plumber, is generated by the facts. In other words, the fact (memes) form the conditions under which circumstances it is appropriate or common to select a particular regulation meme.

Therefore it is suggested that fact memes and regulation memes go hand-in-hand, see Figure 3 and are both imitated from person to person. However, it should be considered to call fact memes simply 'facts', as facts can be 'an instant of experience'.

Imitation and information transfer contribute to the understanding where and when a pattern of interaction stagnates or continues, due to the attention on the replication of memes.

The selection mechanism contributes to the understanding why a certain meme is transferred or not, due to insight of the internal and external selection process (Polski & Ostrom 1999, p.22; Bandura 1999).

The overall value of the conceptual framework can increase when the variation mechanism is worked out in more detail, by determining how and what can be varied and under which circumstances.

The IAD framework contributes to the analysis of evolving processes in socio-technical systems as helps to identify the action arena, flows of information (rules-in-use) in the pattern of interaction, influence of the environment, etcetera. However, during the literature research it became clear that people find it difficult to define specific norms, laws and shared strategies which are in use, as people do not organize their knowledge within the borders of institution 'types' (norms,

values and shared strategies) (Crawford & Ostrom 1995, p.595).

7. Conclusions

The objective of this paper has been to answer the following research question: *What conceptual framework can generate a deeper understanding of evolving processes in socio-technical systems?* At the beginning of this scientific paper it is stated that the conceptual framework should at least incorporate a gene-like entity, the Darwinian principles, institutions and decision making of humans in a socio-technical system.

The conceptual framework combined Universal Darwinism with institutional analyses, Memetics and molecular genetics. This combination of theories help to get a deeper understanding of evolving processes in socio-technical systems. However, the overall explaining value of the conceptual framework would increase if the variation principle is further operationalized.

Overall, the conceptual framework can be useful for situations/problems that contains:

- Regularity, as otherwise there are not institutions guiding the behavior.
- People, as they carry and replicate the memes.
- Variation of memes, as various decisions should possibly be made during a decision making process.
- Information transference, as the memes are transferred from person to person.

Situations that are less suitable to be analyzed with the formulated conceptual framework entail extreme situations (like unexpected disasters, where people tend to make 'decision-making errors (McKenzie 2003; Burns et al. 2013)), high bottom-up changing/variation rate of institutions and/or no regularity in behavior (and therefore no guidance of institutions).

Future research

The focus for future research is advised to be the operationalization of variation in socio-technical systems, as the exact logic is still unclear (Aldrich et al. 2008). Here it is suggested to use a small, non-descriptive agent-based model for testing the variation

mechanism, as such a model set up is less occupied describing the events correctly and more free to experiment with researching more general mechanisms, like the variation of memes. Furthermore, the framework should be tested by designing an agent-based model of evolving processes in a socio-technical system.

A general advantage of simulations is that different theories can be tested together, which is not possible in the real world (Gilbert 2004). An agent-based model is advised due to its

bottom-up approach and its capacity of modeling adaptive and emerging systems with inter alia evolutionary programming (Csala 2012).

References

- Aldrich, H.E. et al., 2008. In defence of generalized Darwinism. *Journal of Evolutionary Economics*, 18(5), pp.577–596. Available at: <http://link.springer.com/10.1007/s00191-008-0110-z> [Accessed August 12, 2013].
- Bandura, A., 1999. Social cognitive theory : An agentic Albert Bandura. *Asian Journal of Social Psychology*, 2, pp.21–41.
- Blackmore, S., 1998. Imitation and the definition of a meme. *Journal of Memetics*, Evolutiona(2), pp.1 – 12.
- Blackmore, S., 2000. *The Meme Machine* 1st ed., Oxford: Oxford University Press. Available at: <http://www.keepandshare.com/doc/4130148/blackmore-meme-machine-pdf-june-12-2012-1-56-pm-3-1-meg>.
- Bots, P.W.G., 2007. Design in socio-technical system development: three angles in a common framework. *J. of Design Research*, 5(3), p.382. Available at: <http://www.inderscience.com/link.php?id=14883>.
- Burns, P. et al., 2013. Human behaviour during an evacuation scenario in the sydney harbour tunnel. *Australian Journal of Emergency Management*, 28(1), pp.20–27. Available at: <http://www.scopus.com/inward/record.url?eid=2-s2.0-84882986296&partnerID=40&md5=a1739eacda4f2bc6ea860e48651f1156>.
- Crawford & Ostrom, 1995. A Grammar of Institutions. *The American Political Science Review*, 89(3), pp.582–600.
- Csala, D., 2012. Agent-Based Modeling vs. System Dynamics. *System Dynamics for Business Policy*, p.32. Available at: http://www.academia.edu/3105560/Agent-Based_Modeling_vs._System_Dynamics [Accessed March 30, 2014].
- Darwin, C., 1859. *The origin of species* 15 st., London: John Murray.
- Dawkins, R., 1976. *Selfish Gene* 30th ed., Oxford: Oxford University Press. Available at: <http://www.arvindguptatoys.com/arvindgupta/selfishgene-dowkins.pdf>.
- Dennett, D.C., 2007. Darwin's' dangerous idea. In *The evolutionists*. New York, New York, USA: Simon and Schuster, pp. 25 – 51. Available at: [http://books.google.nl/books?hl=nl&lr=&id=6iscM4gmVEsC&oi=fnd&pg=PA25&dq=darwin's'](http://books.google.nl/books?hl=nl&lr=&id=6iscM4gmVEsC&oi=fnd&pg=PA25&dq=darwin's)

+dangerous+idea&ots=HzbWhaQgx0&sig=UbBfdyXSdA6CMDeHqdCkmAFedTQ#v=onepage
&q=darwin's' dangerous idea&f=false.

- Ghorbani, A., 2013. *Structuring Socio-technical Complexity* 1 st., Delft: Nest Generation Infrastructure Foundation.
- Gilbert, N., 2004. Agents-based social simulation: dealing with complexity. *The Complex Systems Network of Excellence*, 9(25), pp.1–14.
- Hodgson, G.M., 2010. Darwinian coevolution of organizations and the environment. *Ecological Economics*, 69(4), pp.700–706. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0921800908002966> [Accessed November 6, 2013].
- Hodgson, G.M., 2002. Darwinism in economics: from analogy to ontology. *Journal of Evolutionary Economics*, 12(3), pp.259–281. Available at: <http://link.springer.com/10.1007/s00191-002-0118-8>.
- Hodgson, G.M., 2008. How Veblen Generalized Darwinism. *Journal of economic issues*, XLII(2), pp.399–406.
- Hodgson, G.M., 2013. Understanding Organizational Evolution: Toward a Research Agenda using Generalized Darwinism Corresponding. , p.22.
- Hodgson, G.M. & Knudsen, T., 2010a. Generative replication and the evolution of complexity. *Journal of Economic Behavior & Organization*, 75(1), pp.12–24. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0167268110000454>.
- Hodgson, G.M. & Knudsen, T., 2010b. Generative replication and the evolution of complexity. *Journal of Economic Behavior & Organization*, 75(1), pp.12–24. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S0167268110000454> [Accessed September 2, 2013].
- Hodgson, G.M. & Knudsen, T., 2006. Why we need a generalized Darwinism, and why generalized Darwinism is not enough. *Journal of Economic Behavior & Organization*, 61(1), pp.1–19. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S016726810500199X> [Accessed August 12, 2013].
- Hull, D.L., 1988. A mechanism and its metaphysics: An evolutionary account of the social and conceptual development of science. *Biology and Philosophy*, 3(2), pp.123–155. Available at: <http://link.springer.com/10.1007/BF00140989>.
- J.B. Reece & Urry, L.A., 2010. *Campbell Biology - Concepts and Connections* 9th ed., New Jersey: Pearson Education.
- Kasmire, J. et al., 2011. Universal Darwinism in Greenhouses: proof of concept using an agent based model. In *International Conference of Networking, Sensing and Control*. Delft: IEEE, pp. 11–13.
- Lewis, O. & Stienmo, S., 2012. How Institutions Evolve: Evolutionary Theory and Institutional Change. *Polity*, 44, pp.314–339. Available at: <http://www.palgrave-journals.com/polity/journal/v44/n3/full/pol201210a.html>.
- Liagouras, G., 2009. Socio-economic evolution and Darwinism in Thorstein Veblen: a critical appraisal. *Cambridge Journal of Economics*, 33(6), pp.1047–1064. Available at: <http://cje.oxfordjournals.org/cgi/doi/10.1093/cje/ben061> [Accessed November 6, 2013].

- McKenzie, C.R.M., 2003. Rational models as theories – not standards – of behavior. *Trends in Cognitive Sciences*, 7(9), pp.403–406. Available at: <http://linkinghub.elsevier.com/retrieve/pii/S1364661303001967> [Accessed November 6, 2013].
- Mesoudi, A., Whiten, A. & Laland, K.N., 2006. Towards a unified science of cultural evolution. *The Behavioral and brain sciences*, 29(4), pp.329–47; discussion 347–83. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/17094820>.
- Ostrom, E., 1991. Crafting institutions for self-governing irrigation systems. , 13(33).
- Polski, M.M. & Ostrom, E., 1999. An Institutional Framework for Policy Analysis and Design. , pp.1 – 49. Available at: <http://mason.gmu.edu/~mpolski/documents/PolskiOstromIAD.pdf>.
- Stoelhorst, J.W., 2008. The explanatory logic and ontological commitments of generalized Darwinism. *Journal of Economic Methodology*, 15(4), pp.343–363. Available at: <http://www.scopus.com/inward/record.url?eid=2-s2.0-57649224015&partnerID=40&md5=d95af58a9e7e83aae51783b0eb92a39c>.
- Stoelhorst, J.W. & Huizing, A., 2006. The firm as Darwin Machine: an evolutionary view of organizational knowledge and learning. *Working Papers on Information Systems*, 6, pp.1 – 27. Available at: <http://sprouts.aisnet.org/6-15> 28.
- Tashkкори, A. & Teddlie, C., 2003. *Handbook of mixed methods in social and behavioral research* 1 st. S. Publications, ed., United Kingdom. Available at: <http://books.google.nl/books?hl=nl&lr=&id=F8BFOM8DCKoC&oi=fnd&pg=PR9&dq=handbook+of+mixed+methods+in+social+&+behavioral+research+2002+newman+sage&ots=gTiOyApsPd&sig=SH9lZoxdrbj0qaAbEUdR1oBxW3I#v=onepage&q=167&f=false>.
- Veblen, T., 1899. *The Theory of the Leisure Class* 1st ed. M. BANTA, ed., Oxford, UK: Oxford University Press. Available at: <http://digamo.free.fr/veblen99.pdf>.
- Williamson, O.E., 1998. Transaction cost economics: How it works; where it is headed. *De Economist*, 146(1).