# Technological development by value networks in a multi-region industry; An agent-based model for innovation policy experimentation

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**Aims of the study**:

1. Propose an agent-based model of technology development by value networks over the industry life-cycle, with an explicit multi-regional perspective.
2. Engineer policies that stimulate the innovative performance of regions by enabling 'breathing' of the regional layout of value networks.

**Keywords**: technology development, value network, regional layout, industry life-cycle
**Methodology**: experimentation with agent-based model simulation

In manufacturing industries, development and production of products take place in value networks. Value networks consist of firms connected through technological input-output relationships. Raw resources are extracted by upstream firms, then processed by intermediary suppliers, and after a number of production steps ultimately assembled into a final good delivered to the end-consumer. Although extraction processes occur where raw resources are located and final goods are to be sold where consumers can buy them, final assembly and intermediate production steps are also often concentrated in geographical space (Audretsch & Feldman, 2004). However, manufacturing industries go through phases of inception in which new product technology is developed, growth in which product-market segmentation occurs, maturation and decline. Ultimately, fierce price and scale competition erodes profit margins, which forces firms to look for radical technological breakthroughs. In Vermeulen & De Kok (2013), we studied the development of value networks over this industry life-cycle, particularly the interaction between the production and innovation network activities. In a companion paper, we argue that value networks have a certain *regional layout* in the sense that the different firms in the value network may or may not reside in the same region. Generally, in the production network, the regional layout is determined by factor costs, particularly during the growth and mature phases. The innovation network, active particularly during the decline and inception phases, changes subject to the search for technological knowledge through collaboration with new partners. We expect that the regional layout of value networks reflects the challenges of the different industry life-cycle phases. We expect that ties are generally intraregional during the mature stage of the industry life-cycle, while ties are more often interregional to accommodate experimental recombination with new knowledge during the decline and inception stages of the industry life-cycle.

We specify an agent-based model in which firm agents autonomously form multi-tier value networks that develop and produce products for the end-consumer market. At the core of the agent-based model is our operational artifact-transformation model of technology. Firm agents use transformations they have mastered to form output out of input artifacts (or raw resources). Each artifact is thereby a tree of input artifacts connected by the transformations used, whereby these input artifacts may or may not be produced by and acquired from other firm agents. Given the inputs needed, firm agents look for (alternative) suppliers, thus forming and changing the production network. Firms in the value network routinely improve the products produced. We operationalize incremental search by having agents attune their own artifact to the artifacts by agent up and/or downstream in their value network.
As said, in the decline and inception phase of the industry life-cycle, firms look for radical breakthroughs. In our model, we operationalized this as a search for new transformations that enable the production of new products. Transformations span a phylogenetic network, where

raw resource extractions are the roots of the network and where phylesis, speciation and reticulation events form advanced transformations out of more primitive transformations. Agents search for new transformations in this (undisclosed) network by trying to extend their current transformations (for phylesis and speciation) or by trying combinations of their transformations, possibly with transformations of other agents (for reticulation).
The availability of particular artifacts allows new transformations, while new or altered transformations may allow production of new or improved artifacts. So, both the portfolio of artifacts produced and the transformations available to firms develop over time, paced by competition of the value networks that ultimately produce the final products brought onto the market.

For policy experimentation and engineering purposes, we control the initial distribution of transformations over agents and of these agents over regions. Furthermore, we control the spatial limit to both the production network partnership (and thereby formation of the product) and the innovation network partnership (and thereby transformation discovery). We then study technological progress under different distributions (over regions, over a regional public pool, and over firms in the value networks) and different spatial limits of network formation heuristics used by the agents.
Of all temporal policy programs, we find that a program shortly described as ‘paced and temporized clustering’ performs best. In general, policies that enable the existing market-driven dynamics are conducive for technological performance. In the decline and inception phases, the innovation network (should) extend(s) interregionally to acquire new transformations, while in the growth and mature phases, the network (should) converge(s) to static and efficient local production. However, we also find a so-called *regionality paradox*. Policies should prevent that value networks and thereby regions converge prematurely in the inception phase. Furthermore, particularly in the mature phase, market forces may have firms outsource particular production steps to other firms, either within the region or even in other continents, to lower production costs. Regional regulation should not counteract such ’natural shifts’ because it may hurt total value network performance and thereby endanger the employment and economic growth in the region altogether. So, apart from ‘pacing and temporizing’, the network’s regional layout should be allowed to ‘breath’ with the competitive challenges of the industry life-cycle phases.
Moreover, we also find that establishing a research institute offering a publicly available pool of diverse transformations in times of industry decline and inception boosts performance of technology developed in the region and curbs the need to seek interregional ties.