The network topology and the agility of a supply chain

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Objective

To analyze the influence of the network structure on the agility of a supply network, which is understood as "the ability to respond rapidly to unpredictable changes in demand or supply" [1].

Introduction

Previous results point to the prevalence of scale-free structures and derivatives as the most convenient topologies for agile supply networks. Our main hypothesis is that this is not the case for supply networks where every agent is supplied by other agents in the precedent tier and supply to agents in the subsequent tier. This condition is adapted to the case of some real food supply chains, where the product and information need to pass through intermediaries and bypass seldom occurs.

The model

In order to test our hypothesis, we build a model, called Supply Chain Random Network (SCRN), which represents a supply network with three tiers (suppliers, wholesalers and retailers). We assume that the agents' degree distribution in every tier follows a certain probability distributions. So, the network topology is a combination of two bipartite networks. A sample of the random graph is obtained by following the same procedure used for the configuration model [2].

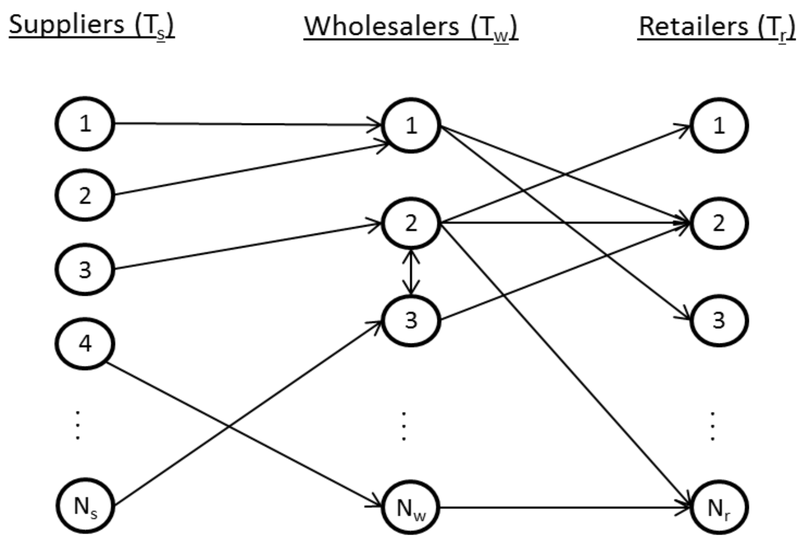

Figure 1. Representation of the supply chain random network with three tiers. Arrows indicate flow and direction of material between firms. The bidirectional arrow indicates horizontal relationships between wholesalers.

We assume a hierarchy rule to allocate orders and supplies:

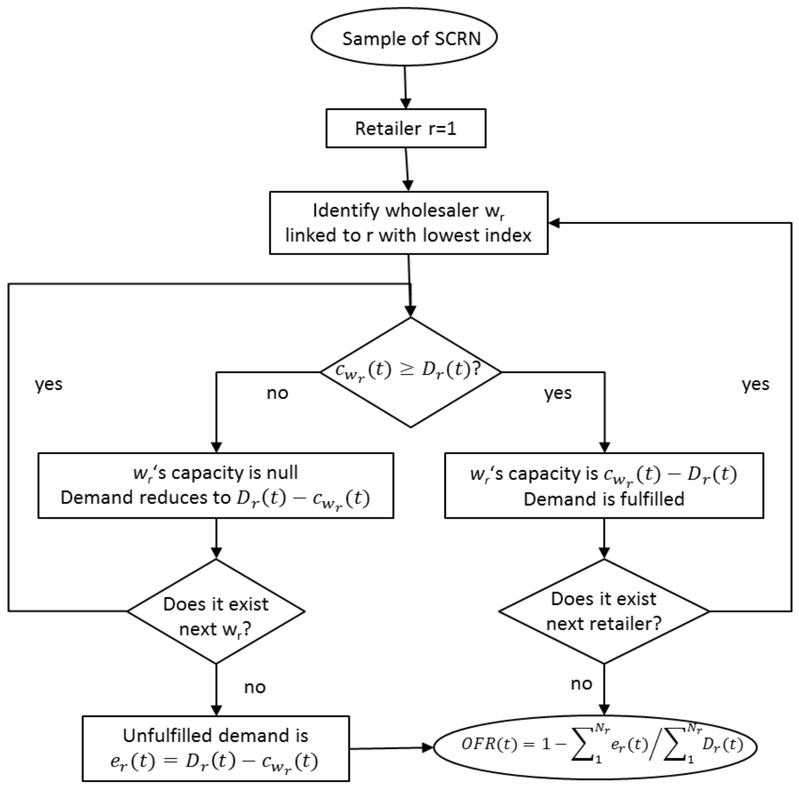

Figure 2. Flow chart of the order allocation rule in the SCRN at every time step. $D_r(t)$ is the demand from retailer r at time t and $c_{wr}(t)$ is the total amount of material retailer wr can distribute at time t. Agility is measured through the order fulfillment rate at every time step, OFR(t).

Simulation and empirical results

Empirical data

An empirical supply chain (SC) was reconstructed based on several interviews made to a sample of 10 wholesalers in the Mercado del Mar (MM), in Guadalajara, Mexico, the second largest fish marketplace in the country. The degree distribution in the MM was estimated.

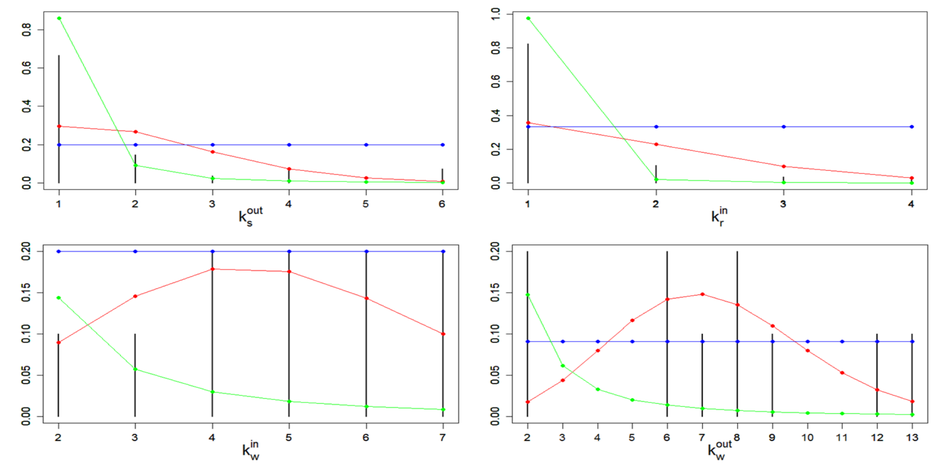

Figure 3. Empirical degree distributions of links between the three tiers in the SC of the MM in Guadalajara: k_s^{out}, out-degree distribution of suppliers; k_w^{in}, in-degree distribution of wholesalers; k_w^{out}, out-degree distribution of wholesalers; k_r^{in}, in-degree distribution of retailers. Three hypothetical degree distributions with the same mean than the empirical sample were added: Blue, uniform distribution; Red, zero-truncated Poisson distribution; Green, power-law degree distribution.

Simulation results

We assume a constant demand throughout 15 time steps excepting t=3, where a sudden increases occurs.

Agility is measure by the Order Fulfillment Rate of the demand from retailers at every time step.

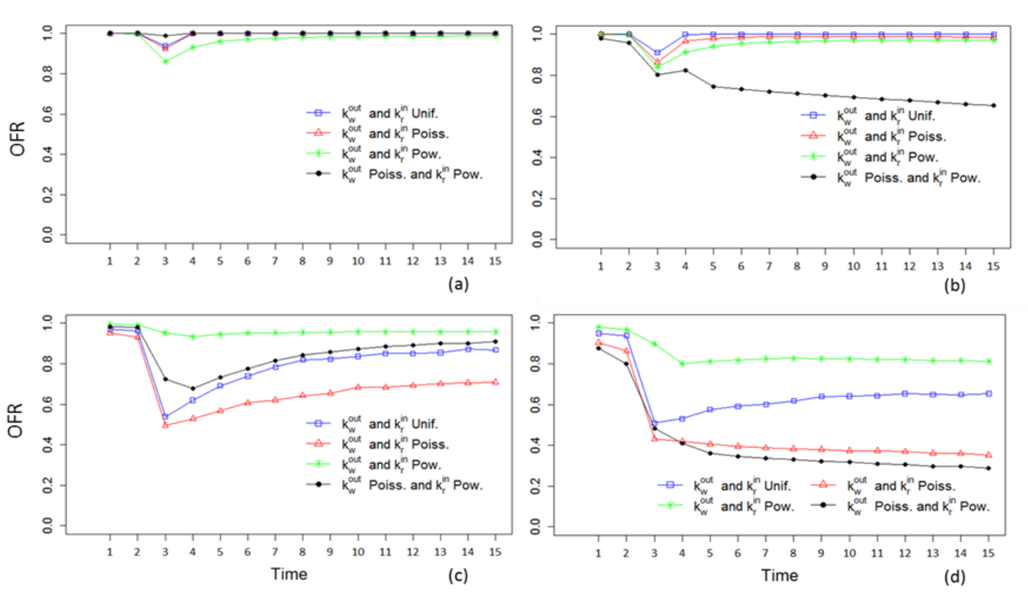

Figure 5. Trajectory of the order fulfillment rate (OFR) along 15 time periods in the SCRN. Every graph presents four trajectories corresponding to different discrete distributions: All Uniforms (Unif.); All zero-truncated Poisson (Poiss.); All zero-truncated power-law (Pow.); k_w^{in} and k_w^{out} zero-truncated Poisson and k_r^{in} zero-truncated power law (empirical sample).

(a) Production is evenly shared among suppliers; relationships among wholesalers and retailers are ordered according degrees;
(b) Production is evenly shared among suppliers; relationships among wholesalers and retailers are randomly assigned;
(c) Production is shared among suppliers following a zero-truncated power-law probability function; relationships among wholesalers and retailers are ordered according degrees;
(d) Production is shared among suppliers following a zero-truncated power-law probability function; relationships among wholesalers and retailers are randomly assigned;

Technical details: (i) The ratio of the number of firms between tiers is 3:1:6, the number of wholesalers is N_w=100 and there is not horizontal relationships; (ii) The mean in-degree of retailers is $\bar{k}_r^{in}$=2 (iii) The figures are obtained by doing 1000 simulations of the SCRN and taking mean values.

Conclusions

- In the type of supply chains analyzed here, homogeneous distribution of links favors agility more than heterogeneous distributions of links if the product is evenly shared among suppliers.
- However, heterogeneous distributions are better for agility if the product is not evenly shared among suppliers.
- Higher agility levels are obtained by increasing the number of relationships among firms in two subsequent tiers. Horizontal links between firms in the same tier also increase SC agility.

References

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