

# **The opponent's review**

## **on Kirill Vasilyevich Tsyganov Master's thesis**

### **“A Model of Oligopoly Based on Network Approach”.**

The master's thesis of Kirill Vasilyevich Tsyganov is devoted to game-theoretic modeling quantity competition of finite number of firms producing homogeneous product with a special structure of firms' costs. Firms are included into the network which linearly affects their production costs: the more links the firm has, the lower costs per unit are. Kirill considers two-stage game: at first stage firms form the network, while at second stage firms compete in quantity in accordance with costs determined by this network. The strategy of a firm at the first stage is to offer forming link to some subset of other firms, a link is formed when both firms mutually wish it. The strategy at the second stage is choosing the quantity of production. The market price linearly decreases as a function of total output. Firms know the network structure and are able to calculate costs of all competitors. The goal of every firm is to maximize its total benefit. The thesis studies several versions of firms' interaction: non-cooperative setting, full cooperation on both stages, and cooperation only at the stage of quantity competition.

The purpose of this thesis is to construct and analyze mathematical models of how network sharing costs in oligopoly influence equilibrium outcomes under cooperation and without it. This is an important point for understanding what incentives of firms in market competition are. It is to be noted that this problem is now really urgent in modern literature since it is relevant to micro-foundations of various economic processes. Introduction of this thesis (Section 1) presents quite full review of related research in this area and allows make a conclusion that this thesis is of theoretical importance.

To realize the main purpose author solves several problems: 1) he constructs formal two-stage oligopoly game and finds Nash solution in non-cooperative version by using backward induction approach (in Section 2); 2) he analyzes different widespread network topologies and discusses which topology is more preferred for the firm in dependence from its location in the network; 3) he examine two cooperative settings with cooperation on both stages and only on the second stage, formalize the notion of characteristic function in maximin terms, and find cooperative solutions: Shapley value and CIS value (in Section 3); 4) he conducts sensitivity analysis by adding and removing link in the network and demonstrates analytically how this transformation affects equilibrium outputs (for all examined games); 5) he develops several modifications made the model more realistic: alternative way to production costs accounting distance between collaborative firms (Section 2.6), introducing non-zero offering costs and solving the appropriate game (Section 4), considering alternative principles for building characteristic function in cooperative game (Section 5). Conclusion contains a brief survey of research and confirms that all purposes are reached.

I would like to emphasize that all propositions have strong mathematical proofs and verification which demonstrates high level of Kirill's mathematical skills. Language of master's thesis is clear enough; all formulations are expressed legibly in accordance with academic standards. Since for all models accurate analytical solutions are obtained, this could be useful for further practical application for concrete market structures. The example (Section 2.5.2) demonstrates how it can be done.

Though automatic checking revealed some elements of plagiarism in this thesis, manual control shows that all these elements are just standard terminology, or introductory phrases, or incorrect automatic treatment of mathematical formulae. Therefore, I assert that there is no plagiarism in this research, and all results presented in this thesis are novel.

As a little criticism I must indicate that in introduction the text is not divided into paragraphs in a proper way (only three too long paragraphs at four pages). One more remark is that this thesis contains probably too many various models of network quantity competition, so the main focus is moved to their formal solving. I believe, it would be better if there were the less number of models, but more discussion and interpretation of each result since every solution deserves a special attention. Nevertheless, these remarks do not reduce the positive impression of the whole research.

**General conclusion:** master thesis of Kirill Vasilyevich Tsyganov meets the requirements of Master program Game Theory and Operations Research, and deserves an *excellent* grade, thus the author can be given the desired degree.

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Подпись заверяю

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