

## JOURNAL OF SECURITY AND SUSTAINABILITY ISSUES

ISSN 2029-7017 print/ISSN 2029-7025 online

2015 December Volume 5 Number 2

[http://dx.doi.org/10.9770/jssi.2015.5.2\(12\)](http://dx.doi.org/10.9770/jssi.2015.5.2(12))

### EFFECTIVE AND SUSTAINABLE COOPERATION BETWEEN START-UPS, VENTURE INVESTORS, AND CORPORATIONS

**Bulat Akhmadeev<sup>1</sup>, Sergey Manakhov<sup>2</sup>**

<sup>1</sup>*Plekhanov Russian University of Economics  
Stremyanny per. 36, 117997 Moscow, Russian Federation*

<sup>2</sup>*Scientific research institute "Development of education"  
Plekhanov Russian University of Economics,  
Stremyanny per. 36, 117997 Moscow, Russian Federation*

*E-mails: <sup>1</sup>bulat.a@mail.ru; <sup>2</sup>sman2003@mail.ru*

*Received 25 July 2015; accepted 10 October 2015*

**Abstract.** The paper studies the effective, strategic and sustainable interaction between start-ups, venture investors and corporations occurring within the course of innovation investments; it analyses some results of merger and acquisition processes. When modelling these interactions between the entities of innovation ecosystems the authors used agent-based method as the most applicable for decentralized system modelling which also includes the venture investment sector and the merger and acquisition market. Modelling various case scenarios for government regulator, the authors propose some cases and sustainable solutions which enable the overall growth of economy and lead to the optimization of inputs and outputs and to the systematization of the model.

**Keywords:** agent-based modelling, decentralized systems, venture investments, mergers and acquisitions, innovation development

**Reference** to this paper should be made as follows: Akhmadeev, B.; Manakhov, S. 2015 Effective and sustainable cooperation between start-ups, venture investors, and corporations, *Journal of Security and Sustainability Issues* 5(2): 269–284.

DOI: [http://dx.doi.org/10.9770/jssi.2015.5.2\(12\)](http://dx.doi.org/10.9770/jssi.2015.5.2(12))

**JEL classifications:** M21

## 1. Introduction

The competitive advantage of national companies in international markets is one of the main conditions of the economic development, enhancement of life quality and successful realization of national priority programmes. The resolution of these issues is hardly possible without effective use of results of the fundamental scientific research and developments in the commercial sector of an economy (see e.g. Krejci *et al.* 2015; Kozubíková *et al.* 2015, Ignatavičius *et al.* 2015; Tvaronavičienė, Černevičiūtė 2015). Competitive advantage in innovative economy is mainly determined by efficient commercialization of innovations and the right usage of knowledge. Therefore, the process of creation of new technologies needs to be considered and studied well (Howitt 2004; Tvaronavičienė 2014; Rezk *et al.* 2015).

The realization of new ideas in the real economy is encompassed by both positive and negative factors that affect the formation of candidate innovations. If a breakthrough technology exists in a too adverse environment,

its progress can stop. On the other hand, a moderate competitive environment can give growth to potential technologies at the same time eliminating futureless projects (Geroski 1990; Matetskaya 2015; Tunčikienė, Drejeris 2015).

Consequently, it is important to study the role of prolific environment, under which we consider a system that includes all objects and their surroundings, both functioning as one unit. A prolific innovative environment assumes presence of a creative entrepreneurial atmosphere, research institutions working in cooperation with business, start-ups' research and development (R&D) state support and the access to venture capital etc. (Abrahám *et al.* 2015; Laužikas, Mokšėckienė 2013; Tunčikienė, Drejeris 2015).

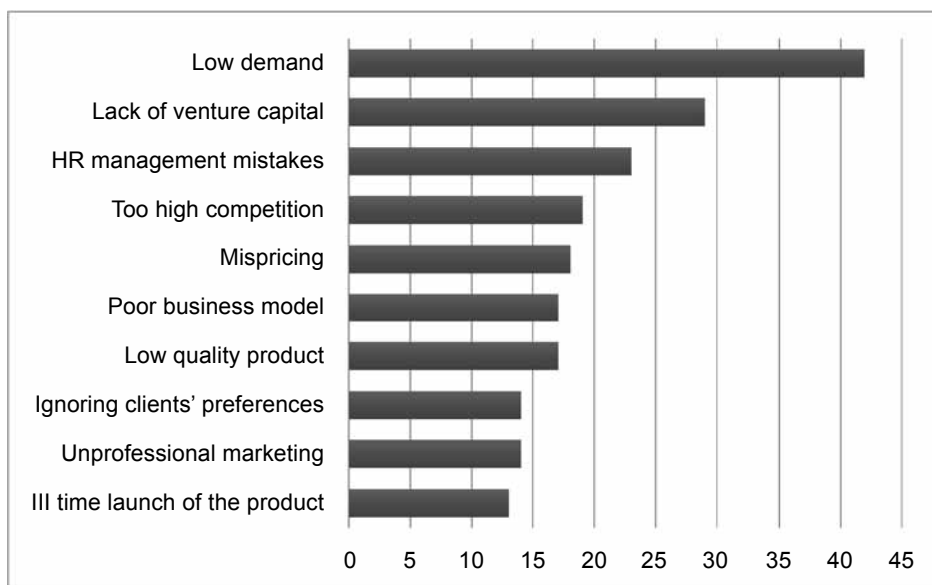
## 2. The start-up phenomenon and the reasons of their failure

As the global practice shows, big corporations are not able to grasp all the spectrum of emerging innovative technologies even in their own area of business. Having poor opportunities to pursue emerging innovative technologies and new trends, they are bound to seek other ways of development, one of which is acquisition of smaller innovative companies or purchase of their shares.

A start-up is an immature company that after its creation gets to an eco-surrounding, which as a rule functions under rigorous rules of market competition (Bruton and Rubanik 2002; Mesnard and Ravallion 2006; Grubicka, Matuska 2015; Pather 2015). This can be compared based on the analogy of biological systems where a baby of some animal starts living in an ecosystem and he faces multiple attacks from other species of the same system. Often such animals die during their first moments of life.

The survival rate of start-ups during their first few years is very low (see e.g. Morril 2015; Laužikas *et al.* 2015). The reasons for that are manifold. According to CB Insights (2015), that has carried out a study of the main reasons of start-ups' failure during their first four years of existence, the main reasons are as follows (Figure 1).

Figure 1. The main reasons of start-up failure (percentage)



Source: CB Insights (2014)

The statistical data on start-up failure shows that the older a company is the more chances it has to fail. For example, on the tenth year there are only 29% start-ups still functioning (Figure 2).

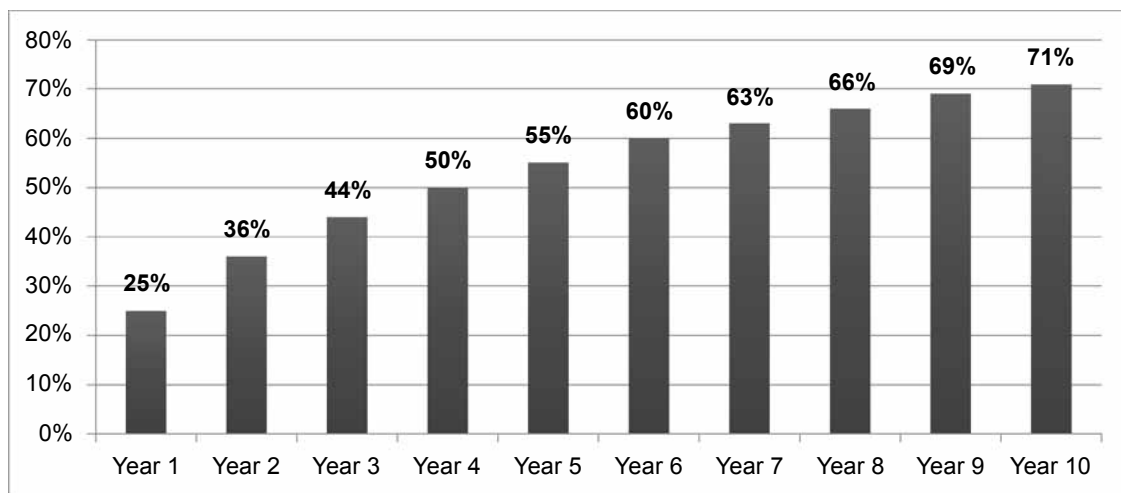
The Figure 1 indicates that start-ups have low success rate mainly because of lack of capital and business expe-

rience. As a result of existence of such factors in a certain ecosystem, the potential of innovative start-ups is not used effectively; also commercially unsuccessful start-ups can be better utilized instead of letting them go of.

The analysis of investment practice into start-ups indicates the following problems:

- i) The number of investments on the 1<sup>st</sup> round (seed investments) exceeds the number of 2<sup>nd</sup> round investments five times. This results in supply and demand misbalance.
- ii) More than half of start-ups cannot find venture capital after the 1<sup>st</sup> round and die within the first three years. [1]
- iii) Consequently, venture capitalists' investments are misapplied.

**Figure 2.** Start-up failure by year



Source: Brain (2015)

Therefore, the aforementioned problems condition the need to design a multi-agent model of interaction between start-ups, venture capitalist and big corporations (start-up-investor-corporation model) aimed at finding the optimal parameters of the system.

### 3. Start-up-venture investor-corporation model

Aiming at optimizing both global and individual parameters of the system in hand, we propose the following principal scheme of cooperation of agents in the ecosystem (see Figure 3).

The simulation has an information field where agents move in random directions with random speed and have limited information about the whole system (and other agents) showed as a radius of their field of vision. Thus, the agents-investors have a certain probability to meet suitable start-ups and invest in them at any time step.

The venture investors can invest in start-ups at the early stages by buying shares in start-ups' capital. The corporations can both invest by buying shares and also acquire start-ups. The model allows to simulate and study long life-cycle of start-ups that consists of several stages of investment; the last stage, at favorable conditions, can be a start-up's Initial Public Offering (IPO) and thereby the transformation of a start-up into a corporation. Below we give a more detailed description of the agents' parameters, functions and their algorithms of behavior at different stages of their development. Global model parameters can be presented as follows:

The simulation information field with the height and width equal to 1000 units.

$t$  – period of simulation;

$S(t)$  – number of start-ups;

$C(t)$  – number of corporations;

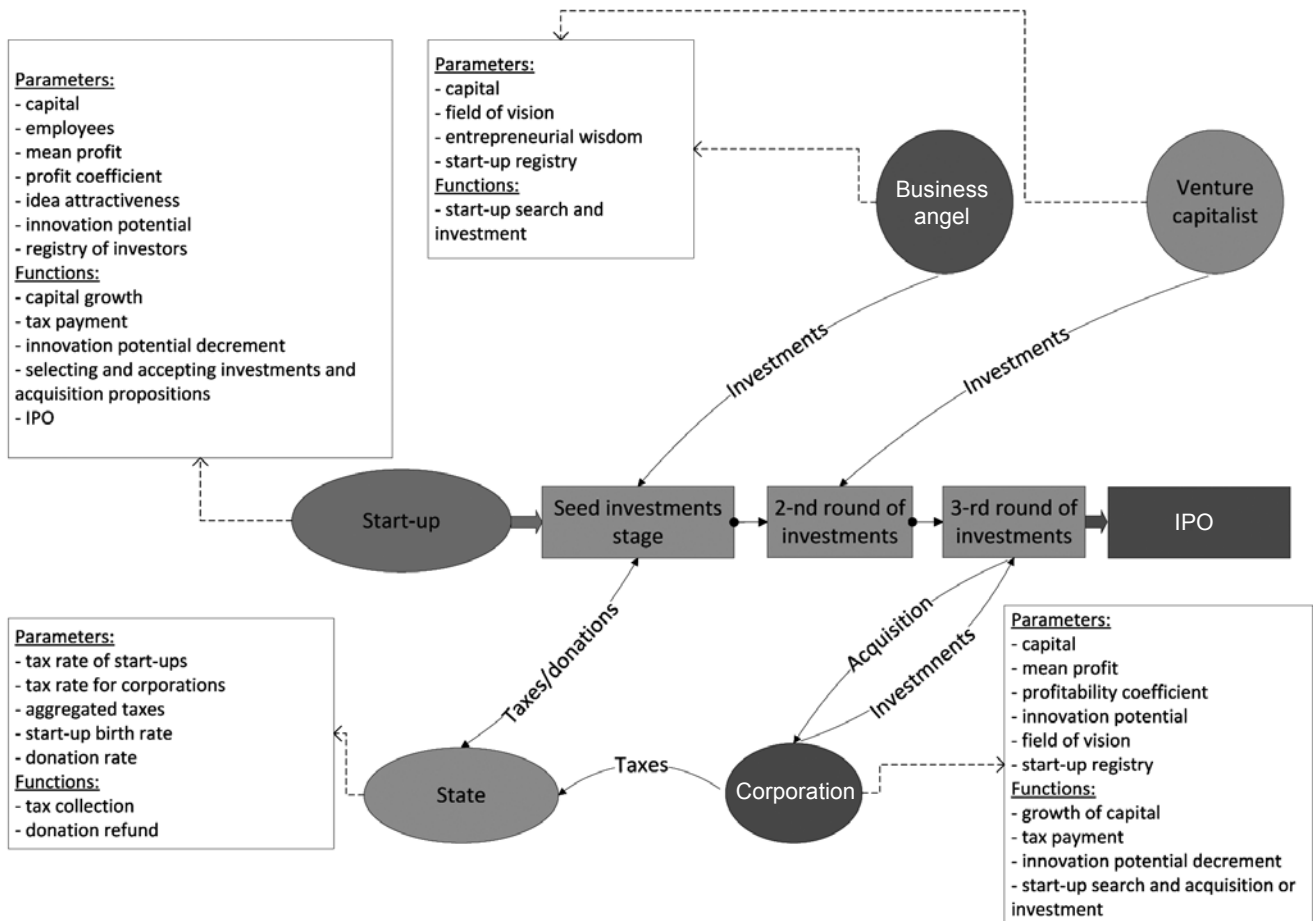
$V(t)$  – number of venture investors;

- $T_S$  – tax rate for start-ups;
- $T_C$  – tax rate for corporations;
- $T$  – overall collected taxes;
- $\Theta$  – start-up birth coefficient;
- $\Lambda_S$  – maximum allowable number of start-ups;
- $\Lambda_C$  – maximum allowable number of corporations.

The start-ups' increment function at every period of simulation is as follows:

$$S_t = S_{t-1} \cdot (1 + \Theta) \quad (1)$$

Figure 3. Cooperation scheme between agents: start-ups, venture investors and corporations



Source: Own results

Start-up class parameters:

$A_S$  – a start-up's capital; set randomly from the equal distribution (min; max) at the time of creation of this agent;

$B$  – a start-up's number of employees; set randomly from the equal distribution (min; max) at the time of creation of this agent;

$\gamma$  – a start-up's idea attractiveness coefficient, available for other agents; set randomly from the equal distribution (min; max) at the time of creation of this agent;

$\delta$  – a start-up's innovative potential coefficient, unknown for other agents; set randomly from the equal distribution (min; max) at the time of creation of this agent;

$M_S$  – the mean of the normal distribution of a start-up's profit, which is found the following way:

$c(t) = invnormal(dRate(t))$  – the probability distribution of profit of dead start-ups in the inverted normal

distribution, where  $dRate(t)$  is the proportion of died start-ups in the period  $t$  (see Figure 2);  
 The collected mean value of profit adjusted for the initial capital is denoted by the following formula:

$$m(t) = -A_0 - c(t) \cdot r(t) \quad (2)$$

where  $A_0$  – the initial capital,  $r(t)$  – collected mean value of the mean-square deviation found by the following formula:

$$r(t) = \sqrt{r^2(t-1) + \sigma(t)} \quad (3)$$

The mean-square deviation of profit in the period  $t$ , where  $v$  - the coefficient of deviation increment, which is found by the following formula:

$$\sigma(t) = \sigma(t-1) \cdot v \quad (4)$$

The mean value of profit of a start-up in the period  $t$  is found by the following formula:

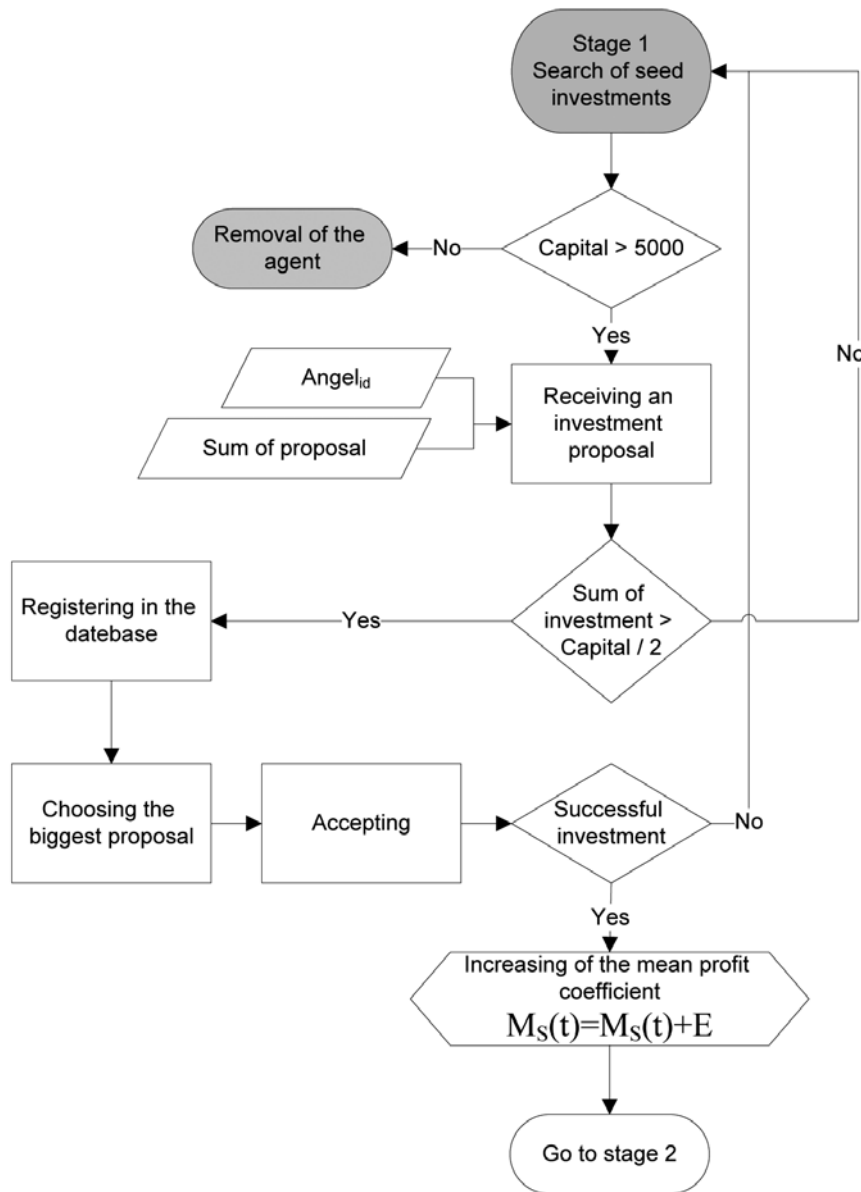
$$M_S(t) = m(t) - m(t-1) \quad (5)$$

$\alpha(t)$  – the coefficient of capital increment in the period  $t$ , belongs to the normal distribution with the deviation  $\sigma(t)$  the mean value  $M_S(t)$ , in each period  $\alpha$  is recalculated;

The functions are the following: firstly, the profit  $P_S$  for the time period  $t$  is calculated by the formula (6). The profit is affected by the start-up's attractiveness  $\gamma$ , potential  $\delta$  and the rate of competition between start-ups  $\frac{\Lambda_S}{S(t)}$ :

$$P_S(t) = \alpha(t) \cdot \frac{\Lambda_S}{S(t)} \cdot \gamma \cdot \delta \quad (6)$$

Figure 4. The algorithm of search of seed investments



Source: Own results

Then taxes a paid from the profit  $P_S(t)$ :

$$T(t) = P_S(t) \cdot T_S \quad (7)$$

where  $T_S$  – tax rate for start-ups.

A start-ups capital  $A_S$  increases by the current profit  $P_S(t)$  excluding the taxes:

$$A_S = A_S(t-1) + P_S(t) \cdot T_S \quad (8)$$

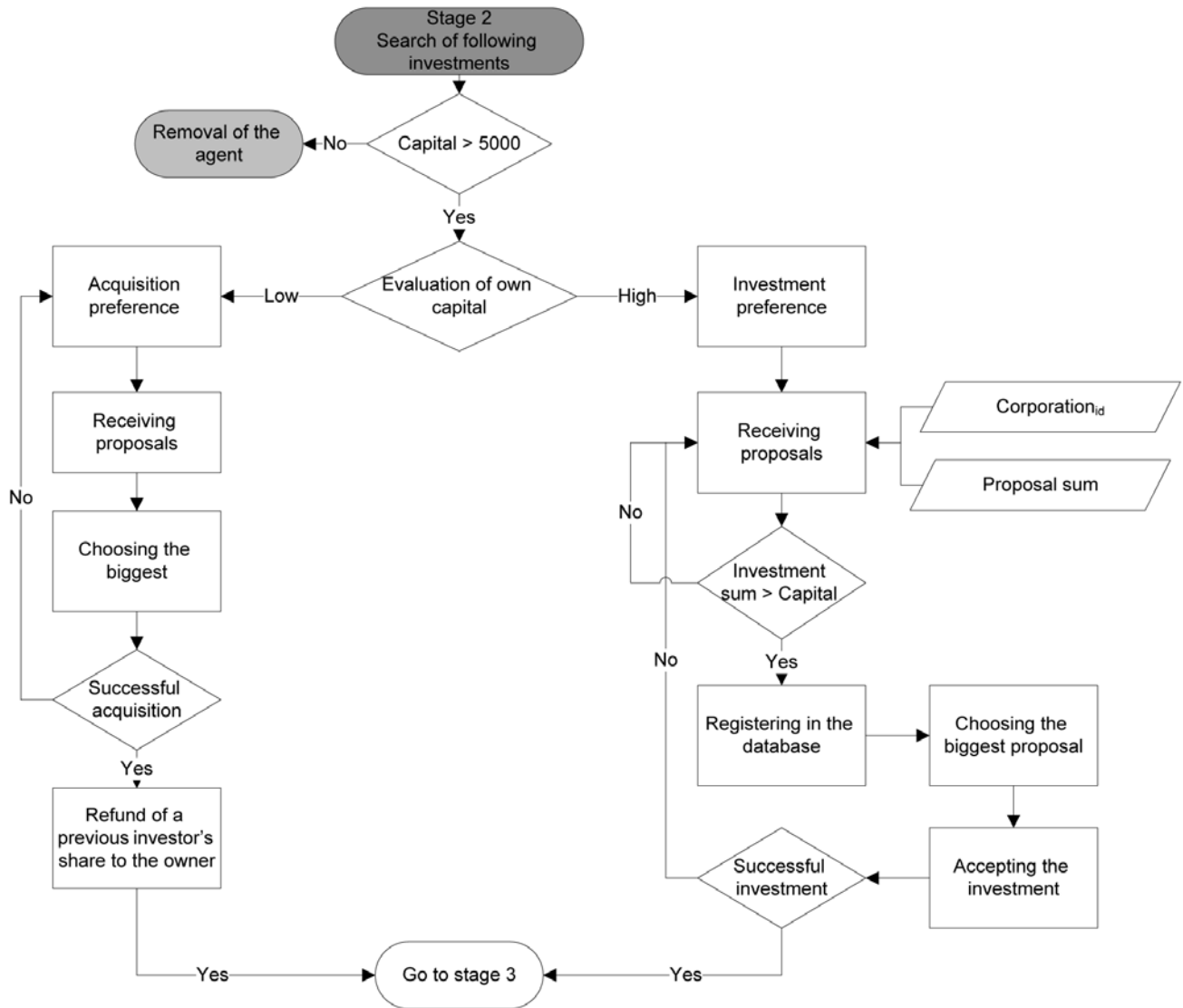
In every time period (t) of the simulation a start-up's innovation potential decreases by 5%:

$$\delta(t) = \delta(t-1) \cdot 0,95 \quad (9)$$

In every time period a start-up's capital gets checked – if  $A_S < 5000$ , this start-up is removed. Start-up's algorithms and stages of development:

- 1) «Searching seed investments»: all initial parameters and the status “looking for an angel investor” (see Figure 4).
- 2) «Search of venture capital»: an angel has already invested and the start-up has an opportunity to market its products (see Figure 5).

Figure 5. The algorithm of search of next venture capital



Source: Own results

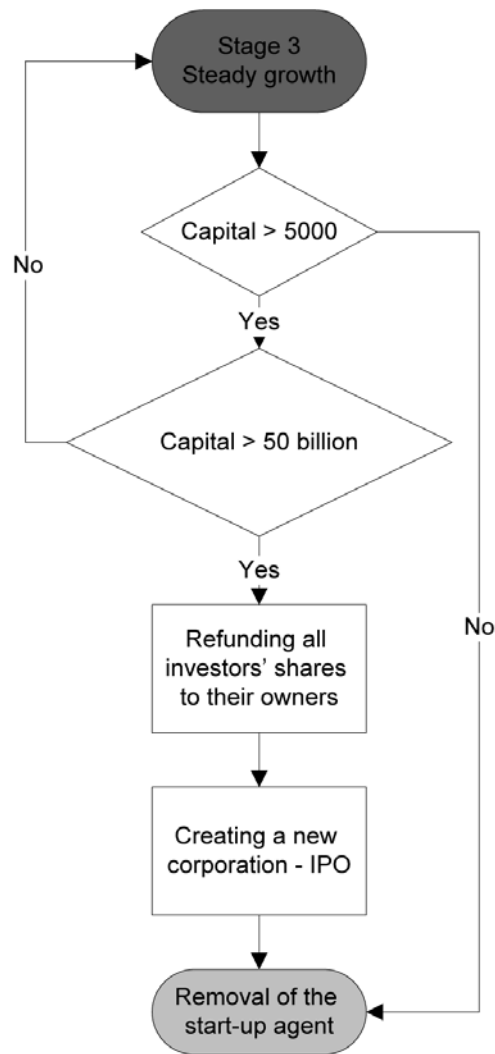
Then start-up searches a corporation in order to attract additional investments or to be acquired by the corporation (see Figure 5). If some corporation invests or acquires, it refunds previous venture investors' shares in the start-up:

$$A_V = A_V + A_S \cdot Share \quad (10)$$

where  $A_V$  – venture capitalist's capital,  $A_S$  – start-up's capital.

3) «Steady growth»: if on the previous time period no corporation acquired this start-up, then if the start-up's capital reaches a high point:  $A_S > 50\,000\,000$  the start-up gets transforms into a corporation (IPO) (see Figure 6).

Figure 6. The algorithm of steady growth and IPO of a start-up



Source: Own results

In case of IPO, the start-up refunds to venture investors as well as to corporations that had invested in previous time periods. The refund calculates the capital increment as well:

$$A_C = A_C + Share \cdot A_S \quad (11)$$

where  $A_C$  – a corporation’s capital.

The refund to a venture capitalist is carried out by the formula (10). Venture capitalist class has the following parameters:

$A_V$  – an investor’s initial capital; set randomly from the equal distribution (min; max) at the time of creation of this agent;

$A_{VS}$  – an investor’s invested capital calculated as a sum of shares in start-ups, in which the investor has invested;

$R$  – radius of field view of the investor, set randomly from the equal distribution (min; max) at the time of creation of this agent;

$\omega$  – «entrepreneurial wisdom» of the investor, the ability to see a start-up’s innovative potential, set randomly from the equal distribution (min=0; max=1);

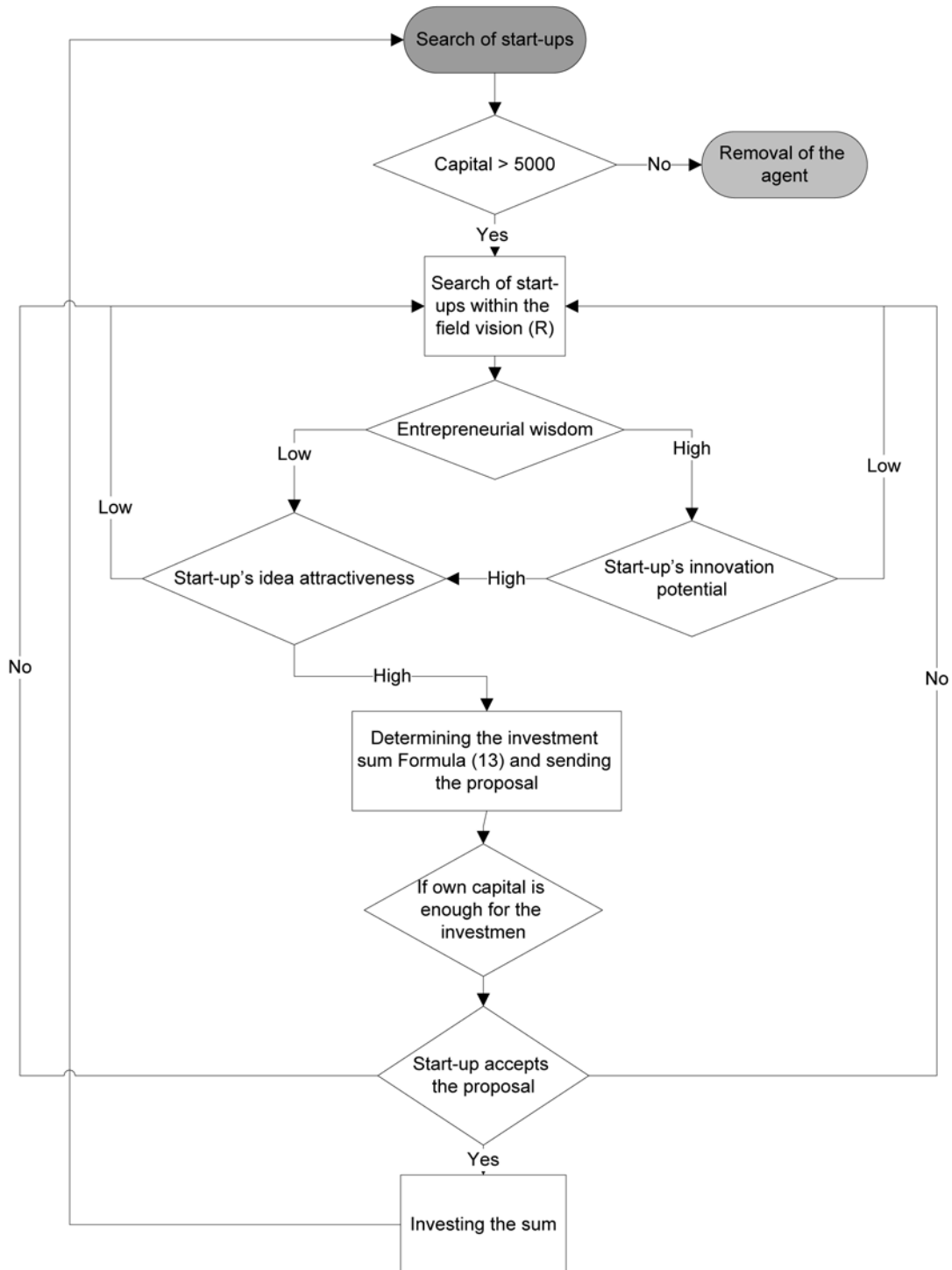


The functions are the following: the invested capital for the period  $t$  calculated as a sum of shares in start-ups that got investments:

$$A_{VS}(t) = \sum_{j=1}^n A_{S_j}(t) \cdot Share_j \quad (12)$$

where  $n$  – number of start-ups received investments,  $t$  – time period of simulation,  $j$  – a start-up from investor's collection,  $A_{S_j}(t)$  – capital of  $j$ -th start-up,  $Share_j$  – shares in  $j$ -th start-up.

Figure 7. Venture investor's algorithm of investment process



Source: Own results

1. Search of start-ups in radius R;
2. If  $\gamma_j > 0$ , then investment ( $I$ ) into a start-up – random value from the equal distribution, which depends on investor's own capital  $A_V$ :

$$I = (\min = 10\% \cdot A_V; \max = 35\% \cdot A_V) \quad (13)$$

3. If the entrepreneurial wisdom is high  $\omega > 0,5$ , the investor is able to see a start-up's potential:
  - a. If a start-up has a positive innovative potential ( $\delta > 0$ ), then the investor send an investment proposition to a start-up;
  - b. Is a start-up accepts an investment proposition, then investment of the sum  $I$ :

$$A_S = A_S + I \quad (14)$$

Subtraction of investment sum from investor's own capital:

$$A_V = A_V - I \quad (15)$$

- c. Else – denial of investment.
4. If the entrepreneurial wisdom is low  $\omega \leq 0,5$ , then sending an investment proposition without checking for potential; is a start-up accepts, then investment of the sum  $I$  by formulas (13) (14),
5. In case of investment:
  - a. entrepreneurial wisdom of investor increases by 5% ( $\omega = \omega \cdot 1,05$ )
  - b. the information about investments is registered in a database *sList*, where the share in the company is calculated by the formula (16):

$$\text{CapShare} = \frac{50-20}{\max-\min} \cdot \text{Inv} + 20 - \frac{30 \cdot \min}{\max-\min} \quad (16)$$

where  $j$  – a selected start-up for investments from the whole collection within the radius R; min and max are limitary values of investment sum determined in the formula (13);

If  $A_{V_S}(t) + A_V < 5000$ , then this agent is removed.

Corporation class is coded by the following parameters:

$\delta$  – a corporation's innovative potential coefficient, unknown for other agents; set randomly from the equal distribution (min; max) at the time of creation of this agent;

$M_S$  – mean value of the profit;

$A_C$  – a corporation's capital; set randomly from the equal distribution (min; max) at the time of creation of this agent;;

$A_{CS}$  – a corporation's capital calculated as a sum of shares in start-ups, in which the investor has invested;;

$R$  – radius of field view of the corporation, set randomly from the equal distribution (min; max) at the time of creation of this agent;

$\omega$  – «entrepreneurial wisdom» of the corporation, the ability to see a start-up's innovative potential, set randomly from the equal distribution (min=0; max=1);

$\varepsilon = \delta + \alpha$  – «innovation hunger» of the corporation (the lower it is the higher is the hunger – the need in new start-ups to be acquired).

The functions are the following: firstly, profit  $P_C$  is calculated for the period  $t$  by the formula (17); the profit is affected by the innovative potential  $\delta$  and the competition intensity among corporations  $\frac{\Lambda_C}{C(t)}$ , where  $\Lambda_C$  – limitary number of corporations that the market can hold,  $C(t)$  – number of corporations in the period  $t$ :

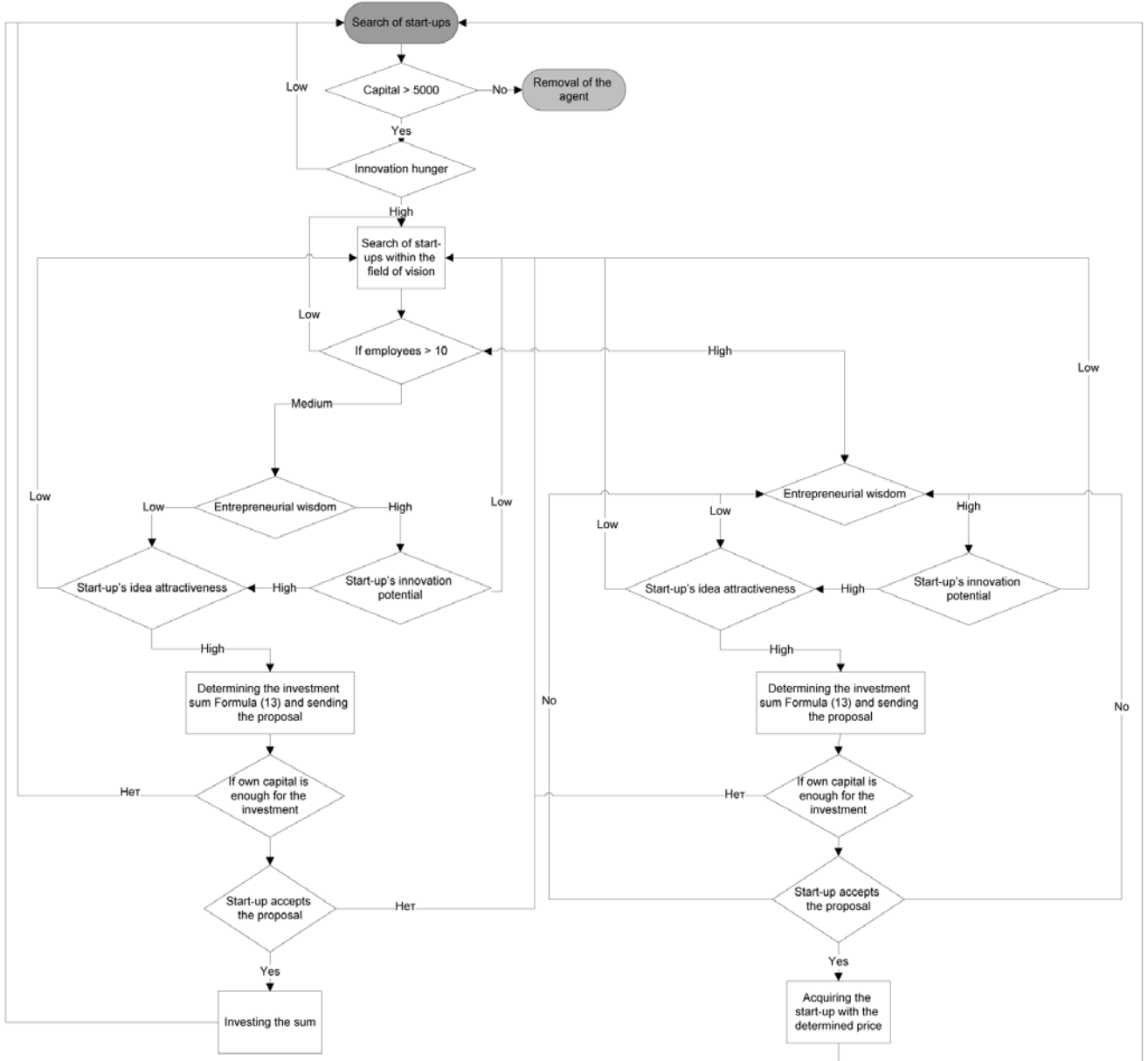
$$P_C(t) = \alpha(t) \cdot \frac{\Lambda_C}{C(t)} \cdot \delta \quad (17)$$

Then taxes from profit  $P_C(t)$  are refunded:

$$T(t) = P_C(t) \cdot T_C \quad (18)$$

where  $T_C$  – tax rate for corporations.

**Figure 8.** Corporation's algorithm of choosing start-ups



Source: Own results

Corporation's capital  $A_C$  increases by the current profit  $P_C(t)$  excluding the taxes:

$$A_C = A_C(t - 1) + P_C(t) \cdot T_C \quad (19)$$

Every time period  $t$  the innovation potential decreases by 5%:

$$\delta(t) = \delta(t - 1) \cdot 0,95 \quad (20)$$

Invested capital for the period  $t$  is calculated as a sum of shares in start-ups that got investments:

$$A_{CS}(t) = \sum_{j=1}^n A_{S_j}(t) \cdot Share_j \quad (21)$$

where  $n$  – number of start-ups that have been invested,  $t$  – time period,  $j$  – start-up form the investment collection,  $A_{S_j}(t)$  – capital of  $j$ -th start-up,  $Share_j$  – shares in the  $j$ -th start-up's capital. The algorithm of action is in Figure 8.

1. Check for innovation hunger: if  $\mathcal{E} < 0,1$ , then
2. Search of all start-ups in the radius  $R$ ;
3. If the capital of start-up is within the range  $500000 > \alpha(t) > 1500000$  and number of employees  $\beta > 10$ , then determining the sum of investment ( $I$ ) – random value from the equal distribution and depending the its own capital -  $A_C$ :

$$I = (\min = 10\% \cdot A_C; \max = 35\% \cdot A_C) \quad (22)$$

4. If the entrepreneurial wisdom is high enough  $\omega > 0,5$  then it see the start-up's potential:
  - a. If a start-up has a positive potential ( $\delta > 0$ ), then sending the investment proposition to a start-up;
  - b. If the start-up accepts the proposition, then investing the sum  $I$  by the formulas (22) и (23):

$$A_S = A_S + I \quad (23)$$

Subtraction of investment sum from the capital:

$$A_C = A_C - I \quad (24)$$

- c. Else – refusal of investment.

The share in start-up's capital is calculated by the formula (21).

5. If the entrepreneurial wisdom is low ( $\omega \leq 0,5$ ), then sending the investment proposition without checking the start-up's potential; if the start-up accepts the proposition, then investing the sum  $I$  by the formulas (22) (23).
6. If the start-up's profit is high  $\alpha_j > 1500000$  and it has enough employees  $\beta > 10$ , then the corporation acquires the start-up after checking the potential (depending on the entrepreneurial wisdom) analogous to n.4.
7. Then refund of previous investments to their holders – investors and corporations:

$$A_{V_j} = A_{V_j} + A_S \cdot Share_{V_j} \quad (24)$$

where  $A_{V_j}$  – capital of investors that had previously invested,  $A_S$  – capital of the start-up,  $Share_{V_j}$  – this investor's share in the start-up's capital.

$$A_{C_j} = A_{C_j} + A_S \cdot Share_{C_j} \quad (25)$$

where  $A_{C_j}$  – capital of corporations that had previously invested,  $A_S$  – capital of the start-up,  $Share_{C_j}$  – this coroporation's share in the start-up's capital.

Then the acquiring corporation subtracts the sum of the acquired start-up's capital from its own:

$$A_C = A_C - A_S \quad (26)$$

The innovation potential of the start-up is transferred to the acquiring start-up (divided by 5);

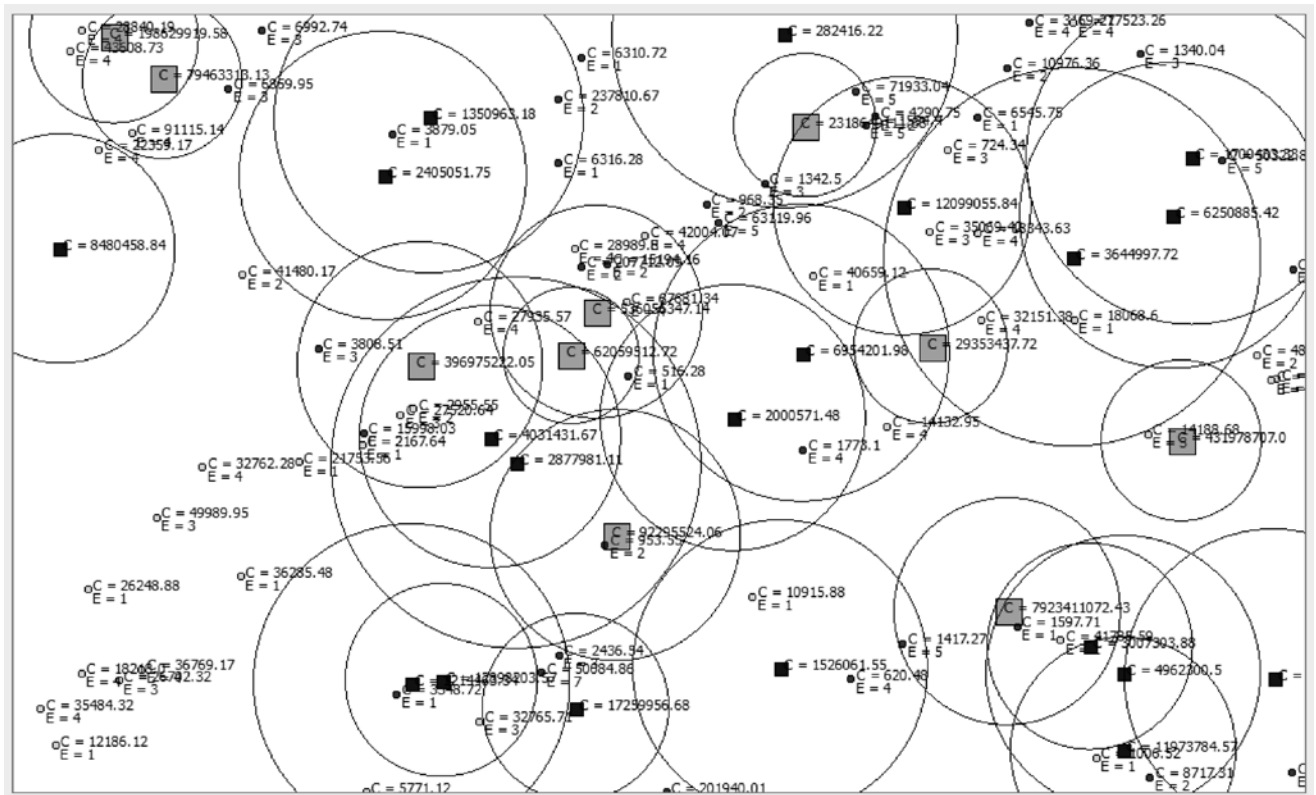
$$\delta_c = \delta_c + \frac{\delta_s}{5} \quad (27)$$

where  $\delta_c$  – corporation's potential,  $\delta_s$  – start-up's potential. Then the start-up agent is removed. If a corporation's capital  $A_C \leq 5000$ , then it's removed.

#### 4. Software for simulation of the model

For approbation of the multi-agent model described above we designed a special software. It allows to visualize the interaction between agents in real-time mode: movement in random directions in the information field, the field of vision of the agents, the process of investment and acquisition of one company by another, the process of IPO. Agents corporations are represented by pink square pictograms, venture investors – by blue square pictograms, start-ups – by green circles (on the seed stage), by blue circles (on the 2-nd stage) and by blue circles (on the 3-rd stage). In case of IPO, the start-up is transformed into a corporation and changes its pictogram. If a corporation acquires a start-up it get removed from the field. The visualization of the simulation is presented on Figure 9.

Figure 9. The visualization of the model start-up-investor-corporation



Source: Own results

The analysis of the simulation results is possible through a function of visualization of main systems indicators: population of agents, aggregate capital of each agent-type, sum of taxes collected from start-ups and corporations, number of investments from venture capitalists and corporations, number of acquisitions and IPOs and also the number of died start-ups that had positive potential but could not find venture investments.

In order to find the most efficient model mode we stood out parameters that could be changes in real economy by the government regulator. (See Table 3).

Table 3. Changeable parameters of the model

Parameters	Model variables
Tax rate for start-ups	$T_s$
Tax rate for corporations	$T_c$
The intensity of start-up births	$\Theta$
Donation rate	Rate
Field of vision	R

Source: Own results

The following parameters have been chosen for the objective function:

- 1) The collected taxes for all modelling time period (to maximize) –  $Tax_{sum}$ ;
- 2) Mean value of the aggregate capital of corporations and start-ups for each period (to maximize) –  $CapS_{mean}$  and  $CapC_{mean}$ ;
- 3) The number of potentially innovative start-ups died (to minimize) –  $dRate_p$ ;

Based on the set parameters of the model we carried out simulations with different input parameters. Each simulation lasted for 120 time periods. Taking into account large number of random probabilistic values and events in the simulation we did 5 replications for each set of parameters. The parameter values and the objective functions are presented in Tables 4-8.

**Table 4.** Real parameter values in Moscow (2014)

No.	Tax-rate <sub>s</sub>	Tax-rate <sub>c</sub>	sBirth-Rate	Don-Rate	R	$Tax_{sum}$	$CapS_{mean}$	$CapC_{mean}$	$deaths_p$
1	15%	20%	6%	0,7%	0,5%-7%	1984 k	566727	1506277 k	128
2	15%	20%	6%	0,7%	0,5%-7%	2387 k	682027	144108 k	122
3	15%	20%	6%	0,7%	0,5%-7%	2297 k	619039	1845190 k	133
4	15%	20%	6%	0,7%	0,5%-7%	2193 k	580636	1983972 k	122
5	15%	20%	6%	0,7%	0,5%-7%	2197 k	674004	1310207 k	137
<b>Mean:</b>						<b>2211 k</b>	<b>624486</b>	<b>1357950 k</b>	<b>128</b>

Source: Own results

**Table 5.** Real parameter values in Moscow (2014) with increased start-up birth rate

No.	Tax-rate <sub>s</sub>	Tax-rate <sub>c</sub>	sBirth-Rate	Don-Rate	R	$Tax_{sum}$	$CapS_{mean}$	$CapC_{mean}$	$deaths_p$
1	15%	20%	<b>18%</b>	0,7%	0,5%-7%	4887 k	1576345	1067842 k	390
2	15%	20%	<b>18%</b>	0,7%	0,5%-7%	4388 k	1760646	1568228 k	355
3	15%	20%	<b>18%</b>	0,7%	0,5%-7%	4580 k	2060823	1517132 k	364
4	15%	20%	<b>18%</b>	0,7%	0,5%-7%	4108 k	1530313	2364935 k	277
5	15%	20%	<b>18%</b>	0,7%	0,5%-7%	4662 k	2230833	839104 k	399
<b>Mean:</b>						<b>4525 k</b>	<b>1831792</b>	<b>1465448 k</b>	<b>357</b>

Source: Own results

**Table 6.** Real parameter values in Moscow (2014) with decreased start-up tax rate and increased corporation tax rate

No.	Tax-rate <sub>s</sub>	Tax-rate <sub>c</sub>	sBirth-Rate	Don-Rate	R	$Tax_{sum}$	$CapS_{mean}$	$CapC_{mean}$	$deaths_p$
1	<b>10%</b>	<b>25%</b>	6%	0,7%	0,5%-7%	2086 k	673025	1703158 k	145
2	<b>10%</b>	<b>25%</b>	6%	0,7%	0,5%-7%	1966 k	698954	1745054 k	133
3	<b>10%</b>	<b>25%</b>	6%	0,7%	0,5%-7%	1780 k	569953	1473101 k	129
4	<b>10%</b>	<b>25%</b>	6%	0,7%	0,5%-7%	1883 k	616753	1923129 k	127
5	<b>10%</b>	<b>25%</b>	6%	0,7%	0,5%-7%	1801 k	508193	1459331 k	147
<b>Mean:</b>						<b>1903 k</b>	<b>613375</b>	<b>1660754 k</b>	<b>136</b>

Source: Own results

**Table 7.** Real parameter values in Moscow (2014) with increased donation rate

No.	Tax-rate <sub>s</sub>	Tax-rate <sub>c</sub>	sBirth-Rate	Don-Rate	R	$Tax_{sum}$	$CapS_{mean}$	$CapC_{mean}$	$deaths_p$
1	15%	20%	6%	<b>5%</b>	0,5%-7%	2247 k	953150	1628824 k	127
2	15%	20%	6%	<b>5%</b>	0,5%-7%	2601 k	1063912	1953251 k	140
3	15%	20%	6%	<b>5%</b>	0,5%-7%	2327 k	945497	2071220 k	129
4	15%	20%	6%	<b>5%</b>	0,5%-7%	2733 k	1218323	1386803 k	117
5	15%	20%	6%	<b>5%</b>	0,5%-7%	2046 k	731092	1624013 k	128
<b>Mean:</b>						<b>2390 k</b>	<b>982394</b>	<b>1732822 k</b>	<b>128</b>

Source: Own results

**Table 8.** Real parameter values in Moscow (2014) with increased field vision

No.	Tax-rate <sub>s</sub>	Tax-rate <sub>c</sub>	sBirth-Rate	Don-Rate	R	Tax <sub>sum</sub>	CapS <sub>mean</sub>	CapC <sub>mean</sub>	deaths <sub>p</sub>
1	15%	20%	6%	0,7%	<b>40-60%</b>	1828 k.	502179	1280191 k.	103
2	15%	20%	6%	0,7%	<b>40-60%</b>	2294 k.	682439	1465406 k.	100
3	15%	20%	6%	0,7%	<b>40-60%</b>	2209 k.	680757	1301137 k.	89
4	15%	20%	6%	0,7%	<b>40-60%</b>	2055 k.	538525	2326815 k.	95
5	15%	20%	6%	0,7%	<b>40-60%</b>	2219 k.	606240	2073544 k.	98
<b>Mean:</b>						<b>2121 k.</b>	<b>602228</b>	<b>1689418 k.</b>	<b>97</b>

Source: Own results

## 5. Conclusions

The designed multi-agent model and its simulation in the specially created software enabled to analyze different modes of system action in time and to get the following practical results. Firstly, the carried out approbation using the statistical data on the area of research showed that by regulating the level of state interference through changing the input parameters given in table 3 we can elicit better scenarios of system action.

Second, it must be stated that for maximization or minimization of each objective function different modes are suited:

- i) for maximization of aggregated taxes the increment of start-up birth rate by 3 times proved to be more effective. The growth of aggregated taxes was 111% for 120 time periods of simulation.
- ii) the least effective modes was when differentiating tax rates – for start-ups decreased from 15% to 10% and for corporations increased from 20% to 25%. Herewith, the aggregated tax amount was lower than with other modes. It can be shown that the aggregated capital of start-ups and corporations increased by 13%.
- iii) the increased donation rate mode proved to be effective: despite the increased fund allocation for start-up donation 7 times, the aggregated taxes grew by 8%, aggregated corporations' capital grew by 28%, aggregated start-ups' capital grew 57% with the same level of innovative start-ups death rate.
- iv) the fifth mode with increased field vision radius and all other parameters on the initial level proved to be effective for the growth of aggregated corporations' capital by 24% and the innovative start-ups death rate decreased by 32%.

Therefore, each of the 4 carried out modes has its own advantages depending on what kind of interference on the system will be chosen by the government with the consideration of different regions' peculiarities and what kind of administrative, financial and personnel resources the state has. The further research on the topic is going to be devoted on the collection of various statistical data of different countries and regions and on the study of their differences and on comparison of their innovative strategies.

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