Title: **AMOEBA: An Agent-based Model Of Entrepreneurship and Business Activities**

Special Session: **S_ZI. The Spatial Dimension of Entrepreneurship**

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Abstract:

Most of the recent theoretical and empirical trends establish a strong relationship between entrepreneurship, knowledge, innovation and economic growth. Braunerhjelm (2011) has highlighted the complex relationships between these variables.

Based on this approach, a key question is why there are individuals who engage in risky entrepreneurship and create new companies. This leads to the concept of ‘opportunity’. In literature, the study of ‘opportunities' offers a double vision. Traditionally, it was considered as a factor exogenous to the individual who decided to start a new venture. However, based on the models of knowledge production function (Wagner, 2006; Ramani et al, 2008), the firm is considered exogenous to the model, but the opportunities are endogenous and it is the result of the investment by the company in the creation of new knowledge through R&D and human capital growth. Audretech and Keilbach (2011) remark this dichotomy in the study of opportunities reflects the independence of the two basic units that make decisions in the entrepreneurial field: the firm and the entrepreneur.

The location of entrepreneurial activity is another key aspect in regional economic development. Most of the traditional approaches –the context is constant and the opportunities are exogenous- are based on the assumption that there is a completely elastic supply of firms. If the necessary conditions such as availability of land and financial resources are met, new firms will be located.
More recently, it has been considered that the availability of 'entrepreneurship capital' is a key element without which the territory is unable to generate the appearance of firms although there is a suitable environment. The entrepreneurship capital evolves slowly and directs the development of business activity spatially. This explains the high inertia in the spatial dynamics of entrepreneurship (Pablo-Martí et al, 2012). This concept of entrepreneurship capital, characterized by Audrestch and Keilbach (2004), Audrestch (2007) and Audrestch and Keilbach (2007), is associated with the knowledge and innovation in a local environment and is regarded as a new production factor that allows us to link entrepreneurship to growth economic.

Despite the development of analytical literature in recent years, especially after the emergence of the current crisis, in specialized forums it is argued that most of these models are partial, since they don’t include restrictions as limited rationality or imperfect information. Therefore, their results are not completely reliable.

This lack makes necessary to develop more comprehensive and realistic models in the field of entrepreneurship. Among others, agent-based models (ABM) arise as one of the most promising alternatives (Howitt, 2006; Solow, 2010; Tesfatsion, 2007). This methodology allows modeling individual interactions between the entrepreneur, the firms and their local environment.

This paper presents an agent-based model that includes all the main related variables mentioned above: knowledge, innovation, location, entrepreneur and firm. It uses real data (from Census, Amadeus and GEM data bases), and makes possible to forecast the entrepreneurship and business activity at a local or country level. It provides solutions to the questions unanswered by traditional models. From the perspective of entrepreneurship and business activity, the paper develops an agent-based model (ABM) in order to analyze the effect of behaviors, decisions and interactions dynamics on spatial distribution of capital entrepreneurship. Therefore, two basic types of agents are considered: individuals and firms. The individuals belong to a society made up of households and they act as entrepreneurs–businessperson that create firms. Firms have their own dynamics and adopt decisions as far as their approach of economic and business performance.

References:


We include a preliminary mathematical appendix with the main parts of the model to show how we are trying to obtain the results described in the extended abstract.

1) ENTREPRENEURSHIP

Every individual has a value for the variable ENTREPRENEUR, but there are different determinants of the ENTREPRENEURIAL SPIRIT (an index between zero and one that indicates the probabilities to be entrepreneur in t+1) depending on the characteristics of the individual. In the case of individuals who are not entrepreneurs, the main difference is the possibility of being working or having different level of studies. This difference in expressed in a classification accordingly to the minimum age for employment.

a) **Age<15**

\[
\text{ENTREPRE_SPT} = \left(1 + e^{-\beta_0 + \beta_1 \text{GEND} + \beta_2 \text{ENTREPR} + \beta_3 \text{INC. NEC} + \beta_4 \text{GENETIC}}\right)^{-1}
\]

For those individuals who are part the potential workforce, the main difference in order to compute the change in their entrepreneurial spirit comes from their past: if they were entrepreneurs in the past and they are not longer being entrepreneurs this fact conditions their chances of being entrepreneurs again.

b) If ENTREPR_PAST (t-1) = 1

\[
\text{ENTREPRE_SPT} = \left(1 + e^{-\beta_0 + \beta_1 \text{GEND} + \beta_2 \text{ENTREPR} + \beta_3 \text{INC. NEC} + \beta_4 \text{GENETIC}}\right)^{-1}
\]

c) Else

\[
\text{ENTREPRE_SPT} = \left(1 + e^{-\beta_0 + \beta_1 \text{GEND} + \beta_2 \text{ENTREPR} + \beta_3 \text{INC. NEC} + \beta_4 \text{GENETIC}}\right)^{-2}
\]

Current entrepreneurs change their entrepreneurial spirit depending on their gender, if they have dependent siblings or ascendants or their age among other factors.

\[
\text{ENTREPRE_SPT} = \left(1 + e^{-\beta_0 + \beta_1 \text{GEND} + \beta_2 \text{ENTREPR} + \beta_3 \text{INC. NEC} + \beta_4 \text{GENETIC}}\right)^{-2}
\]
d) \( \text{ENTREPREN\_SPIRIT} = \left( \frac{1}{1 + e^{-\left(\beta_{j4} + \beta_{j5}D\_END + \beta_{j11}D\_DEPEND + \beta_{j11}INC\_HEC + \beta_{j14}W\_OPPORT + \beta_{j16}F\_FAILURE + \beta_{j16}U\_UNEMP + \beta_{j16}W\_D\_D\_S\_T\_F\_A\_I\_F\_Y + \beta_{j16}U\_N\_L\_O\_C\_A\_T\_E\_N\_T + \beta_{j16}F\_ENT\_E\_N\_T\_P\_D\_Y\_A\_N\_N\_Y}} \right)^{-1} \)

If \( \text{ENTREPREN\_SPIRIT} > \text{RNG}(0,1) \) THEN \( \text{ENTREPRENEUR} = 1 \)

Else \( \text{ENTREPRENEUR} = 0 \) except if he is a businessman (\( \text{ENTREPRENEUR} = 2 \))

2) BUSINESS CREATION

Firstly, the entrepreneur chooses the sector. At regional level there is computed \( \text{SECTOR\_EXPECT} \) for every sector.

\[
\text{SECTOR\_EXPECT}_i = \frac{\sum_{j=1}^{n} \text{FIRM\_PROFIT}_j / \text{TOTAL\_ASSETS}_j}{\text{SECTOR\_FIRMS}}
\]

A variable \( \text{SECTOR\_MOD} \) is defined in order to adapt the sector decision to the educational background of the entrepreneur.

Every individual assigns expected utility values to every sector according to:

\[
\text{SECTOR\_OPT} = \beta_{j30} \text{SECTOR\_EXPECT} \times \beta_{j40} \text{SECTOR\_MOD} \times \beta_{j41} \text{SECTOR\_RATE\_CREATION}
\]

However, individuals have fuzzy rationality, and they will not choose always the best sector.

After choosing the sector the entrepreneur chooses the desired size of the new company according to the successful ones created in the sector the last period. The entrepreneur knows a higher initial size means more probability of success once the firm is created, but less chances to create it, then they try to create slightly bigger companies that the ones created in the last period, on average terms following a normal distribution.

\[
\text{INIT\_SIZE} = N(\beta_{j42} \text{SECTOR\_AVE\_SIZE}, \beta_{j43} \text{SECTOR\_SIZE\_σ})
\]

\( \text{INIT\_SIZE} \) should be at least a fixed amount: \( \beta_{j47} \text{SECTOR\_AVE\_SIZE} \).

If not, extract a new value of the normal distribution.

After computing the size of the firm the entrepreneur chooses which part will be extracted from his personal wealth and which one should be obtained in the financial market. If the project does not get funding the firm is not created.

\[
\text{INIT\_LOAN} = \text{INIT\_SIZE} - \beta_{j45} \text{WEALTH} \text{RNG}(0,1)^2
\]

If \( \beta_{j46} \left(1/\text{LICENSE\_EASINESS}\right) \left(\text{SECTOR\_AVE\_INIT\_SIZE}/\text{INIT\_SIZE}\right) > \text{RNG}(0,1) \) the firm obtains a licence

A new agent –firm is created. Its property is attached to the entrepreneur.

The businessperson wishes to create other firms if he/she observes that the entrepreneurial activity is profitable, although his/her firms are not obtaining the adequate results, basically because they are not located in the adequate sector.

If \( \text{PROFIT\_SECTOR} \) of at least one sector is higher than the \( \text{FIRM\_PROFIT}/\text{TOTAL\_ASSETS} \) in every one of his firms, then \( \text{NFIRM\_WANTED} = 1 \)

The entrepreneur assesses the current situation of each and every one of his/her firms and closes the firms with no employees (the \( \text{WORKFORCE} = 0 \) in all of his establishments) and that appear to be hardly viable in the future \( \text{FIRM\_PERFORM} = 0 \).

If \( \text{FIRM\_AGE} > 4 \) and \( \text{WORKFORCE} = 0 \) and \( \text{FIRM\_PERFORM} = 0 \)

Then that \( \text{FIRM} \) is closed.

If the entrepreneur has no firms left after the closing downs he is converted again to entrepreneur \( \text{ENTREPRENEUR} = 1 \).

Update \( \text{FAILURE} = 1 \).
3) BUSINESS GROWTH

It is determined whether the employer’s size optimizer (Optimizer) using a logistic function in which firm size is considered, the number of dependents in the family, age and gender of the entrepreneur.

\[
\text{OPTIMIZER\_SPIRIT} = \left(1 + e^{-(\beta_0 + \beta_1 \text{SIZE} + \beta_2 \text{DEPEND} + \beta_3 \text{GENDR} + \beta_4 \text{AGE})}\right)^{-1}
\]

If OPTIMIZER\_SPIRIT > RNG(0,1) Then OPTIMIZER = 1, Else OPTIMIZER = 0

If OPTIMIZER = 1, WANT\_GROWTH = 1 IF and at least one of the following statements is true:

- GAZELLE = 1
- SIZE is not OPTIM\_SIZE
- FIRM\_PERFORM is not 1
- ESTABLISH = 0

The company wants to change its size if it is having a rapid expansion, its size is not optimal or the results are different from the average.

Else WANT\_GROWTH = 0

OVERSIZED = 1 if ESALES/WORKFORCE < $\beta_{32}$ AVE_SALES_EMP_SECT

If ESALES/WORKFORCE > 0.5 AVE_SALES_EMP_SECT the process is smooth:

\[
\text{WORKFORCE\_FIR} = |\text{RNG}(0,1)|^2 (\text{WORKFORCE} - (\text{SALES}/\text{AVE_SALES_EMP_SECT}))
\]

Else the firm decides if closes the establishment or not.

CLOSURE\_EST = 1 IF FIRM\_PROFIT = 0 or ESALES/WORKFORCE < 0.5 RNG(0,1)^2 AVE_SALES_EMP_SECT

Then, WORKFORCE\_FIR = WORKFORCE

Reduce ESTABLISH in 1 End the relation between location and firm

Else CLOSURE\_EST = 0

Then, WORKFORCE\_FIR = |\text{RNG}(0,1)|^1/2 (\text{WORKFORCE} - (\text{SALES}/\text{AVE_SALES_EMP_SECT}))

\[
\text{WORKFORCE\_HIR} = |\text{RNG}(0,1)|^1/2 (\text{SALES}/\text{AVE_SALES_EMP_SECT}) - \text{WORKFORCE}
\]

If WORKFORCE\_HIR > WORKFORCE\_FIR > -1

Relocate the workers among the establishments minimizing the spatial movement between the facilities.

Then, If WORKFORCE\_HIR > WORKFORCE\_FIR > 0 hire new workers if POSS\_FUND > 0

4) PRODUCTION

\[
\text{EXP\_DEM}_{t+1} = \text{DEM}_{t+1} (1 + \Delta \text{PRICE}_{t+1} + \Delta \text{PRICE\_SECT\_REG}_{t+1}) + \alpha_1 (1 + \text{PRICE}_{t+1} - \text{PRICE\_SECT\_REG}_{t+1})
\]

\[
\text{STOCK\_OPT}_t = \alpha_1 + \alpha_2 (\Delta \text{PRICE}_{t+1} - \Delta \text{COST}_{t+1} + \alpha_3 ([\text{INT\_FIRM}_{t+1}\cdot \text{DEBT\_FIRM}_{t+1}] / \text{COST}_{t+1}) \cdot \text{EXP\_DEM}_{t+1}
\]

If STOCK\_OPT > STOCK < 0 then PROD_t = 0, the establishment skips steps 1.3 and 1.4

Else the production if the maximum of

\[
\text{PROD}_t = A_{t-1} \cdot \text{WORK\_PROD}_{t+1}^{\alpha_4} \cdot \text{FIX\_CAP}_{t+1}^{\alpha_5} \cdot (\text{QUA}_{t+1} / \text{QUA\_SECT\_REG}_{t+1})^{\alpha_6}
\]

And PROD = STOCK\_OPT - STOCK

Once the production has been determined, the establishment decides the necessary quantity of raw materials of every sector i to acquire in the current period.

\[
X_{\text{ACQ}_{t+1}} = \alpha_9 \cdot \text{PROD}_t
\]

Only visible suppliers are eligible (with VIS > $\alpha_{10}$)

\[
\text{VIS}_{t+1} = \alpha_{11} \cdot \text{VIS}_{t+1} + (\text{WORKFORCE}_{t+1} / \text{DIST\_EST} + 0.5)^2 + \alpha_{12} \cdot \text{INTERNET}
\]

For every sector each establishment determines all the visible suppliers and choose one or more among them.
EFF_PRICE_t = PRICE_t + \alpha_3 \cdot DIST_EST

EST_OPT_t = \alpha_4 \cdot QUA_t - 3 \alpha_5 \cdot EFF_PRICE

The establishment will continue with its current supplier(s) if all of the following statements are true:

- The supplier has available products: STOCK > 0
- The supplier continues being visible: VIS_t > \alpha_{10}
- The supplier is sufficiently good:

$$EST\_OPT_t > (\alpha_{14} + \alpha_{15} \cdot FIRM\_PERF + \alpha_{16} \cdot OPT\_SPRT + \alpha_{17} \cdot WORKFORCE) \cdot (\max \ EST\_OPT)$$

If DEM_{t>F1} > EXP\_DEM_{t>F1} and PROD > 0
Then PRICE_{t+1} = \alpha_{18} \cdot PRICE_t

If DEM_{t>F1} < EXP\_DEM_{t>F1} or PROD = 0
Then PRICE_{t+1} = \max (\alpha_{19} \cdot PRICE_t, \alpha_{20} \cdot (RAW\_MAT + WORK\_PROD \cdot AVE\_WAGE) / PROD)

5) INNOVATION

The company cannot change R&D_{t+1} but decides its value indirectly depending on other decisions:

If the company innovates in the previous period and has a good performance continues innovating.
If INNO_{t-1} = 1 and FIRM\_PROFIT > 0
and PROFIT\_RATE > RNG(0,1)^{1/2} \cdot PROFIT\_SECTOR
Then INNO_t = 1

If the firm doesn’t innovate and performs better than average, it can start innovating with a probability equal to the percentage of companies in the sector that already innovate.
If INNO_{t-1} = 0
And PROFIT\_RATE > PROFIT\_SECTOR
INNO_t = 1 with a likelihood EST\_INNO

Else INNO_t = 0
If INNO_t = 1, PERS\_INNOV_t > 0

$$H_t = \left( \sum_{j=1}^{n_t} (1 - \alpha_{22}) \cdot PERIODS\_EDU_j + \sum_{j=1}^{n_t} (1 - \alpha_{22}) \cdot QUA\_CURR_j \cdot PERIODS\_JOB\_POS_j \cdot \alpha_t \right)$$

PERS\_INNOV_t = \max (\alpha_{22} \cdot (AVE\_WAGE\_INNO_{t-1}) / POSS\_FUND_t, \alpha_{23} \cdot PERS\_INNOV_{t-1})

If there are redundant workers and INNO = 0 they can be fired.

There are redundant workers if

$$PROD_t < A_{t-1} \cdot WORK\_PROD_t^{\alpha_{4}} \cdot FIX\_CAP_t^{\alpha_{8}} \cdot (QUA_{t-1} / QUA\_SECT\_REG_{t-1})^{\alpha_{8}}$$

First it is computed the OPT\_WORK\_PROD as

$$OPT\_WORK\_PROD_t = (A_{t-1} \cdot FIX\_CAP_t^{\alpha_{8}} \cdot (QUA_{t-1} / QUA\_SECT\_REG_{t-1})^{\alpha_{8}} \cdot PROD_t^{\alpha_{4}})^{1/\alpha_{4}}$$

And RED\_WORKERS_t = WORK\_PROD_t - OPT\_WORK\_PROD_t

If it needs more staff to innovate (PERS\_INNOV) they change their activity. If still needs more workers, new ones are hired to innovate.

If PERS\_INNOV_t > PERS\_INNOV_{t-1} change (PERS\_INNOV_t, PERS\_INNOV_{t-1}) workers from innovation to production, choosing the ones with higher human capital until RED\_WORKERS_t = 0. Then hire new workers to reach the computed number of PERS\_INNOV_t.
Another way to innovate is to purchase innovation services.

If INNO\_EXT\_t\_1=1 and FIRM\_PROFIT>0
and PROFIT\_RATE>RNG(0,1)\^{1/2} PROFIT\_SECTOR
Or if INNO\_EXT\_t\_1=0
And PROFIT\_RATE>PROFIT\_SECTOR
INNO\_EXT\_t=1 with a likelihood of EST\_INNO\_EXT
Then INNO\_EXT\_t=1
Else INNO\_EXT\_t=0

INNO\_EXT is purchased to sector 22"PROFESSIONAL, SCIENTIFIC AND TECH" but these services are not used to produce goods and services but to improve R&D\_t+1
If INNO\_EXT=0
Only visible suppliers are eligible (with VIS(t)>\alpha_24)

\[ VIS_{t+1} = \alpha_{11} VIS_{t}, t-1 + (WORKFORCE_t \cdot DIST\_EST^2) \]

If Q\_INNO\_EXT\_t\_1>0
Q\_INNO\_EXT\_t = \alpha_{25} Q\_INNO\_EXT\_t\_1
\alpha_{25} is the rate of growth of profits after taxes if there are benefits, zero if there are losses. In this way, innovative firms will increase the external innovation purchase at the same rate the benefit increase or reduce if it they have losses.
Else Q\_INNO\_EXT\_t = \alpha_{20} AVE\_Q\_INNO\_EXT

R&D\_t+1 = (1-\alpha_{20})R&D\_t + \alpha_{20}(PERS\_INNOV_i \sum H_j) + \alpha_{20}(Q\_INNO\_EXT) + SPILLOVERS

Where SPILLOVERS= \sum(AVE\_R&D\_t-1 - R&D\_t-1)/N \cdot 1/25 \cdot (DIST\_EST+25) \cdot RNG(0,1) \cdot (1+\alpha_{20}) LOCAT\_ENTRE
QUA\_t+1 = QUA\_t + \alpha_{31} (R&D\_t / QUA\_t) + \alpha_{32} (AVE\_QUA\_RAW_i \cdot AVE\_QUA\_RAW_i)