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New-Issues Markets as Behavioural Barriers to Entry:
An Agent-Based Model of Choices and Market Structure

Master's thesis in Economics, in the specialty of Industrial Economics, presented to the Faculty of Economics of the University of Coimbra for the obtainment of the degree of Master

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[…] the still picture can provide useful publicity but can also give a very misleading idea about the movie.

(Fisher, 1978)

Resumo

A possibilidade de que a existência de mercados primários possa promover, através de uma resposta comportamental de potenciais entrantes, uma maior concentração nos setores econômicos é o objeto do presente estudo. Eu analiso em quais condições os empreendedores optam por abandonar seus planos de adentrar uma indústria com o propósito de investir em valores mobiliários de companhias daquela mesma indústria. Para abordar essa matéria, foi desenvolvido e simulado na plataforma NetLogo, um modelo baseado em agentes, nomeado *Utility Load*, no qual os empreendedores baseiam-se em uma heurística híbrida da *Prospect Theory* com modelos de passeio aleatório de tomada de decisão percetual para escolherem entre iniciar uma empresa, reunir um portfólio ou nada disto, postergando sua decisão. Eu chego à conclusão de que um longo horizonte temporal do investimento ou elevado cupão dos títulos de dívida, ao oferecerem maiores perspetivas de ganhos, atraem a vasta maioria dos potenciais entrantes para o mercado primário, o que por sua vez tem um efeito nefasto na estrutura do setor ao aumentar sua concentração – medida pelo Índice Herfindahl-Hirschman. Ademais, o modelo indica que uma racionalidade mais limitada aumenta o bem-estar, enquanto permitir às empresas emitir continuamente dívida para o público diminui o bem-estar. Os resultados restringem o escopo da realidade a ser emulada experimentalmente e abrem portas para futuras investigações empíricas sobre este assunto ao torná-las mais acessíveis.

Palavras-chave: Modelos Baseados em Agentes, Barreiras a Entrada, Empreendedorismo, Mercado Primário, Concentração do Mercado.

Abstract

The possibility that the existence of New-Issues Markets (NIM) could promote, through a behavioural response of potential entrants, a greater market concentration on economic sectors is the object of the present work. I analyse in what conditions do entrepreneurs choose to abandon their plans of entering some industry in order to invest in securities of companies in that same industry. To engage this matter an agent-based model, named Utility Load, was developed and simulated in NetLogo platform, where the entrepreneurs rely on a hybrid heuristic among Prospect Theory and Random Walk Model of perceptual decision-making to choose between starting a firm, assembling a portfolio or doing neither by postponing their decision. I arrive at the conclusion that a lengthy investment horizon or high bonds' coupon, by offering greater prospective gains, attracts the vast majority of potential entrants to the NIM, which has a nefarious effect on the sector's structure by increasing its concentration – measured by the Herfindahl-Hirschman Index. Moreover, the model indicates that a more bounded rationale is welfare increasing whilst allowing firms to continuously issue new debt to the public diminishes welfare. The results narrow the scope of reality to be emulated in experimental works and open the door for future empirical researches on this matter by making them more attainable.

Keywords: Agent-Based Model, Barriers to Entry, Entrepreneurship, New-Issues Market, Market Concentration.

List of abbreviations and symbols

ABM: Agent-Based Model

HHI: Herfindahl-Hirschman Index

NIM: New-Issues Market

PT: Prospect Theory

RWM: Random Walk Model of perceptual decision-making

Content

1 Introduction

Market structure has been a fascination of Industrial Economics for decades and, mainly for normative reasons, the focus of the overwhelming majority of the studies has been on the behaviour of firms and regulation.

Even though entrepreneurship has become an important agenda with the recent necessity of structural reforms in several countries, little was written about the relationship between entrepreneurship and market structure.

Hereafter, the firm-centred focus will be defied by shifting the spotlight to the decision making of the entrepreneurs. The argument is grounded on the assumption of a trade-off that potential entrants have – assuming they possess the monetary resources – between, on one hand, creating a start-up company or, the alternative, investing in a portfolio of securities in the same industry that they intended to join.

Hence, our departure question will be: in what conditions, if any, the *portfolio prospect* would render an opportunity cost high enough to convert the majority of potential entrants (entrepreneurs) into security holders (investors)? The concern is that, if this happens in reality, then the capital markets might contribute to diminish competition within economic sectors, not to mention that part of the inflow of resources would be financing the incumbents' growth (via New-Issues Market), thus also contributing to a greater industrial concentration.

To engage this matter, I implement an interdisciplinary approach by using a spatial model of product differentiation[1] integrated in an Agent-Based Model of an economic sector where, on each period, entrepreneurs must choose between entering the market, investing on firms by acquiring stocks and bonds[2], or doing neither and delaying their decision to the forthcoming period.

The entrepreneurs rely on cognitive rules based on the Prospect Theory (Kahneman & Tversky, 1979; 1992)[3] and models of perceptual decision-making (Smith & Ratcliff, 2004;

[1] Slight variation (detailed later) of the model presented by the seminal work of Salop (1979a).
[2] Henceforth I shall refer to these alternatives as «*start-up prospect*» and «*portfolio prospect*» respectively.
[3] The author understands Cumulative Prospect Theory (Kahneman & Tversky, 1992) as an extension of the original theory (Kahneman & Tversky, 1979) and implements the former.

Bogacz, 2007). The model, named Utility Load, was built to run into NetLogo, a freeware under constant improvement by Northwestern University and available at their website[4].

Undeniably, this is a vast topic, so I will be focusing in the departure question's scope, though admitting that the uppermost objective is to verify if there are enough evidence to justify further studies in this line.

The remainder of this work is divided among four parts: next chapter starts with a brief description of relevant definitions that are recurrent throughout the thesis, followed by a brief literature review at the end of which the reader is advised to investigate the attached figures of the model's interface [Figures 1 and 2] and to interact with the model by downloading a copy[5], before proceeding to chapter three, where the methodology and the Utility Load Model are formally presented. Chapter four discusses the dynamics of the model and presents the results of the simulations. Finally, chapter five concludes the discussion and offers some pointers for future works.

[4] To download a copy of NetLogo please access: http://ccl.northwestern.edu/netlogo/

[5] The model is openly available at **https://goo.gl/ljLBT2** or at the NetLogo User Community Models webpage: **http://ccl.northwestern.edu/netlogo/models/community/index.cgi**

2 Literature Review

2.1 Relevant definitions

2.1.1 Behavioural barriers to entry

Strategic competition occurs in various battlegrounds and encompasses many aspects; erecting barriers to entry is one way, since the conditions of entering a market are one of the shapers of its structure. However, what constitutes an entry barrier has been historically a topic of controversy and interest in Industrial Organization (McAfee, Mialon, & Williams, 2004).

In the present work I adopt a raw definition of entry barrier as «a factor that prevents welfare-increasing entry», the latter definition descends from Fisher's statement that "a barrier to entry exists when entry would be socially beneficial but is somehow prevented" (1978, p. 28). Furthermore, I use the term behavioural barrier to entry to emphasize how the entry is prevented, which is by inducing some behavioural response from potential entrants.

2.1.2 New-Issues Market (NIM)

Also known as the primary market, it's a niche of the capital markets where newly issued debt or equity based securities are first sold to the public. Usually, the issuers are companies and governments but, for our purposes, NIM shall refer strictly to the portion of the capital market where only firms obtain financing by means of issuing bonds or stocks.

2.1.3 Agent-Based Model (ABM)

It's a computer program modelled to capture simplistically and (hopefully) realistically some domain of reality with the intent of explaining an existing phenomenon. The power of these models arise from the capability to emulate several heterogeneous individuals (agents) acting and interacting among themselves and with their environment, over time resulting in a naturally emerged macro-scale (population) behaviour.

2.1.4 *Perceptual decision-making*

Given some behavioural intention, this refers to the cognitive process of translating perceived stimulus information into actions (Smith & Ratcliff, 2004).

2.2 Framework

The possibility that the mere existence of a capital market could promote, through a behavioural response of entrepreneurs, a greater concentration on various economic sectors falls on what Salop categorises as an innocent entry barrier, one that is "unintentionally erected as a side effect of innocent profit maximization" (1979b, p. 335). Nonetheless, an innocent barrier still influences the market structure, hence affecting welfare distribution. This statement exposes the multiple layers associated with the problem and, accordingly, the necessity of "an 'issue-oriented' rather than a discipline-confined style of research" (Squazzoni, 2010) arises[6], particularly, one favourable to an interdisciplinary and more holistic approach.

Beginning in the 90s, the dawn of the information age provided a fruitful environment for the development of agent-based modelling. In the United States the technique became popular mainly by the efforts of the Santa Fe Institute whilst in Europe the propagation was mainly driven by some innovative social scientists. Nonetheless, in recent years, thanks to bitter example about the insufficiencies of conventional Economics provided by the 2007-2008 financial crisis, agent-based modelling has gained momentum inside the Social Sciences (Squazzoni, 2010).

Gilbert formally defines agent-based modelling as "a computational method that enables researchers to create, analyze, and experiment with models composed of agents that interact within an environment" (2008, p. 4).

Heterogeneity, autonomy, explicit space, local interactions, bounded rationality and non-equilibrium dynamics. These are simultaneously key features of an ABM (Epstein, 2006, p. 1588) and the most accurate reasons for the increasing popularity of this generative method as the *par excellence* explanatory technique for complex social phenomena (Squazzoni, 2010, p. 200).

[6] The present thesis is a live example of this idea as the finest contribution brought to Economics by ABM.

Epstein (2006) cleverly discourses about the core epistemological issues related to agent-based modelling using first-order logic, although a thoroughly discussion on these topics is beyond our scope here, it's worth quoting Epstein's refutations of the indictment that ABMs have no equations and are not deductive:

> Every agent model is, after all, a computer program […] As such, each is clearly Turing computable (computable by a Turing machine). But, for every Turing machine, there is a unique corresponding and equivalent partial recursive function […] *(Epstein, 2006, p. 1590)*.
>
> […] recursive functions are computed deterministically from initial values […] Given the nth (including the initial) state of the system, the (n+1)st state is computable in a strictly mechanical and deterministic way by recursion. Since this mechanical procedure is obviously deductive, so is each realization of an agent model. *(Epstein, 2006, p. 1592)*.

The generality of agent-based modelling is another main epistemological issue since much of the explanatory power of an ABM derives from a realistic representation of the social actors, thus the agents must rely on cognitive rules that, ideally, are guided by empirically founded research.

To my knowledge, the seminal works of Kahneman and Tversky (1992; 1979) on Prospect Theory (PT) are still the best approximation for the behaviour of people choosing under conditions of risk and uncertainty, the fourfold pattern of risk attitudes defined as "risk aversion for gains and risk seeking for losses of high probability; risk seeking for gains and risk aversion for losses of low probability" (Kahneman & Tversky, 1992) has been extensively verified by several researches[7].

Despite its prestige, however, PT's parameters are typically estimated for choices made during one period of time. To implement PT dynamically an effective method[8] can be derived from perceptual decision-making models. These are broadly studied models derived from neurophysiological and psychological experimental data, were subjects are given two choices and rely on sensory stimuli to choose one, their response-time and neuronal activity are then measured with the intent of inferring causality (Bogacz, 2007).

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[7] To find empirical works supporting Prospect Theory see Table 11.3 (Fox & Poldrack, 2009, p. 158).

[8] See (Rustichini, 2009).

The results from several studies link the decision timing with the neural activity reaching a cognitive threshold (e.g.: confidence level), although the timing also depends on the decision's difficulty – the delay increases as the sensorial information perceived by the subjects becomes more ambiguous (Smith & Ratcliff, 2004).

Leaning on these evidences, the Utility Load Model integrates PT with what is known in the Neurosciences' literature as Random Walk Model (RWM) of perceptual decision-making. Under this class of models the evidence in favour of each alternative is continuously "accumulated as a single total: information in favour of one response is evidence against the other" (Smith & Ratcliff, 2004, p. 162). To explain this further, the concurrent signals from the environment are perceived by different neuronal groups whose activities are inhibitory of each other, thus, when the surplus of evidence gathered in favour of one signal surpasses some cognitive threshold, the decision linked to that signal is made.

3 Methodology

The ABM reported here[9] applies PT as the cognitive rule used by the entrepreneurs on each time step of the RWM to evaluate and compare the *start-up prospect* against the *portfolio prospect*[10]. Also, I use a variation[11] of Salop's circular model (1979a) as the industry's architecture, so *firms* act as if they were in a product differentiated market with non-price local competition. Additionally, an environmental parameter – partially determined exogenously and partially by *firms*' *performance* – is defined to represent the economic climate[12]. The resultant ABM is one where people behave with bounded rationality[13] and, in order to assess each alternative, observe the conjunctures of the sector and the economy.

I have mentioned the major theories underlying the ABM presented here, which was named «Utility Load Model», in tribute to the core attribute of the model being the *load* of information resultant from past comparisons of *utilities* and carried out from one period to another by entrepreneurs, hence working as a robust memory.

3.1 Purpose

The Utility Load Model was designed to study the relationship amongst entrepreneurship and market structure of an economic sector. The model allows direct interaction between *firms* and *people*[14] via New-Issues Market and indirect interaction through an environmental parameter.

Under what circumstances are the decisions of entrepreneurs conditioned by the existence of the NIM as an opportunity cost for starting a new firm? And what are the consequences for the industry's concentration?

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[9] This chapter will follow the «Overview, Design concepts, and Details (ODD) protocol», which is an ABM internationally standardized report procedure that aims "to create factual model descriptions that are complete, quick and easy to grasp, and organized to present information in a consistent order" (Railsback & Grimm, 2011, p. 36).

[10] It's worth noticing that a similar idea – although with different methodology – for integrating utility assessment functions into RWM was proposed by Rustichini (2009, pp. 38-41).

[11] I diverge from Salop's model with respect to adopting non-price competition, rigidity of *firms'* addresses and in the determination of the demand as changeable.

[12] Note that this could be interpreted as a market or economic index.

[13] An axiom of Prospect Theory (Kahneman & Tversky, 1992).

[14] Please note that hereafter I use the terms «entrepreneurs» and «people» interchangeably since *people* is the coding term adopted in the Utility Load Model to represent entrepreneurs.

3.2 Entities, state variables, and scales

The Utility Load Model contains three main types (breeds) of agents: *people*, *firms* and *investors*. The world is a box of 33 x 33 patches and the agents' locations are determined at their creation by a random variable (*heading*) ranging from 0 to 359. Additionally, this variable organises them clockwise in ascendant order.

Simulation can run indefinitely, although it's advised to pay attention to the long-term trend of the number of agents, since an increasing quantity of agents might reduce the simulation's velocity. The time step is not specified, but could be interpreted as the time needed for firms to account and report new profits (e.g. a month).

All agents own the following state variables determined at creation:

- *Heading:* for *firms* is the address in the circular product space, i.e., their brand specification or the variety of their manufactured product; for *people* represents the address that a new firm would have if the person chose to create it[15].
- *Age:* it starts at 1 and grows linearly with each time step that the agent exists.
- *Size:* for *firms* is set as 1,5 times their *resources*; for *people* is fixed at 1,5 and 0,6 for *investors*.
- *Resources*: equals 1000.
- *Who:* a unique number attributed to each agent.
- *Colour:* brown for incumbent *firms*; green for new *firms*; red for *investors*; grey for *people* or in the rare case of not existing *firms* in the market when a person decides to invest, yellow.
- *Shape: people's* shape is «person business»; *firms* is «factory» and *investors* is «circle».

Apart from the above common attributes, *people* and *investors* also own *threshold* (random variable ranging from 1 to 10); *bias* (random variable ranging from -3 to 3)[16] and *longevity* (defined by the slider *life-expectancy* on the interface).

Technically, the undirected links (titled *securities*) in the model are also agents, but then again, they don't own state variables.

[15] A straightforward interpretation is that, for them to even consider starting a company as an option, entrepreneurs have an idea or a business plan of what they would produce if they enter the market.
[16] For an illustration refer to Figure 4.

3.3 Process overview and scheduling

The processes run within each time step (tick) by each entity are:

- *Observer* (the user): setup; run, and update plots.
- *People:* get older; check if is dead; compare the utility of prospects; verify if utility *load* reached a *threshold*; turn into a *firm*, *investor* or wait.
- *Firms:* get older; check if is dead; calculate *revenues*, report results and update their attributes values.
- *Investors:* get older; check if is dead.
- *Environment:* update the environmental parameter.

The main agents' processes are run by each agent of a certain breed in random order, this does not influence the results because agents of the same breed do not directly interact with each other.

The schedule of the model is fairly complicated due to numerous recursive procedures so, for the sake of perspicuity, it is represented as a pseudo-code in the Attachments.

3.4 Design concepts

3.4.1 Basic principles

The decision-making process of *people* (entrepreneurs) in the Utility Load Model is based on a rather harmonious hybrid model of PT and RWM, where every person has an attribute named *load*, which the current value reflects how close from deciding one is[17].

It's assumed that *people's* decision *threshold* is the amount of evidence (or information) one must gather (i.e. *load* variable must achieve) before deciding in favour of the *portfolio prospect*. The *threshold* for the *start-up prospect* is the additive inverse[18]. Additionally, each person has a randomly determined *bias*[19] towards one of the alternatives. The *bias* is simply the initial value of *load*.

[17] Idem.
[18] This symmetry is actually supported by Kahneman and Tversky theory, see (1992, p. 307).
[19] The model has a switch to turn-off the *bias* attribute (see Figure 1) for hypothesis testing which sets *bias* equals zero for all people.

At each time step (tick), every person in the model compares the subjective utility of the *start-up prospect* with the *portfolio prospect* one, if the latter is the highest value, then one unit is added to the current *load* value, otherwise one unit is subtracted. If, at any point, *load* is greater than *threshold* or lower than its additive inverse a decision is made to become an *investor* or a *firm*, respectively.

All entrepreneurs own «1000 *resources*[20]», upon decision these *resources* will become the assets of a newly formed firm or a portfolio of stocks and/or bonds.

Firms can freely enter a circular market[21], there's no entry deterrence nor institutional entry barriers. The circumference's perimeter consists of 360 demand segments containing a uniformly distributed demand of 500[22] – i.e. 500 is the perimeter of a sector with a central angle of 1 – which varies 20% in conjunction with the environmental parameter deviation (positive or negative).

Following entry, *firms* engage in non-price competition (e.g.: research and development, marketing, advertisement, etc.) with their immediate neighbours for the local demand – clockwise and counter-clockwise demand segments. Consequently, the proportion of each demand segment captured by one firm is straightforwardly defined as the firm's *resources* relative to sum of the neighbour's *resources* to its own.

Soon after, m*arket-share* is defined to be the percentage of the circumference's perimeter (total demand) that is captured by a firm, i.e., the sum of the held clockwise and counter-clockwise demand segments divided by the total demand.

All *firms* participate in the NIW for their entire existence[23], the first one thousand securities sold by any new firm will be accounted as shares, and all investments received after that are assumed to originate from the sales of bonds with periodically interest

[20] For technical reasons a precise definition for «*resources*» was avoided, the rationale is that this perhaps ambiguous definition allows for a lighter code via easier intra-breeds communication. So the interpretation of this attribute is done contextually: if we refer to a person's resources, then these are monetary resources; if it's a firm's resources, it translates as assets; and an investor's resources is just the portfolio's value.

[21] Design based on Salop's model of a circular market (1979a, p. 144).

[22] There's no special reason for the 500 value, in fact, a back-of-the-envelope test of several different values showed that as long as the distribution of the demand is uniform, there's none significant departure from the model's behaviour.

[23] For simplicity, the model ignores the intermediate stages between starting a firm and its initial public offering. The justification is that our main focus is on the conditions that lead to people's decision, thus a detailed post-choice behaviour would be an unnecessary complication.

payments, the magnitude of the *interest* is defined by the respective slide bar on the model's interface (see Figure 1).

When a person decides to invest, she builds a portfolio based on the use of a simple ($^1/_N$) investment strategy, as Gigerenzer (2008, p. 22) demonstrates, this is not an implausible nor necessarily sub-optimal assumption. «N» is defined as the sum of her *threshold* and *bias* divided by twenty (the maximum possible length of the *threshold* axis[24]), the result is used as proxy for the extent of the diversification that the agent will perform[25].

The portfolio will then be the *investor's resources* divided equally between the top N companies given some criterion[26], subsequently, N undirected links are created to connect the *investor* with her portfolio's *firms*.

Finally, the environmental parameter or *lambda*, is partially endogenously defined as an addition of 1 to its past value if more than 50% of the *firms* made profit in the current period (which also changes the background colour to blue), otherwise the endogenous part will be a subtraction of 1 (background changes its colour to red). There is also an exogenous part which is randomly defined as positive or negative 1 and added to the current parameter value[27].

3.4.2 Adaptation

People are able to adapt to their present economic conjuncture due to the input variables of the PT functions being contingent on the values assumed by the global parameters at each iteration.

The PT functions are defined as[28]:

$$v(x) = \begin{cases} x^{0,88} & if\ x \geq 0 \\ -2.25(-x)^{0,88} & if\ x < 0 \end{cases} \qquad (1)$$

[24] See Figure 4.
[25] It's assumed that an original inclination towards the *start-up prospect* (negative *bias*) derives from a more risk-seeking profile, implying less diversification if this agent would opt towards building a *portfolio*.
[26] The default criterion is *market-share*, but it could be easily substituted by *reliability* (number of periods a company made profit over her age) or *performance*.
[27] The environmental parameter is defined at the end of a period and will only affect the decisions in the next iteration.
[28] See (Kahneman & Tversky, 1992, p. 309).

$$w^{+}(p) = \frac{p^{0,61}}{\left(p^{0,61} + (1-p)^{0,61}\right)^{\frac{1}{0,61}}} \tag{2}$$

$$w^{-}(p) = \frac{p^{0,69}}{\left(p^{0,69} + (1-p)^{0,69}\right)^{\frac{1}{0,69}}} \tag{3}$$

Where (1) is the PT value function, which attributes a subjective value to a gain or a loss; (2) and (3) are the weighting functions which yield, respectively, the subjective probabilities in gain and loss contexts.

For the purposes of the Utility Load Model, *x* and *p* must be defined for both the *portfolio* and the *start-up prospects*. The maximum loss in both cases is simply *people's resources*, to calculate the maximum gain the entrepreneurs emulate both scenarios, however, they do it based on present information, so there are no guarantees that the market will be the same in the following period.

Keeping the «heuristic spirit» of the Utility Load Model, the probabilities (*p*) are simply obtainable values, for the probability of loss «*p(loss)*» of the *portfolio prospect* the algorithm is to retrieve the values of the *firms'* «*risk-measure*» which comprises the *firms'* mortality rate if a firm is selling bonds in the NIM and (1 - *reliability*)[29] if it's selling stocks instead. The probability of gain with the *portfolio prospect* is just (1 - *p(loss)*).

For the *start-up prospect*, the entrepreneurs observe the environmental parameter and make use of a rule inspired by the mechanics of the Availability Heuristic, a well-known cognitive bias defined as "the ease with which instances come to mind" (Kahneman & Tversky, 1973, p. 220). Under this, for the probability of gain, *people* observe the number of positive observations relative to the series' length and, analogously, the negative observations for the probability of loss, ergo, if the economic scenario shifts, the relation among the entrepreneurs' assessment of each prospect's utility will follow.

3.4.3 Heterogeneity

With the exception of *resources* and the parameters defined in the interface by the user, all other agents' attributes are dimensions of their heterogeneity.

[29] Recall from footnote 26 that "reliability" is defined as the number of periods that the firm made profit over its age.

3.4.4 Stochasticity

Given that the function of a random variable is also a random variable, the dimensions of stochasticity in the model arise from the randomly determined[30] *heading*, *threshold* and *bias* attributes of the agents, in addition to the random part of the environmental parameter.

3.5 Initialization

The topography of the model is such that *people*, *firms* and *investors* are organized around three concentric circumferences with radius 15, 12 and 8, respectively[31]. The *firms'* circumference is visible and coincides with their product space, where each position corresponds to a variety of the product. The innermost circumference is the NIM, populated by the *investors*.

The agents are initialized by the Setup button that will create a number of *firms* equal the value in the «*incumbents*» slide bar, the analogous is true for *people* and the «*newcomer*s» slide bar.

The «exogenous-death» will add a death rate for the population of *people* in the model, and the «exogenous-exit» will add a probability to *firms* go bankrupt on each period[32]. The «without-market?» switch turns off the option of portfolio investment (see Figure 1).

The interface also contains ten plots (see Figure 1) which are draw from internal global parameters whose initial values are determined at setup procedure and updated on every tick. Plots A, G and B display the progress over time of the quantity of agents from each breed, the environmental parameter and its mean, and the Herfindahl-Hirschman Index[33] (HHI) and its mean, respectively. Additionally, C is a monitor that shows the current value of the HHI mean.

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[30] Based on pseudorandom numbers.
[31] This radius is merely aesthetic and has no role in defining the sector perimeter (demand segment).
[32] Caution is advised when altering this input since, even at 1%, the mortality rate of firms will rise abruptly.
[33] Herfindahl-Hirschman Index is an indicator of the amount of competition within an industry, it ranges from 0 (perfect competition) to 10000 (monopoly), and it's defined as the sum of the squared market-shares (in whole percentage form) of all firms in some sector.

Plot J displays the number of positive (and negative) observations of the environmental parameter, over time, as a percentage of the total number of observations. Plot K indicates the *firms*' mortality rate for each period.

Finally, Plots D, E and I present the histograms for the current distributions of *people's biases* and *thresholds* attributes, and the environmental parameter values, respectively. Plots F and H display the subjective value of gains and the subjective probability of gain for each prospect, these values are requested from a random person at each time step and, as such, the value of the series in a particular period has little meaning, only the long-term trend of these charts are informative.

3.6 Input data

According to Kahneman and Tversky, "when faced with a complex problem, people employ a variety of heuristic procedures in order to simplify the evaluation of prospects" (1992, p. 317). Pursuant to this, simple heuristics are applied to approximate the probabilities (*p*) and afterwards inputted into *people's* weighting function[34]; whereas for the subjective value function, the maximum possible gain and loss (*x*) are emulated for each prospect. All values for the parameters in the PT's functions are the same as those estimated by Kahneman and Tversky (1992, pp. 311-312).

3.7 Submodels

The setup procedures set the layout of the environment, create the initial agents and set the global variables and agents' attributes initial values. Setup also resets everything if there is a previous run of the model displaying.

The running procedures encompass three major submodels: companies, people and environment procedures.

3.7.1 Companies procedures

Firms get older mainly for the calculation of the *reliability* attribute, which is defined at their creation as *profit-history*[35] over *age* and updated every period. They may exit the

[34] This assumption is motivated by the study of Availability Heuristic as well (Kahneman & Tversky, 1973).
[35] A stock variable that stores the total number of periods that the firm obtained profit.

market due to endogenous reasons (*resources* being less than zero) or to exogenous ones – the «exogenous-exit» slider assigns a probability of exit per period to all *firms*.

The revenues are calculated in all time steps *t* and the result is stored in the *revenue* attribute for the remaining of the period. For a given firm *j*, *revenue* is set as follows:

$$revenue_{j,t} = \left(d \cdot r \cdot rm + d \cdot l \cdot lm \right)_{j,t} \qquad (4)$$

Where «*d*» is the value of demand segment for the period, «*r*» is the distance to nearest clockwise neighbour and «*rm*» the portion of the clockwise demand captured by the firm[36], «*l*» and «*lm*» are the analogous variables for the counter clockwise segment. The *market-share «ms»* attribute is simply defined as:

$$ms_{j,t} = \frac{\left(r \cdot rm + l \cdot lm \right)_{j,t}}{360} \qquad (5)$$

Next, the *firms* report their performance as being:

$$performance_{j,t} = \left(revenue - costs - i \cdot debt \right)_{j,t} \qquad (6)$$

Where «*i*» is the interest paid regularly to bondholders (coupon), debt is the amount of bonds the *firms* sold in the NIM, and costs are defined as:

$$costs_{j,t} = tc \cdot \left(revenue + resources \right)_{j,t} \qquad (7)$$

Where «*tc*» is the percentage input given by the interface's *total-cost* slider. Thus, costs are defined linearly as a fixed proportion of the revenues and resources of each period[37].

3.7.2 People procedures

People get older and, if they achieve their life expectancy, die. On every period they evaluate and compare the utility of each prospect to check if their decision threshold was reached (for an illustration of this process please refer to Figure 3). If *people* choose to form a *portfolio* they will divide their resources equally among N *firms*, where N is the diversification proxy for a subject *i* at period *t*, and it's defined as:

$$N_{i,t} = int\left(firms_t \cdot \left(\frac{threshold + bias}{20} \right)_i \right) \qquad (8)$$

[36] Recall that *rm* is just the *firm's resources* relative to its neighbour.

[37] Assumption made for the sake of simplicity.

Where «$firms_t$» is the current number of *firms* in the market and «int» is the operator that extracts the integer part of the result[38].

In order to determine the subjective value of the gain with the *portfolio prospect*[39] *people* multiply the maximum possible gain with a bond or stock by their respective quantities in the prospective portfolio. Subsequently, the result will be inputted into Equation 1.

The maximum possible gain with a bond is computed as:

$$bg_{i,t} = \frac{resources}{N_{i,t}} \cdot 1 + i^{\;rl} \qquad (9)$$

Where «*bg*» is the maximum gain with a bond and «*rl*» is the person's «remaining life» defined as *life-expectancy* minus *age*. Note that *rl* could also be understood as the investment horizon, i.e., how long the person expects to hold the bonds.

Likewise, *people* compute the maximum gain with stocks using a simple proxy «*bs*» for the share appreciation:

$$bs_{i,t} = \frac{resources}{N_{i,t}} \cdot \frac{sector}{firms}_{t} \qquad (10)$$

Where *bs* indicates how large would the firm be in the present if the demand was distributed equally; «*sector*» is the sum of all *firms*' current *resources*.

To estimate the maximum possible gain with the *start-up prospect*, *people* emulate the scenario of the present market while including their «possible future start-up», the resulting computation is the *revenue* that their start-up would get, *ceteris paribus*, if they chose to create one.

The *investors* breed are considered *people*[40] for what concerns the aging process and they are hidden from the layout in case of all the companies in their portfolios exiting the market.

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[38] Equation 8 is a portfolio diversification proxy, the numerator captures how risk-taker some agent is (assuming risk-taking as lower values of the numerator) and the denominator is the length of the *thresholds* range (extending from -10 to 10).

[39] Recall that the maximum loss is just the amount of *resources*.

[40] For technical reasons a distinction was inevitable, thus *investors* may be interpreted as «post-choice *people*».

3.7.3 Environment procedures

The environmental parameter is resolved and plotted every period, it's partially defined by the percentage of *firms* that had a positive *performance* – if more than half, assumes the value 1, or else (- 1) – and partly a randomly selection from {-1, 1}; both parts are added to the last value of the parameter to determine its present value. The endogenous part of this parameter also sets the background colour to blue or red depending on whether more than half of the *firms* made a profit or not.

Additionally, the sum of the parts of this parameter, which can assume one of {-2, 0, 2}, define the value of the demand segment[41] in the forthcoming period to be one of {400, 500, 600}, respectively.

[41] Recall as being the perimeter of the sector with a one degree central angle.

4 Results

4.1 Simulations

The Utility Load Model was simulated 368 times in order to explore all the combinations of the following parameters' values[42]:

- *no-bias?* {on, off}
- *incumbents* {2, 20}
- *newcomers* {3, 6}
- *life-expectancy* {36, 180}
- *interest* {0.05}
- *exogenous-exit* {0.001}
- *total-cost* {0.5}
- *without-market?* {off}
- *exogenous-death* {0.01}

Each combination ran the «***K***» number of times shown inside the parenthesis in the third column[43] for 600 periods, which gave a total of 221.168 observations[44]. The HHI and its mean (μ) as well as the environmental parameter (*lambda* or λ) and its mean were reported for each run, the results are summarized below:

TABLE 1 SIMULATIONS WITHOUT COGNITIVE BIAS

interest {0.05}; ***no-bias?* {on}**; *exogenous-exit* {0.001}; *total-cost* {0.5}; *without-market?* {off}; *exogenous-death* {0.01}

incumbents	*newcomers*	*life-expectancy*	μ(HHI); t = 600	μ(λ); t = 600	ρ(HHI,λ)	mean[μ(HHI)]	mean[μ(λ)]	corr[μ(HHI),μ(λ)]
2	3	**36 (20)**	*4225,7*	*-198,9*	*-0,915*	3721,2	-86,5	-0,918
		180 (20)	*8713,4*	*-369,2*	*-0,803*	7486,3	-170,0	-0,981
	6	**36 (20)**	*4251,9*	*-240,9*	*-0,861*	3685,5	-107,4	-0,885
		180 (20)	*8646,6*	*-37,0*	*-0,657*	7223,6	1,9	-0,955
20	3	**36 (20)**	*333,5*	*37,2*	*-0,218*	333,7	20,3	-0,437
		180 (20)	*921,5*	*96,3*	*-0,101*	710,9	48,4	-0,032
	6	**36 (20)**	*474,2*	*1,8*	*-0,038*	412,5	3,1	0,086
		180 (20)	*2677,8*	*49,5*	*-0,235*	1154,6	28,8	0,428

[42] See Figure 1 attached.
[43] Due to my temporal constraints and the computational power demanded by the model, the simulations were made in different machines and some overlapping between them was unavoidable, thus, the different number of runs for each parameters' combination.
[44] A spreadsheet containing these simulations' results is available at: **https://goo.gl/g8FLWl**

The previous table illustrates the relations of three user-defined parameters (first three columns) and their impact on lambda and HHI[45], while all other parameters are hold constant (attuned to the values shown above the table).

The statistics displayed in the fourth to sixth columns are, respectively: the mean of the HHI values reported in the last period of each run «$\mu(HHI_{t=600})$»[46]; the mean of the lambda values[47] conveyed at the final step of each run «$\mu(\lambda_{t=600})$»[48]; and the correlation amongst the K observations of the two previous values «$\rho(HHI, \lambda)$»[49].

The three last columns show, respectively: the mean of K observations of the HHI's mean for the 600 periods of each simulation[50]; the analogous measure for the lambda parameter[51]; and the correlation between K observations of the preceding measures.

The afore described sets of statistics[52] give us two distinct perspectives on the model's comportment, namely, while the first three inform the expected final state of the model for the given parameters' values, the last ones provide an idea of the model's expected behaviour throughout the 600 periods[53].

We can infer that the initial conditions of the system are of significant importance to its final state. In the «without bias version» of the simulations[54], the HHI's inner mean tend not to be far, in relative terms, from the end-point mean. The environmental parameter is more erratic and has a strong descending trend for the scenarios starting with fewer *incumbents*, although for the high *newcomers* value and longer *life-expectancy* this trend balances out. As it does in the scenarios with a higher number of *incumbents*.

The strong negative correlations between the HHI and lambda for the low *incumbents'* scenarios tells us that a downward movement of the economic environment

[45] Usually, industries with HHI values between 1500 and 2500 are considered by antitrust agencies as moderately concentrated whilst HHI above 2500 represent a highly concentrated market structure.
[46] Hereby referred as *end-point mean*.
[47] The *lambda* values by their own have no interpretative meaning, their only relevance to this analysis comes from their comparison among different scenarios.
[48] Hereby referred as *end-point lambda*.
[49] Hereby referred as *end-point correlation*.
[50] Hereafter dubbed as *inner mean*.
[51] Hereafter dubbed as *inner lambda*.
[52] Fourth to sixth columns and fifth to ninth.
[53] Hereafter dubbed as *inner correlation*.
[54] See Table 1.

is related to an increase in the industry's concentration, possibly due to a higher *firms'* mortality rate on recessionary periods. However, as the number of agents participating and interested in the market grows, this reading reverses, i.e., in recession the HHI lowers and vice versa[55].

The solid difference in the HHI figures for both *incumbents* settings enlighten the significant impact of latter on the former. Another interesting regularity emerges from the observation of the *life-expectancy* effect, recall that *life-expectancy* also determines the investment horizon[56], and the substantial impact of a five times greater horizon in the HHI's inner and end-point means conveys that the *portfolio prospect* consistently beats the alternative when the choice is between «starting a company» or «doing a long-term investment».

The reason is that a lengthier investment horizon grants, via the PT function, a greater prospective gain with bonds, subsequently attracting the vast majority of potential entrants (*newcomers*) to the NIM. The prior has a nefarious effect on the sector's structure which is pushed towards an oligopoly, reflected by the HHI. The relative impact on the HHI is even greater in the scenario with a higher number of *incumbents* and potentials entrants, as the last two rows of Table 1 illustrate.

Table 2 gives the same measurements as the prior table, but with the «no-bias?» parameter altered, i.e., in the succeeding, people exhibit personal inclination towards one of the prospects:

TABLE 2 SIMULATIONS WITH COGNITIVE BIAS

interest {0.05}; ***no-bias?* {off}**; *exogenous-exit* {0.001}; *total-cost* {0.5}; *without-market?* {off}; *exogenous-death* {0.01}

incumbents	*newcomers*	*life-expectancy*	μ(HHI); t = 600	μ(λ); t = 600	ρ(HHI,λ)	mean[μ(HHI)]	mean[μ(λ)]	corr[μ(HHI),μ(λ)]
2	**3**	**36 (20)**	*78,3*	*11,4*	*0,172*	519,1	6,8	-0,096
		180 (20)	*846,3*	*47,4*	*-0,228*	1807,8	17,3	-0,260
	6	**36 (40)**	*53,2*	*22,2*	*-0,454*	257,2	12,9	-0,174
		180 (40)	*782,3*	*77,0*	*0,038*	1163,6	37,7	-0,144
20	**3**	**36 (28)**	*57,3*	*29,2*	*-0,108*	154,0	20,4	-0,155
		180 (20)	*450,9*	*44,6*	*0,218*	448,7	23,0	0,189
	6	**36 (20)**	*69,4*	*19,9*	*-0,294*	154,3	10,5	-0,429
		180 (20)	*575,5*	*62,0*	*0,022*	517,8	28,8	-0,430

[55] Koellinger and Thurik verify a similar regularity in a 22 OECD cross-country panel study (2009).
[56] Vide Equation 10.

Trivially, adding another dimension of stochasticity (*bias*) to the model makes the patterns of the inner and end-point correlations less clear, in contrast, the relative effects of a longer *life-expectancy* on the HHI become more pronounced. Albeit, the magnitude of the HHI's inner and end-point means are considerably reduced by the augmented randomness of the model.

Another conspicuous distinction of the «with bias» simulations are the strictly positive values of the lambda statistics, which indicate that less rationale from entrepreneurs favours growth. In model terms, the *bias* attribute increases the probability of *load* reaching a *threshold* earlier, therefore, allowing for more uncertain decisions from *people*. Despite the fact that a greater tolerance for uncertainty does not benefit entrepreneurs, it serves the economy by increasing the inflow of investments and new firms in the sector.

Succinctly, by comparing the results of both tables, we can infer that a more bounded rationale is welfare increasing – reflected by the less concentrated market indexes and long-term economic growth trend of Table 2.

Moreover, as a general trend of the simulations, in a context where firms are allowed to continuously issue new debt to the public, the sector tends to be more concentrated that would be otherwise, therefore, diminishing welfare.

4.2 Observed dynamics

4.2.1 Dynamic equilibria

After a warm-up period, the populations of the main agents tend to stabilize around some constant value, which depends on the initial conditions. This is considered a dynamic equilibrium, i.e., a state of the system where continuously opposing forces balance each other, in this case, the creation and death rates of the agents grow at the same rate. Nonetheless, since the model is not a closed system (due to stochastic factors), this equilibrium can be disrupted. Indeed, abrupt changes in the state of the system have been observed for very long simulations (over 5000 periods[57]).

[57] Notice that this is not a robust statistic since these are very time-consuming simulations.

4.2.2 Monopolist disadvantage

More easily observed with combinations of parameters that yield a higher HHI, in this dynamic, when a firm gets to be the only one in the market and continuously supplies bonds for the entire industry's NIM, it can be brought to bankruptcy due to financial debt.

4.2.3 Squeeze-out

Typically observed when three or more *firms* occupy the same address in the product space, if two of them start to grow concurrently, the other(s) is(are) pushed out of the market due to the shortage of local demand, illustrating a seemly paradoxical scenario where aggressive competition amongst immediate neighbours effectively increases market concentration.

4.2.4 Recessionary entrepreneurship

Recessionary periods do not prevent entry. Indeed, it follows from the dynamic equilibrium of the *firms*' population that the rate of entry floats around some constant value. The fourfold pattern observed by Kahneman and Tversky[58] actually explains this dynamic, they observe that people tend to present risk-seeking behaviour for losses with high probability. Since the ABM assumes that recessionary periods are equivalent to the loss context, the longer the recession, the higher will be the probability of loss and more risk-seeking the entrepreneurs will be – entailing the creation of start-ups[59] even in bad economic environments.

4.3 An alternative interpretation

It is worthwhile underlining that the Utility Load Model also has an alternative reading as a multi-brand duopoly, where the incumbent (brown firm) faces the threat of a potential rival (green firm) in the same product space. In this interpretation, the two *firms* not only compete for market-share through multiple varieties of a product, but also for equity and security investors (*people*).

[58] Vide (Kahneman & Tversky, 1992)
[59] Remember that we assume the *start-up prospect* as the more uncertain one.

4.4 Discussion

4.4.1 Conditions in which the NIM is a behavioural barrier to entry

The simulations delivered beforehand, which are not exhaustive of the model's behavioural space, identify two conditions in which the NIM can be understood as a behavioural entry barrier for entrepreneurs, namely: long-term investments' horizons and/or high *interest* rate (coupon) of bonds – since both increase the prospective gains with a portfolio.

4.4.2 Model's realism

The empirical validation of an ABM is an extensive econometric analysis, which by itself is a workload equivalent to a Master's thesis. Therefore, to counter the downside of a purely abstract model, I have based the cognitive rules of the agents on empirically founded theories, namely, PT and RWM.

Furthermore, most of the resulting dynamics of the Utility Load Model can be observed in everyday life, except, perhaps, recessionary entrepreneurship. Koellinger and Thurik (2009) made a panel data study with 22 OECD countries on the relations between entrepreneurship and business cycles, which concluded that some categories of the first precede the upturn of the second. In other words, they empirically observed a regularity similar to recessionary entrepreneurship. They attributed this effect mainly to unemployment and a «nothing to lose» mentality of people. In this regard, the Utility Load Model contributes to their explanation of this phenomenon by bestowing a link between the cognition of entrepreneurs and the correspondent economic reality, via PT functions.

4.4.3 Caveats

Any assumption is a limitation, still some deserve further attention. The Utility Load Model is anchored in a handful of assumptions for the sake of simplicity, namely:

i. *No intermediary stages between start-up and initial public offering*: the reason is to keep the focus of the analysis in the firms that successfully integrate the capital markets. However this creates some theoretical issues, for instance: is the *firms'* mortality rate being underestimated? Are *people* a combination of entrepreneur and venture capitalist? The answer to both questions is affirmative.

To include intermediary stages is certainly an improvement to be done in future versions of the model in order to adjust the mortality rate of *firms* to a more realistic demeanour.

The *people breed* can in fact be interpreted as twofold, although this might appear ambiguous, their categorization does not interfere with the interpretation. Again, the concern of the model is the decision-making, hence, post-choice classification is irrelevant.

ii. *All firms participate in the NIM*: this assumption follows from the previous one, and may be responsible for an underestimated number of *firms* in the market, since not all firms that compete in the product space opt to go public. Notwithstanding, this is very likely a minor deviation, since commonly most private companies are in the tail of the market-share distribution.

iii. *Firms don't compete through prices*: the reasoning is that, in Salop's circular market[60], price competition leads to zero profits equilibrium. So the circular market design adopted here diverges from Salop's horizontal differentiation with respect to the type of competition, to the rigidity of *firms'* addresses, and in determining demand.

iv. *Demand is uniformly distributed*: inherited from horizontal differentiated models, it is an ordinarily used assumption for the sake of the analysis, which might cause an underestimation of the leading *firms'* market power. This assumption could be easily relaxed in future works.

v. *Fixed lifelong portfolios*: investors change strategy in order to adapt to new circumstances, even if a lifelong portfolio is a realistic alternative to a «lifelong investment in a newly created firm», at least some amount of fine tuning should be expected in practice. An effect of such assumption in the results are a more equal distribution of *investors* among *firms*.

[60] Vide (Salop, 1979a)

vi. *Resources evenness*: all *people* start with the same amount of resources (1000), this assumption could be easily loosened so as to follow a more realistic distribution of societal resources. Thus, becoming a dimension of heterogeneity in a future version of the Utility Load Model.

vii. *No speculation*: not as much an assumption as a default interpretation, investors habitually speculate in secondary markets, since the supply of newly issued securities is scarce. The user can easily emulate speculative behaviour in the model by setting *life-expectancy* to low values.

5 Final remarks

5.1 Relevance

A novelty of the present thesis was the study of the connection between the cognitive processes of entrepreneurs (cognition scale) and the industry's correspondent structure (market scale) of an economic system. A researcher trying to find, empirically, a connection between the two scales would encounter many practical issues, one of them being, simply, where to look? There are countless factors that an educated guess would consider as valid candidates to explain the presence (or absence) of such a link.

There are three fundamental questions to be answered before deliberating about the relevance of the Utility Load Model, namely: does the model provide conclusive evidence to accept the hypothesis that the manner in which entrepreneurs make choices influences the market structure? «No». Then, does the model give enough evidence to reject this hypothesis? «No». Lastly, does the model provide more information about the system that one would have had otherwise? «Yes». Perhaps, one might say, the latter is the main contribution of this kind of work.

The results presented here, which were not exhaustive[61], narrow the range of reality where one could research for the relationship among cognition and market scales. In turn, making an empirical or experimental study on this matter more attainable. Moreover, the results exposed anteriorly ascertain that NIM as a behavioural barrier to entry is a plausible collateral effect of the way modern economies are structured.

5.2 Future developments

As stated earlier, the interface of the model contains a switch, named *without-market?,* to study the hypothesis of a sector without NIM. However, I have encounter some technical difficulties in simulating this scenario since, in this condition, the number of operations grows exponentially with time. Given the temporal constraints of this thesis, such hypothesis was left to be studied in the future.

[61] Notice that, in Chapter 4, I only explored a set of possible parameters' combinations. Thus, in theory, there are no reasons why one might not find, by further exploring the model, other factors that connect the cognition of entrepreneurs and the sector's market structure.

I anticipate several ways in which the Utility Load Model could be improved, to mention a few: turning *life-expectancy* into a dimension of heterogeneity; refining the heuristic used to compute the prospective gain with a start-up; allowing for fluctuations in the price of stocks and bonds; refining *firms*' behaviour regarding the issuing of securities; including non-linear cost function; adding government to the mix; and so on.

The current results also leave the door opened for interesting studies of experimental as well as econometric nature that investigate empirical regularities which could validate the model as a prediction tool, thus, this should be expected in forthcoming works.

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Attachments

I. Figures

FIGURE 1 UTILITY LOAD MODEL INTERFACE: BUTTONS AND VIEW

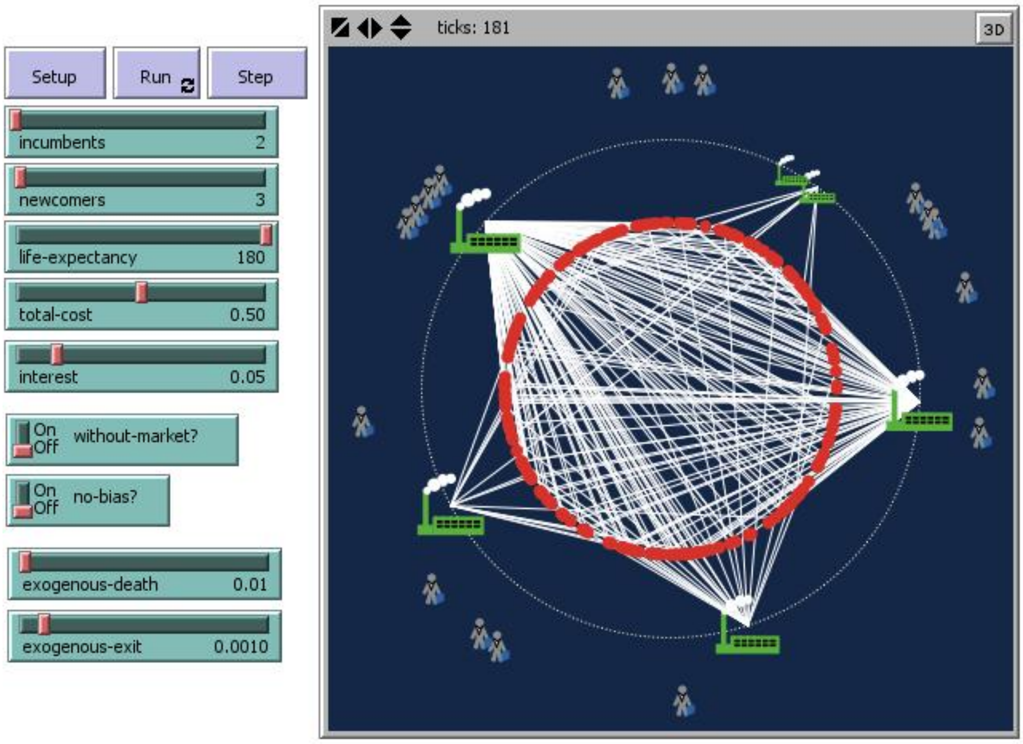


FIGURE 2 UTILITY LOAD MODEL INTERFACE: GRAPHS AND MONITORS

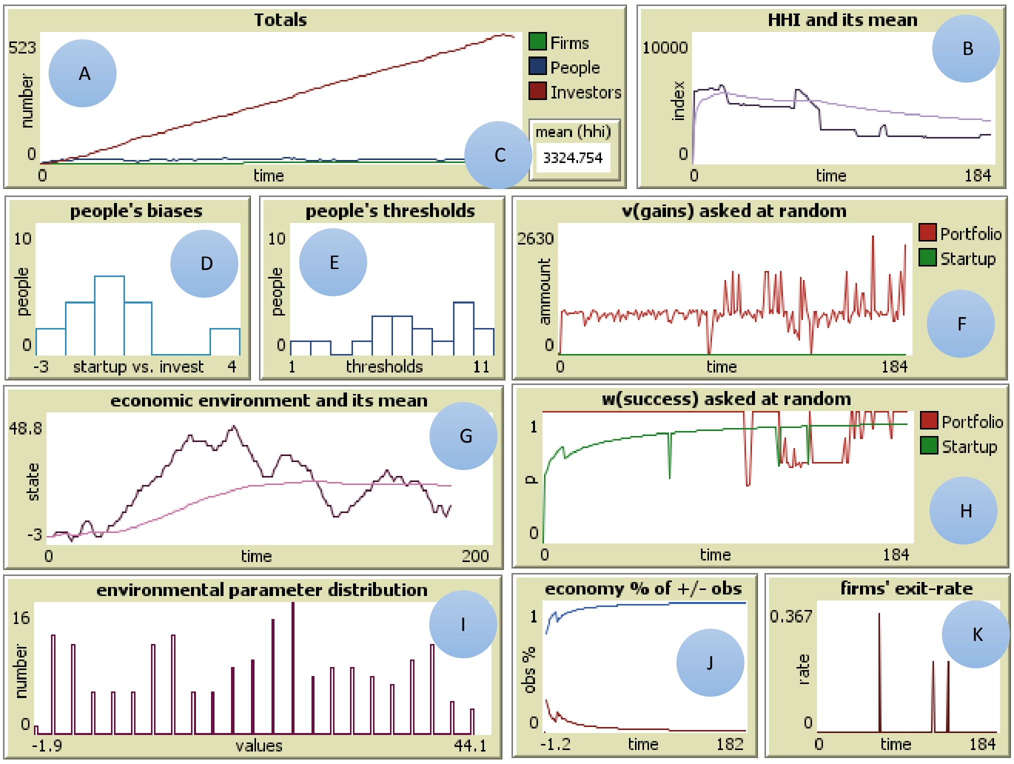


FIGURE 3 PEOPLE'S COGNITION PROCESS

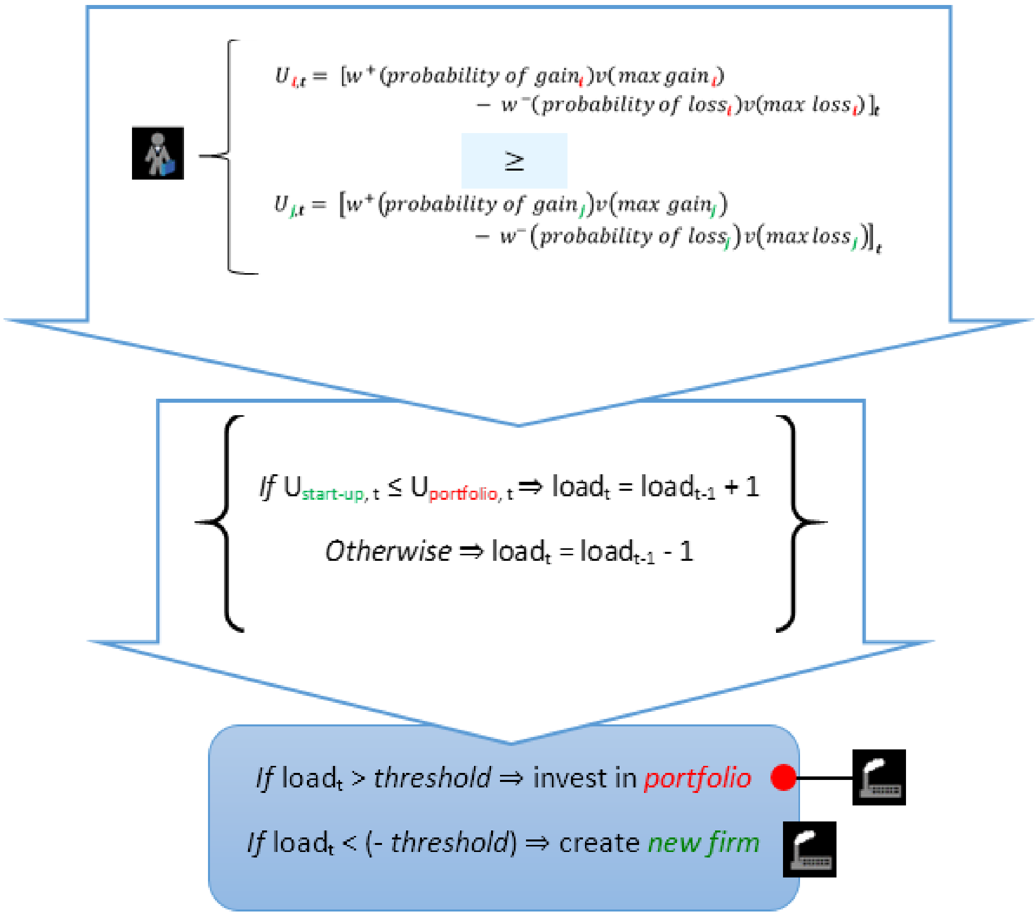
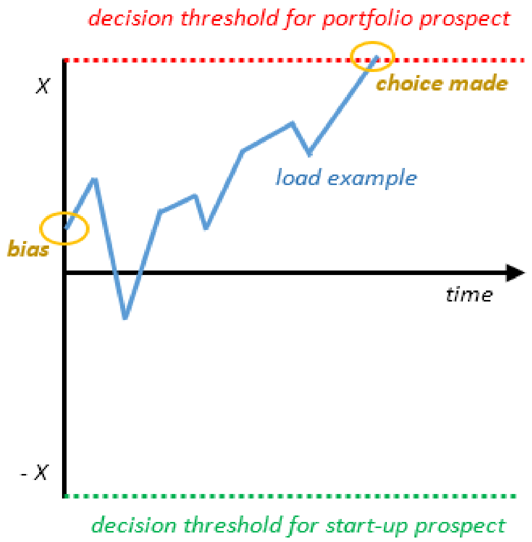


FIGURE 4 EXAMPLE OF RWM PROCESS



II. Schedule's pseudo-code

1. SETUP [DONE ONLY ONCE AT START]
    - **1.1. Sets the layout of the model**
    - **1.2. Creates a number of incumbents (firms) and newcomers (entrepreneurs) equals to the chosen values of their respective sliders**
    - **1.3. Sets the initial values of the internal variables**
2. RUN [DONE CONTINUOUSLY OR ONCE IF THE BUTTON STEP IS USED INSTEAD]
    - **2.1. Creates a number of newcomers (entrepreneurs) equals to the chosen value of the slider**
    - **2.2. Checks if any person dies due to exogenous causes, people's death rate is determined by the respective slider on the interface**
    - **2.3. Runs people's processes one by one at random order**
        - 2.3.1. Check if they reached their life expectancy (determined by the respective slider)
        - 2.3.2. Compare the utilities of the start-up and portfolio prospects
            - 2.3.2.1. If the start-up prospect utility is less than or equal to the portfolio prospect utility, add one to the current value of the *load* attribute. Otherwise subtract one from the current value of the *load* attribute
        - 2.3.3. Checks if the value of *load* is greater than their respective *thresholds*
            - 2.3.3.1. If true and there are no firms to invest in, sets colour to yellow and jumps to step 2.5
            - 2.3.3.2. If true, turns them into investors (red dots) and creates links (white lines) with N firms
        - 2.3.4. Checks if the value of *load* is less than their respective negative *thresholds*
            - 2.3.4.1. If true, turns them into new firms (green factories)
    - **2.4. Runs investors' processes one by one at random order**
        - 2.4.1. Check if they reached their life expectancy (determined by the respective slider)
        - 2.4.2. Checks if the firms in their respective portfolios still exist
            - 2.4.2.1. If none exist, hide the investor from the layout
    - **2.5. Runs firms' processes one by one at random order**
        - 2.5.1. Checks if their resources are negative, if so, they die
        - 2.5.2. Checks if they exit the market due to an exogenous cause, which the probability is determined by the respective slider on the interface
        - 2.5.3. Calculates the period revenues
            - 2.5.3.1. Firms calculate the captured portion of the circumference's segments between them and their immediate neighbours (local demand) as a proportion of their resources relative to their neighbours.

2.5.4. Reports the firms' results

2.5.4.1. Attributes a *risk-type* to them «bond» or «share» according to whether they have debt or not

2.5.4.2. Sets the amount of costs of the period as the input percentage in the *total-cost* slider times their revenues and resources

2.5.4.3. Sets their *performance* attribute to be the amount of revenue minus the costs and the interest paid over the amount of debt (if any)

2.5.4.4. Updates the *resources* attribute to be the past value plus the *performance*

2.5.4.5. Updates the market-shares to the current portions of the total demand captured by each firm

2.5.5. Checks if they had a positive *performance* (made profit)

2.5.6. Updates the value of the *reliability* attribute

2.6. Calculates this period's mortality rate of firms

2.7. Updates the environmental parameter (*lambda*) value

2.7.1. Checks if less than half of the firms made profit

2.7.1.1. If true, subtracts one from the last value of lambda and sets the background to red

2.7.1.2. Otherwise, adds one to the last value of lambda and sets background to blue

2.7.1.3. Chooses at random one of negative or positive one and adds the chosen value to current value of lambda

2.7.2. Checks if the sum of the exogenously and endogenously determined parts of *lambda* is greater, less than or equals to zero

2.7.2.1. If greater than, less than or equal to zero sets the segments of the circumference's perimeter (local demand) to be 600, 400 and 500 respectively (affecting the next period)

2.8. Calculates the HHI of the period

2.9. Updates the plots, global variables and adds one to the time steps (ticks) counter