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SIMULATION OF ALTERNATIVE SCENARIOS IN PORTUGUESE WINE SECTOR: AN AGENT-BASED MODEL APPROACH

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Abstract

The wine sector is one of the most remarkable industries in Portugal exhibited by the several and important demarcated regions. This paper intends to predict the wine industry farm sustainability of two of the most relevant Portuguese regions, North and Alentejo. The available data on the Portuguese Farm Accountancy Data Network (PTFADN 2001-2012) which compiles social, economic and environmental parameters from 2001 until 2012, allowed us to perform the function fitting with MATLAB and gather information about each variable's behaviour. That information was then blended into our selected methodology, an ABM that emulates the current North and Alentejo wine-production reality and simulates their further development. Considering the current status of both regions and our model parameters, the 100 years simulation showed that only 38% and 68.2% of the North and Alentejo farms respectively would subsist by the end of the timeframe. By changing the model initial conditions, alternative scenarios were tested and governmental policies were evaluated. The grape selling benefits generally outperform the direct governmental subsidies, to the point that a simple governmental grape selling benefit of 0.054(€/kg) on the Northern region may avoid the extinction of 15.6% of the farms in the next 100 years. The results also showed that the Alentejo region is generally better prepared to deal with increasing labour and environmental costs opposed to the North region, which saw a severe depletion of the farm survival rates during this experiment.

Keywords: Agent-Based Model, Wine Sector, Performance, Sustainability.

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Introduction

The wine sector presents itself as one of the most important economical and historical Portuguese endeavours. In fact, this sector relevance goes way beyond the pragmatic profit-oriented approach since the extensive Demarcated Regions such as the Douro and the Green Wine Demarcated Regions in the North of Portugal own an uncapped non-tangible value. The extensive vineyards in the Northern region bundle quality wine production (the worldwide known Port Wine is one of the region most cherished treats) with a mesmerizing set of wine landscapes perceived as a potential resource for the development of the tourism (Rachão and Joukes, 2017). Alongside the Northern Region which is characterized by the prominent steep mountain viticulture, Alentejo shows up as the other most relevant wine producing region from

Portugal. Alentejo drifts away from the North's entrepreneurial layout since it's based on plain field viticulture welcoming the high mechanization of vine related tasks. Since the viticulture activity relies on natural scarce resources and there is a major concern with the trade-off between intensive production and the activity environmental impact (Marta-Costa *et al.*, 2012), this premise falls purely into the sustainability notion which is usually defined as a three-dimensional concept (Marta-Costa *et al.*, 2012; Mencarelli and De Propris, 2014). This article follows up this assumption acquainting three core variables (social, economic and environmental) which may describe the long-term sustainability of the featured regions (Alentejo and North). To reach the inner Alentejo/North dynamics MATLAB R2017a software was used to interpolate the data of those two regions into trendy but periodical functions. Afterwards the ABM software (NETLOGO) was selected to simulate the following 100 years acquainting the real data-based dynamics previously found.

This article is divided into 5 sections. After the brief introduction about our working concept and major goals, Section 2 presents the methodological literature review. Section 3 explicitly presents the ABM formulation while Section 4 dives into the numerical simulation with shifting initial conditions. The overall conclusions are finally presented on Section 5.

Literature Review

Agent-based models have become an increasingly important tool. They are particularly valuable for systems that are not understood well enough to build an equation-based model. Those models also display an inherent simplicity that eases the output presentation to people without intensive knowledge about the scientific facts. An *et al.* (2017) considers ABM's as "middle-ware" investigatory objects that can select abstracted representations of real-life that seem too complex for formal traditional mathematical analysis. ABM building allows the researcher to settle arbitrary deterministic events or relationships between agents that underpins the complexity levels and computational expense. On the other hand, the event bundle created by the author may generate unforeseen results and aware him about patterns and relationships that he wasn't aware before (emergence).

The ABM's inner simplicity and absence of evaluation mathematical tools was criticized right way by Lorek and Sonnenschein (1999), so, in order to counter that statement, Grimm *et al.* (2006, 2010) proposed a set of ABM generic format rules that intend to create a standard basis for those models. Called frequently "Overview, Design Concepts, Details" (ODD) the main purpose of this protocol in to make ABMs writing and reading easier and therefore more suitable for replication. It is also worthier to point out that the application of the ODD protocol may be extended to other large and complex models in general.

The properties of individual organisms how they grow or develop (reproduction, dead, hunting, gathering food) and how they interact with each other can be represented quite well by using an ABM. Alongside the inner individual features the environment can also be configured fact that allows the researcher to collect information about the interaction between the individual agents and the environment. The way as the individuals respond to external circumstances in a mapped landscape can be modelled in detail with the ABM approach (e.g. DeAngelis and Mooij, 2005; Grimm *et al.*, 2005; Railsback and Grimm, 2012). Considering that range of possibilities, the ABM methodology presents itself as a perfect contender for Ecology or Biology studies. For example, Santos *et al.* (2017) models an ABM framework that intends to predict bat activity and mortality on wind farms. Sibly *et al.* (2012) presents the energy acquisition by individuals in ABM, emulating the dynamics within an animal population, while DeAngelis (2005) formulates the systematic of ecological and evolutionary processes. Nonetheless, ABM's features also reveal themselves very useful in the social sciences such as Economics or Psychology (Smith, 2007). A few authors such as Kohler (2000), Bonabeau (2002) and Conte (1997) describe the dynamics in human societies and also ABM methods and suggestions to simulate those systems. An (2012) modelled a coupled human decision and natural system (environment) ABM. In fact, those human based dynamics, heterogeneity, decision making process coupled together in this methodology not only present a deliberate invitation to Economic modelling but also as main tool to solve latent economics problems (Farmer, 2009). Regarding more specific Economics applications, ABM methodology has been used to describe Keynesian model of income distribution alongside credit and fiscal policies (Dosi *et al.*, 2010, 2013), financial incentives in market-oriented policies (Sierzchula *et al.*, 2014; and Shafiei, 2012), or analyse threats to the financial stability (Bookstaber, 2012).

Material and Methods

To attain a simulation-wise environment and further apply our featured methodology (ABM) the data available on PTFADN (2001-2012) was considered to model deterministic functions that describe the behaviour of the North and Alentejo farms.

Since we want to evaluate the overall sustainability of the wine farms considering their own heterogeneity, each farm should acquaint a set of variables that display their current entrepreneurial status. As referred on Section 1, the goal is to avoid farm bankruptcy and allow the subsistence of such an important Portuguese sector. The model premise is quite simple. Each farm has a set of inner characteristics such as their own area, bank balance, overall management quality, productivity (size-dependant) and location (Alentejo or North). At each period the farm produces and sells their grapes (for wine production) considering their own productive capacity and foreign market prices: grape selling value, labour, intermediate consumption among others. Afterwards the bank balance is updated and a trigger is settled to evaluate if the farm is sustainable and can proceed their activity or it closes.

Considering the available data on PTFADN (2001-2012) from 2001 until 2012 (for North and Alentejo regions), we collected the values of the subsidies (euro per ha), investment (euro per ha), production (ton per ha), labour costs (euro per ha) and finally an environmental bundle variable which compiles the sum of: electricity, fuel and lubricant, fertilizers, crop protection and water (all specified in euro per ha). Each variable compiles a short-term time series from 2001 until 2012 furtherly interpolated with the MATLAB fitting tool (see Appendix 1 - Figure 4 and 5 for graphical results). It is also important to consider that the farm productivity generally improves with larger areas due to the increasing returns to scale (Sellers and Alampi-Sottini, 2016). To obtain a function that relates the farm size and productivity (Appendix 1 - Figure 6), we used the Galindro *et al.* (2018) results which delivers a productivity coefficient per farm size (nine area intervals) in the Douro Region (three sub-regions). To perform the MATLAB fitting we gathered average values from Galindro *et al.* (2018) bundling the three sub-regions productivity into one and considering the average value of the authors. The size productivity function *V(s)* is now obtained (Equation 11) for the model variables start from the 2012 values (initial conditions) and evolve according to the individually obtained function.

$$P_a(t) = 2169 + 514.7 \cdot \cos(w_1 t) + 1475 \cdot \sin(w_1 t) - 926.7 \cdot \cos(2w_1 t) + 627.6 \cdot \sin(2w_1 t) \quad (1)$$

$$P_n(t) = 3193 + 328.1 \cdot \cos(w_2 t) + 204.9 \cdot \sin(w_2 t) + 168.9 \cdot \cos(2w_2 t) + 170.9 \cdot \sin(2w_2 t) \quad (2)$$

$$L_a(t) = 149.4 + 7.006 \cdot \cos(w_3 t) + 132.9 \cdot \sin(w_3 t) - 116.5 \cdot \cos(2w_3 t) - 3.045 \cdot \sin(2w_3 t) \quad (3)$$

$$L_n(t) = 664.6 + 95.17 \cdot \cos(w_4 t) + 111.4 \cdot \sin(w_4 t) - 36.62 \cdot \cos(2w_4 t) + 50.39 \cdot \sin(2w_4 t) \quad (4)$$

$$E_a(t) = 140.7 + 30.16 \cdot \cos(w_5 t) + 31.61 \cdot \sin(w_5 t) - 29.1 \cdot \cos(2w_5 t) - 22.43 \cdot \sin(2w_5 t) \quad (5)$$

$$E_n(t) = 293 - 5.764 \cdot \cos(w_6 t) + 17.01 \cdot \sin(w_6 t) - 14.02 \cdot \cos(2w_6 t) - 16.21 \cdot \sin(2w_6 t) \quad (6)$$

$$I_a(t) = 623.5 + 516 \cdot \cos(w_7 t) - 303.4 \cdot \sin(w_7 t) \quad (7)$$

$$I_n(t) = 603.2 + 30.02 \cdot \cos(w_8 t) + 150.4 \cdot \sin(w_8 t) + 69.05 \cdot \cos(2w_8 t)$$

$$+126.6 \cdot \sin(2w_8 t) + 112.6 \cdot \cos(3w_8 t) - 109.2 \cdot \sin(3w_8 t) \quad (8)$$

$$S_a(t) = 1715 - 1529 \cdot \cos(w_9 t) - 598.7 \cdot \sin(w_9 t) \quad (9)$$

$$S_n(t) = 5.918e08 - 5.918e08 \cdot \cos(w_{10}t) + 1.299e05 \cdot \sin(w_{10}t) \quad (10)$$

$$V(s) = 0.2558 - 0.000145s + 0.008062s^2 \quad (11)$$

Where variables *t* and *s* represent, respectively, the simulation time-period, with $t \in \{1,2,\ldots,100\}$ and the farm size. Equations (1) and (2) represent the Production (Y); Equations (3) and (4) are the Labour (L); Equations (5) and (6) represent the Environment (E); Equations (7) and (8) are the Investment (I); Equations (9) and (10) represent the Subsidies (S); and Equation (11) are the size productivity (S) (see Table 1). The constant values are given by:

$$w_1 = 0.5023, \quad w_2 = 0.6365, \quad w_3 = 0.5459, \quad w_4 = 0.4698, \quad w_5 = 0.7204,$$

$$w_6 = 1.067, \quad w_7 = 0.312, \quad w_8 = 0.6585, \quad w_9 = 0.07364, \quad w_{10} = -0.0001127$$

Modelling Procedure

The description of the model follows up the suggested specifications of the standard protocol ODD (when applicable) to describe ABMs, proposed by Grimm *et al.* (2010). NETLOGO 6.0.3 software (Wilensky, 1999) was used to perform the simulations and to calculate the several model outcomes. For simplicity both Alentejo and North farms will be simply referred as “wine-farms” since most of the concepts are analogous between them.

Virtual site description

The model simulates the subsistence of Alentejo and Douro farms and emulates two separated landscapes (one per each region) overshadowed by distinctive global variables, since the problem formulation doesn’t acquaint spatial interactions among the agents their location on the 1024 patched grids is arbitrary.

Overview

Entities, state variables and scales

The model contains three types of conceptual variables (Table 1): the patches (unit cells) which form the virtual landscape and splits the studied area into two different regions (North and Alentejo), the generated wine-farms which are able to produce at each period, own a certain initial area (in ha) normally distributed with parameters approximately equal to the average values of the real data PTFADN (2001-2012), a management quality status, an initial bank balance and a Size Productivity value, both acquainting the farm size. Finally, the global variables surround the agent’s production function supplying the market values of the several available features stated on Table 1.

Variable	Alentejo (IC)	North (IC)	Brief Description
Grape selling price (P)	0,82€	0,82€	Grape selling price (€/kg) given by the external market.
Area (A)	~N (19.92, 5)	~N (8.23, 5)	Individual farm area (ha).
Bank Balance (B)	A* ~N (20000, 1000)	A* ~N (20000, 1000)	Initial bank balance from each Douro and Alentejo farm (€).
Quality (Q)	Random number (0.5-1.5)	Random number (0.5-1.5)	Inner farm conditions (management, terrain, vineyard structure) that can overvalue or undervalue the production. (-50% to +50%).
Subsidies (S)	Equation (9)	Equation (10)	Subsidies value that each farm receives from the government per each period (€/ha).
Investment (I)	Equation (7)	Equation (8)	Yearly investment value by the producer (€/ha).
Environment (E)	Equation (5)	Equation (6)	Bundle of intermediate consumption that each farm expends in order to produce (€/ha).
Labour (L)	Equation (3)	Equation (4)	Labour costs that the farm needs to support in order to produce (€/ha).
Production (Y)	Equation (1)	Equation (2)	Individual grape production (kg/ha) of each farm.
Size Productivity (V)	Equation (11)	Equation (11)	Based on Equation 11, *V* displays the productivity of the farm considering its size.

Table 1. *ABM VARIABLES FORMULATION, DESCRIPTION AND INITIAL CONDITIONS(IC)*

Produce

The farm production is the core procedure of this model, at each period the farms perform their activity and gain or lose money according to the production function $R_i(t)$, given by Equation (12), where *i* represents the farm *i* from the set of 500 farms $F = \{1,..,500\}$. The final result updates each farm bank balance and evaluates if the farm is sustainable and able to proceed their activity (*bankruptcy* procedure).

$$R_i(t) = P(t) \cdot A_i \cdot Q_i \cdot a_i + S \cdot A_i - E \cdot L \cdot I \qquad (12)$$

Bankruptcy

Since our goal is to evaluate the sustainability of Alentejo and North wine farms, the bankruptcy procedure checks each farm bank balance and perform an “if” condition, where farms with bank balance below 0€ disappear from the model.

Simulation and Results

The initial model tries to attain information about the evolution of 1000 farms (500 from Alentejo and 500 from the Northern region). It contains a settled seed to entangle the initial stochastic generation of each farm size (A), quality (Q) and bank balance (B). Since the global variables evolution is previously given by the interpolated functions, the initial model outcome is purely deterministic. The grape price is settled to start at 0.82€ and increment by 0.005€ (to acquaint the price inflation). The graphical interface of our model (before running the simulation on

NETLOGO 6.0.3 can be seen on Figures 1A and 1B. The layout is divided into two distinctive areas separated by a neutral black horizontal line. The green area represents the North region and the yellow is the Alentejo region. The houses represent each individual farm (Alentejo-red and North-blue) and their size are directly correlated with their area. It is quite noticeable that Alentejo owns substantially larger farms than North. The Figure 1B shows the graphical interface at the end of the simulation (*t*=100) where 310 farms (62%) from North went out of business, the Alentejo scenario is mildly better with only 159 vanished farms (31.8%). In both regions overall costs increased during the simulation (see Figures 2A and 2B), especially during the latter 50 years.

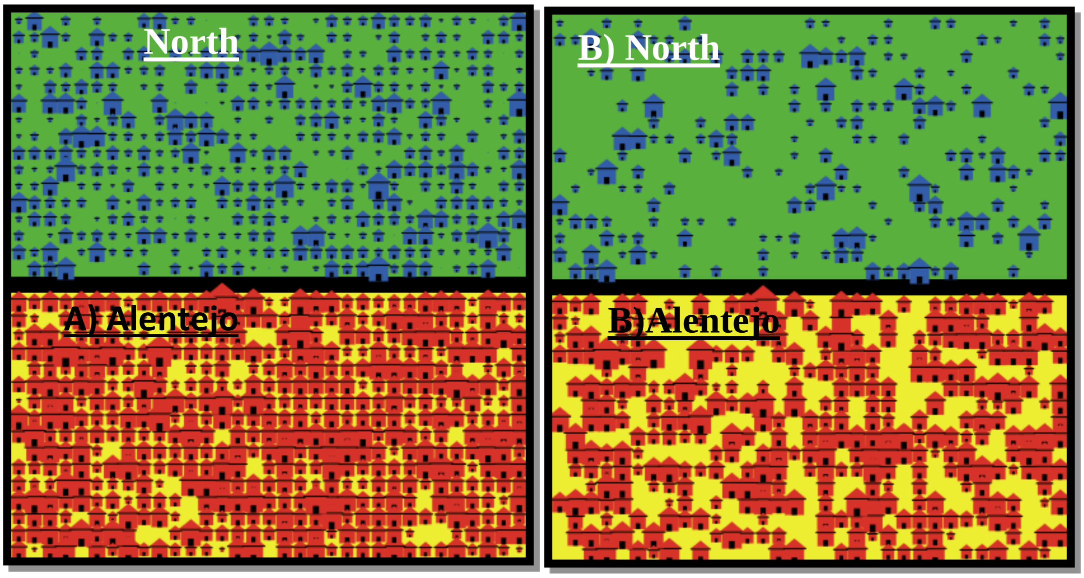

Figure 1. *INITIAL A)(T=0) AND FINAL B)(T=100) ABM GRAPHICAL INTERFACE FOR THE NORTH AND ALENTEJO REGIONS*

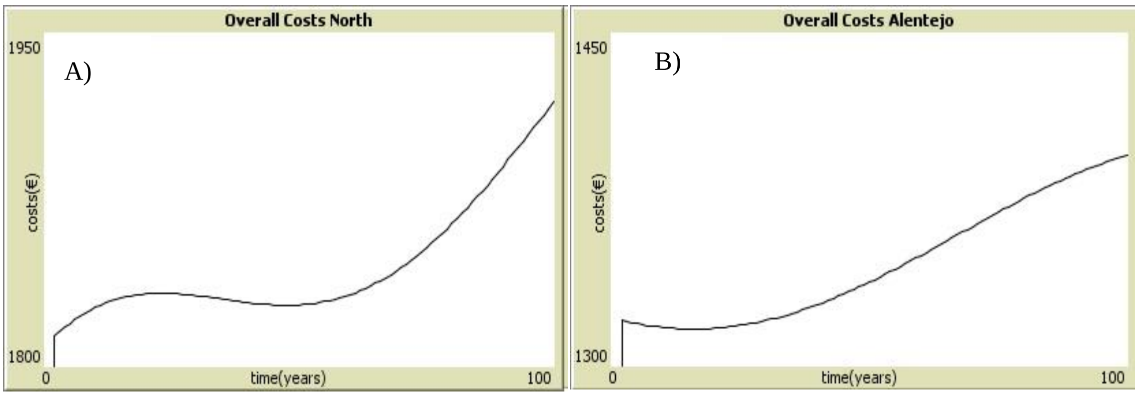

Figure 2. *ABM SIMULATION RESULTS FOR OVERALL COSTS IN NORTH REGION (A) AND ALENTEJO REGION (B)*

The main goal is to avoid this sad fate with such many bankrupted farms in the next 100 years. The subsidies appear in the model with a direct influence into each farm bank balance, we then assume that the government is able to increase this direct aid. Figure 3 provides the impact rate per incremental subsidy level on the farm survival rate at the end of the 100-year simulation. Even though it is possible to improve our benchmark scenario, and almost ensure the complete survival of the whole Alentejo's farms for a 3000 (€/ha) incremental subsidy per period, such measure discloses heavy governmental expenditure.

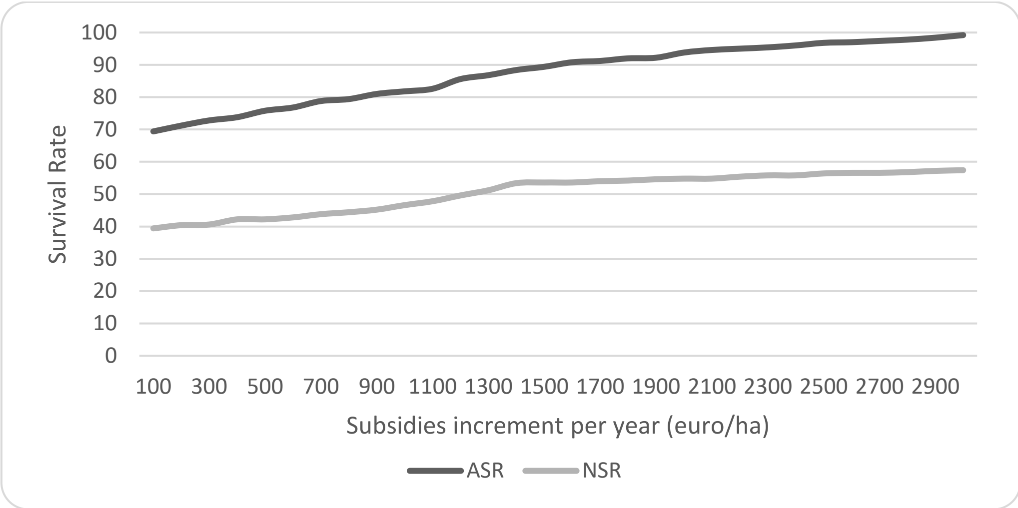

Figure 3. *SURVIVAL RATE OF ALENTEJO (ASR) AND NORTH (NSR) FARMS PER GOVERNMENTAL SUBSIDY LEVEL*

Fortunately, the government owns alternative tools, other option (which is currently active in Portugal) is to provide a beneficial grape selling price (€/kg) to the producer. Starting again from the initial model, we add a certain value (benefit) to the yearly farmers grape selling price. In order to establish some comparison against the previous government support, we calculate the government expenditure per benefit level accounting the overall production per hectare from both regions. The results on Table 3 display the farm survival rate (SR) upon the two different supports with matched governmental expenditure.

Government Expenditure (€/ha)	Beneficial grape price (€) Alentejo	Beneficial grape price (€) North	Alentejo SR Subsidies	North SR Subsidies	Alentejo SR Benefit	North SR Benefit
0	0.000	0	67.2%	38.0%	67.2%	38.0%
100	0.027	0.033	69.4%	39.4%	72.8%	44.2%
200	0.054	0.067	71.2%	40.4%	77.8%	53.6%
300	0.079	0.100	72.8%	40.6%	80.4%	54.8%
400	0.105	0.133	73.8%	42.2%	83.6%	56.4%
500	0.131	0.167	75.8%	42.2%	88.4%	57.4%

Table 2. *COMPARISON OF GOVERNMENTAL SUBSIDIES AND GRAPE SELLING BENEFITS IN THE SURVIVAL RATE OF ALENTEJO AND NORTH FARMS*

It is easy to see that the beneficial grape price measure overshadows the subsidies impact on both regions. The main reason may lay on the fact that this incentive benefits directly the production function outcome allowing roughly productive farms to withstand. While the subsidies are not related to the farm production, the selling price benefit directly shifts up the operational capabilities introducing a multiplicative income effect to the farm that increases the SR substantially. The results on the North are quite impressive, according to our model's conditions and assumptions, it is possible to save 15.6% of this region farms with a 0.067€ benefit and an additional government expenditure of 200 (€/ha). On the other hand, with the same amount of expenditure, 10.6% of Alentejo's farm would also be preserved.

Environmental and labour based impacts

As stated previously during this article the environmental and social variables represent two of the three core concepts that define the firm sustainability. Labour shortages and subsequent wage overpricing can be a consequence of unfavourable demographic dynamics such population aging (Fuchs *et al.*, 2017) and migration towards urban areas (Jan van der Laan, 2016). On the other hand, activities such as the viticulture rely on scarce natural resources. The depletion of those natural resources and the overall environment may trigger increasing prices and governmental taxes in order to discourage excessive demand and preserve the environment. To emulate such scenario alongside the uncertainty concerning Social and Environmental variables, we apply a percentage increase into the labour (L) and environmental (E) cost variables per year. To consider the volatility surrounding such variable we will also apply a random deviation upon that increment level. For this simulation we abandon the fixed seed at the beginning of the model, therefore, to perform this stochastic model we run each simulation 30 times. Table 3 compiles the results, displaying both region survival rates upon different levels of cost increments and randomness.

Social and Environmental percentage increment per year	Random deviation	Alentejo		North	
		Average SR	SR Standard Deviation	Average SR	SR Standard Deviation
0%	0%	68.20%	0.0000	38.00%	0.0000
5%	-3% to 3%	68.14%	8.8474	32.90%	9.5768
10%	-6% to 6%	67.60%	8.9659	31.17%	12.8185
20%	-12% to 12%	67.14%	11.3171	26.75%	17.8581

Table 3. *ALENTEJO AND NORTH SURVIVAL RATES WITH INCREMENTAL ENVIRONMENTAL AND LABOUR COSTS.*

The first remark from our results it is the almost innocuous effect from the increasing costs in the Alentejo region farm SR. On the other hand, the Northern region suffers substantially with the introduced randomness and increasing costs, losing about 11.25% more farms than our initial simulation in the worst-case scenario. There are two possible explanations for this phenomenon: the first is that the North requires more labour intensive than Alentejo and subsequently the impact should be greater. The second explanation lays on the higher productivity levels from the Alentejo farms underpinned by their larger areas. Such advantage may lead those farms to deal better upon negative and unexpected (random) scenarios.

Conclusions

In this article two distinctive wine producing Portuguese regions, Alentejo and North, were presented. After a brief presentation about this sector relevance on the Portuguese economy the sustainability analysis of the studied regions was selected as the major goal of this article. To emulate the wine farm activity from the Alentejo and North regions and furtherly simulate alternative scenarios, the ABM methodology was selected. The model relies on a few assumptions, random generation and interpolated time-dependent functions based on real data accounting also productivity per farm size variable. The initial simulation compiling 500 generated farms per each region displayed an alarming scenario at the end of our timeframe (after 100 years) with the survival of only 38% and 68.2% of the North and Alentejo farms respectively. Governmental policies such as the subsidies and the grape selling benefits were analysed and compared, the results showed that the latter may overperform the subsidies measure on both regions. Considering our model formulation and assumptions a simple governmental grape selling benefit 0.054€ on the Northern region may avoid the extinction of 15.6% of the farms. Finally, some threats were also considered such as rising labour and environmental costs alongside with model stochasticity. The results showed that the Alentejo region is generally well prepared to deal with such negative scenarios opposed to the North region, which saw a severe depletion of the farm survival rates during this experiment. The reason beyond the strength upon negative scenarios of the Alentejo farms in comparison with the North might be explained by their less intensive labour approach (more mechanization) and better productivity levels derived by their larger areas. This article with the chosen methodology (ABM) showed that Alentejo and North farms sustainability on the forthcoming future (specially the North region) are under threat but governmental measures such as the grape selling benefit may play an important role to ensure the sustainability of both regions. For further work, it is possible to get into more detail and include more variables such as the weather conditions or add the real data of individual farms to make the model more accurate.

Appendix 1

North

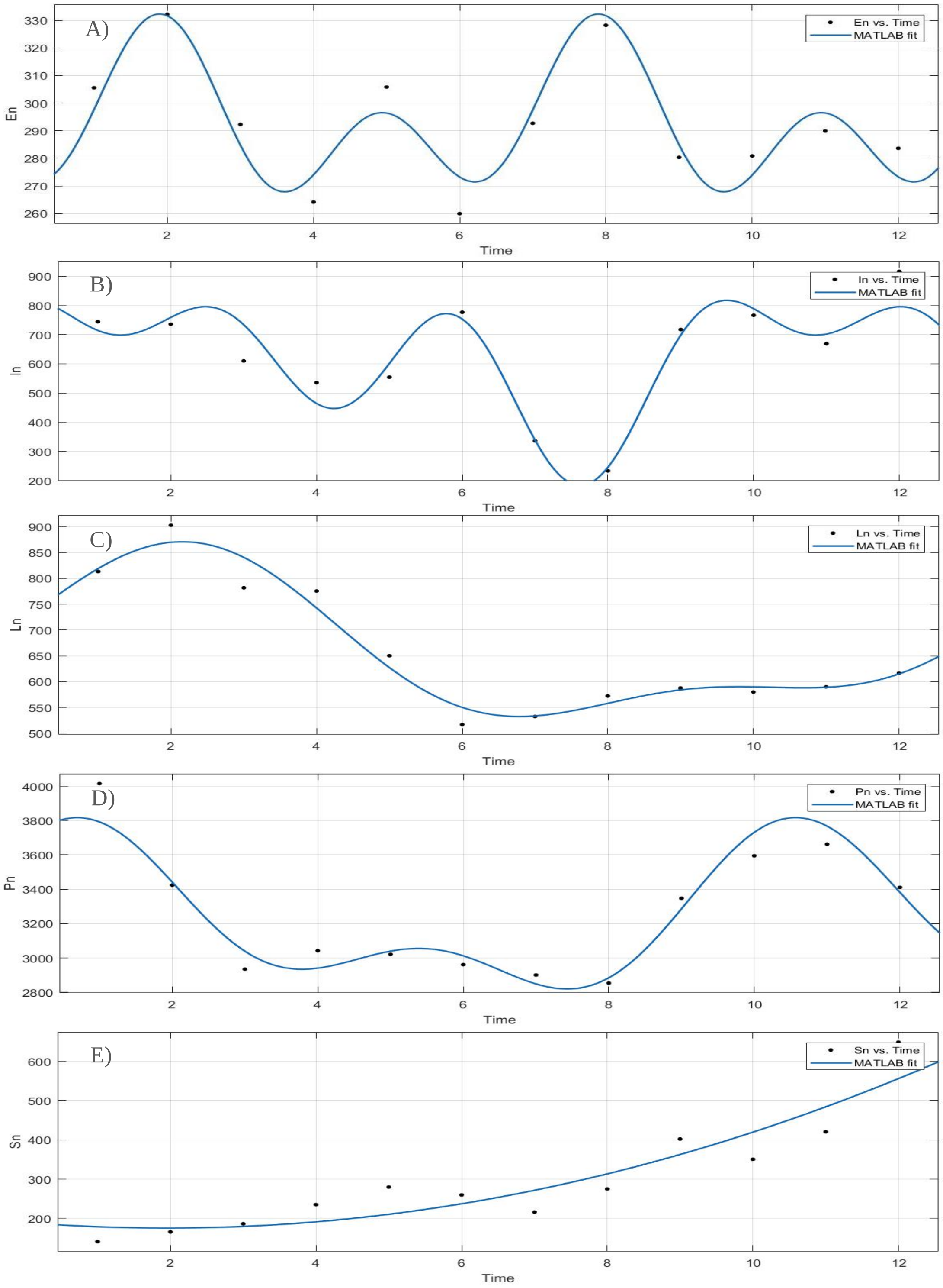

Figure 4. *FIGURE A 1: MATLAB INTERPOLATION OF SHORT-TERM TIME SERIES FROM 2001 UNTIL 2012 FOR NORTH REGION. THE VARIABLES USED FOR BUILD THIS INTERPOLATION WERE A) ENVIRONMENTAL BUNDLE (SUM OF ELECTRICITY, FUEL AND LUBRIFICANTS, FERTILIZERS, PHYTOFARMACEUTICALS AND WATER); B) INVESTIMENTO; C) LABOUR COSTS; D) PRODUCTION AND E) SUBSIDIES.*

Alentejo

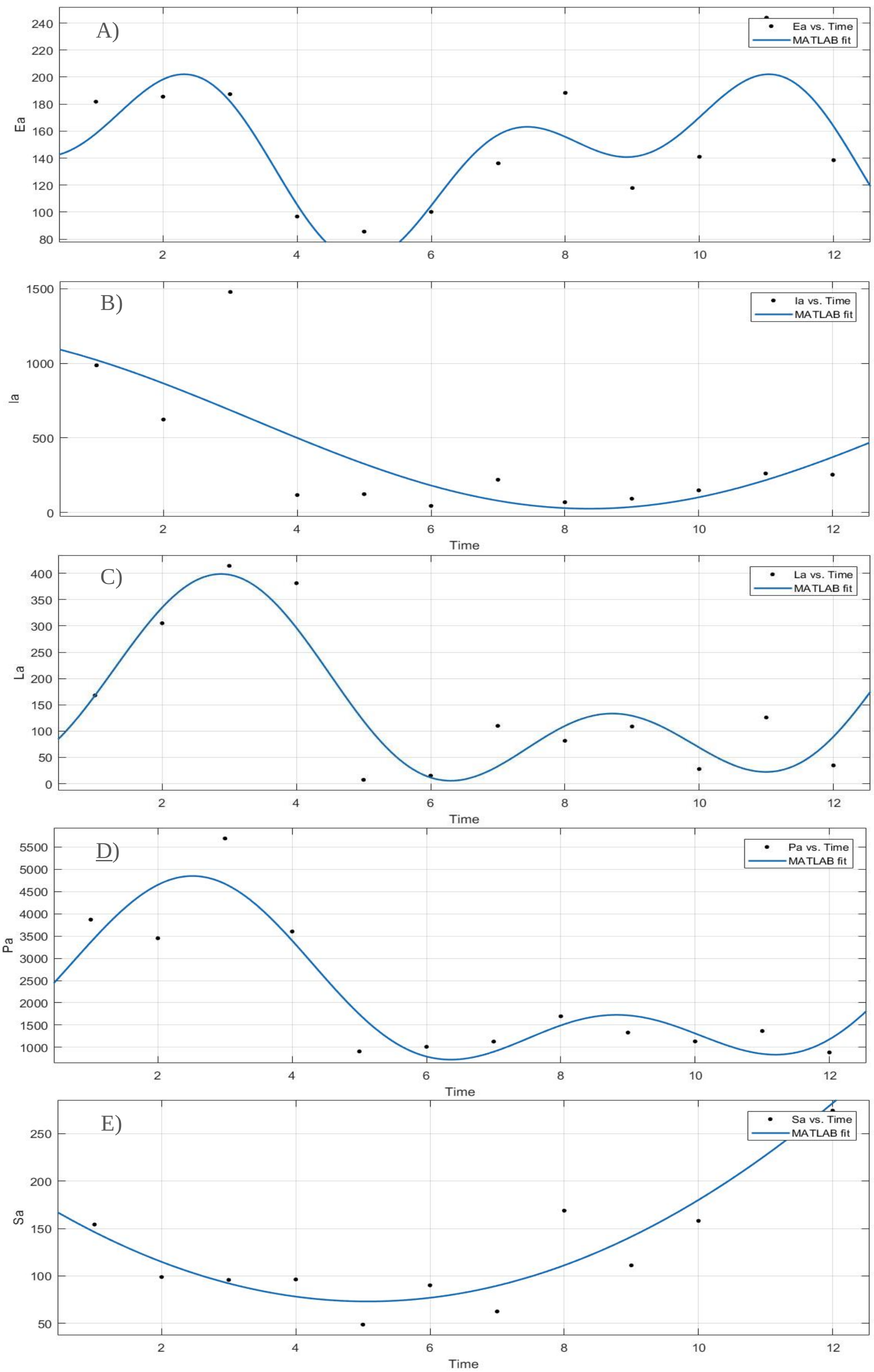

Figure 5. *Matlab interpolation of short-term time series from 2001 until 2012 for Alentejo region. The variables used for build this interpolation were A) environmental bundle (sum of electricity, fuel and lubrificants, fertilizers, phytofarmaceuticals and water); B) investment; C) labour costs; D) production and E) subsidies.*

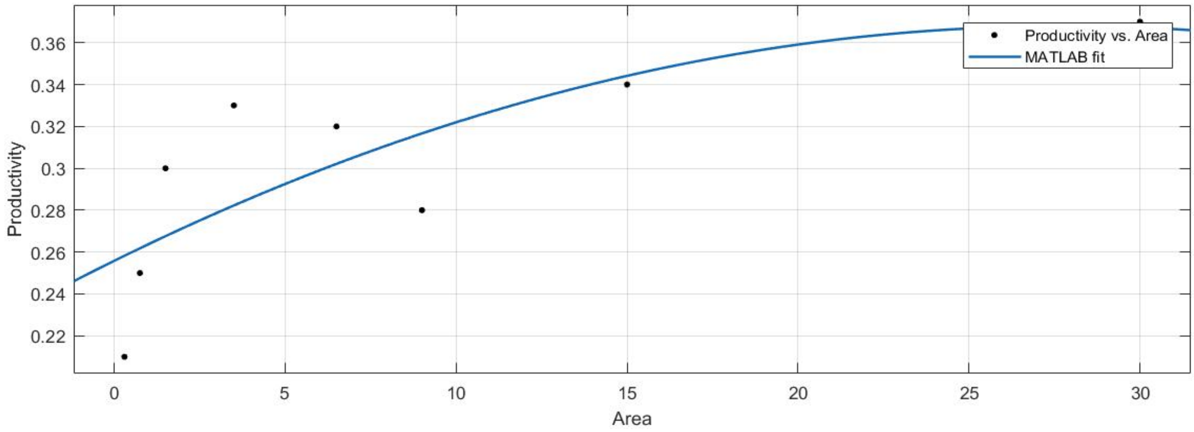

Figure 6. *OBSERVED RELATION BETWEEN THE FARM SIZE AND PRODUCTIVITY*

References

An, G., Fitzpatrick, B.G., Christley, S., Federico, P., Kanarek, A., Miller-Neilan, R., Oremland, M., Salinas, R., Laubenbacher, R. and Lenhart, S. (2017), "Optimization and Control of Agent-Based Models in Biology: A Perspective", *Bull. Of Math. Biology,* Vol.79 No.1, pp. 63-87.

An, L. (2012), "Modeling human decision in coupled human and natural systems: Review of agent-based models", *Ecological Modelling*, Vol. 229, pp 25-36.

Bonabeau, E. (2002), "Agent-based modeling: Methods and techniques for simulating human systems", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 99, No. 3.

Bookstaber, R.M. (2012), "Using Agent-Based Models for Analyzing Threats to Financial Stability", OFR 0003, Available at SSRN: http://dx.doi.org/10.2139/ssrn.2642420

Conte, R., Hegselmann, R. and Terna, R. (1997), "*Simulating social phenomena*", New York, Springer.

DeAngelis, D.L. and Mooij, W.M. (2005), "Individual-based modeling of ecological and evolutionary processes", *Annual Review of Ecology Evolution and Systematics*, Vol. 36, pp. 147-168.

Dosi, G., Fagiolo, G. and Roventini, A. (2010), "Schumpeter meeting Keynes: a policy-friendly model of endogenous growth and business cycles", *Journal of Economic Dynamics and Control*, Vol. 34, pp. 1598-1625.

Dosi, G., Fagiolo, G., Napoletano, M. and Roventini, A. (2013), "Income distribution, credit and fiscal policies in an agent-based Keynesian model", *Journal of Economic Dynamics and Control*, Vol. 37, pp 1598-1625.

Farmer, J.D. and Foley, D. (2009), "The economy needs agent-based modelling", *Nature*, Vol. 460, pp. 685-686.

Fuchs, J., Söhnlein, D., Weber, B. and Weber, E. (2017), "Forecasting labour supply and population: an integrated stochastic model". AIB Discussion Paper, N. 1/2017.

Galindro, A., Santos, M., Santos, C., Marta-Costa, A., Matias, J. and Cerveira, A. (2018), "Wine productivity per farm size: A maximum entropy application", *Wine Economics and Policy,* Vol.7 No.1, pp. 77-84.

Grimm, V., Berger, U., Bastiansen, F., Eliassen, S., Ginot, V., Giske, J., Goss-Custard, J., Grand, T., Heinz, S., Huse, G., Huth, A., Jepsen, J.U., Jørgensen, C., Mooij, W.M., Müller, B., Pe'er G., Piou, C., Railsback, S.F., Robbins, A.M., Robbins, M.M., Rossmanith, E., Rüger, N., Strand, E., Souissi, S., Stillman, R.A., Vabø, R., Visser, U. and DeAngelis, D.L. (2006) "A standard protocol for describing individual-based and agent-based models", *Ecol. Model.*, Vol.198, pp. 115-126.

Grimm, V., Berger, U., DeAngelis, D.L., Polhill, J.G., Giske, J. and Railsback, S.F. (2010), "The ODD protocol: A review and first update", *Ecol. Modelling,* Vol.221 No.23, pp. 2760-2768.

Grimm, V., Revilla, E., Berger, U., Jeltsch, F., Mooij, W.M., Railsback, S.F., Thulke, H.H., Weiner, J., Wiegand, T. and DeAngelis, D.L. (2005), "Pattern-oriented modeling of agent-based complex systems: lessons from ecology", *Science,* Vol. 310, pp. 987-991.

Jan van der Laan, R. (2016), "*Identifying key factors influencing sustainable wine production – A case study on the wine sector in the Porto and Douro region*", Portugal, pp. 1-82.

Kohler, T.A. and Gumerman, G.J. (2000), "*Dynamics in Human and Primate Societies: Agent-Based Modeling of Social and Spatial Processes*". New York, Oxford University Press.

Lorek, H. and Sonnenschein, M. (1999), "Modelling and simulation software to support individual-oriented ecological modelling", *Ecol. Modelling,* Vol.115, pp. 199–216.

Marta-Costa, A., Torres-Manso, F. and Tibério, L. (2012), "Sustainability diagnosis of an agroforestry system", *Regional Science Inquiry Journal,* Vol. IV No. 2, pp. 111-124.

Mencarelli, F. and De Propris, L. (2014), "Mappa dei modelli di produzione sostenibile: gli indicatori della sostenibilità del vino", in: *Forum per la Sostenibilitàdel Vino* (Ed.), Primo Rapporto sulla Sostenibilità del Vino, pp. 35-61.

PTFADN (The Portuguese Farm Accountancy Data Network, 2001-2012), "Resultados médios por exploração", available at: http://www.gpp.pt/index.php/rica/rede-de-informacao-de-contabilidades-agricolas-rica (accessed on 13 March 2018).

Rachão, S. and Joukes, V. (2017), "Co-creating the branding of rural destinations: an analysis of agritourism Facebook pages in the Northern demarcated wine regions of Portugal, *Revista Turismo & Desenvolvimento,* Vol. 27/28, pp. 1933-1946.

Railsback, S.F. and Grimm, V. (2012), "*Agent-Based and Individual-Based Modeling: A Practical Introduction*", New Jersey, Princeton University Press.

Sellers, R. and Alampi-Sottini, V. (2016), "The influence of size on winery performance: Evidence from Italy", *Wine Economics and Policy,* Vol.5 No.1, pp. 33-41.

Shafiei, E., Thorkelsson, H., Ásgeirsson, E., Davidsdottir, B., Raberto, M. and Stefansson, H. (2012), "An agent-based modeling approach to predict the evolution of market share of electric vehicles: a case study from Iceland", *Technol. Forecast. Soc. Change,* Vol. 79, pp 1638-1653.

Sibly, R.M., Grimm, V., Martin, B.T., Johnston, A.S.A., Kułakowska, K., Topping, C.J., Calow, P., Nabe-Nielsen, J., Thorbek, P. and DeAngelis, D.L. (2012), "Representing the acquisition and use of energy by individuals in agent-based models of animal populations" *Methods Ecol Evol,* Vol.4, pp. 151–161.

Sierzchula, W., Bakker, S., Maat, K. and van Wee, B. (2014) “The influence of financial incentives and other socio-economic factors on electric vehicle adoption.”, *Energy Policy*, Vol. 68, pp 183-194.

Santos, M., Bastosa, R., Ferreira, D., Santosa, A., Barrosa, P., Travassosa, P., Carvalho, D., Gomesa, C., Vale-Gonçalves, H.M., Braza, L., Morinha, F., Paiva-Cardoso, M.N., Hughes, S.J. and Cabral, J.A. (2017), “A spatial explicit agent based model approach to evaluate the performance of different monitoring options for mortality estimates in the scope of onshore windfarm impact assessments”, *Ecological Indicators*, Vol.73, pp. 254-263.

Smith, E.R. and Conrey, F.R. (2007), “Agent-Based Modeling: A New Approach for Theory Building in Social Psychology”, *Personality and Social Psychology Review*, Vol.11, pp 87-104.

Wilensky, U. (1999), Center for connected learning and computer-based modeling. In: *NetLogo*. Northwestern University, Evanston, IL

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