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Agent-Based Model and Management Accounting: Culture-Contingent Managerial Behavior in Light of Budgetary Constraints

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Abstract

Objective: The paper aims at creating a model to simulate managerial behavior within a budgetary process affording analysis of evolving overall performance and specific behavioral attributes of the manager-level.

Method: This study explores agent-based modeling (ABM) in management accounting, using Python and Mesa. The model adopts a Consumer Service Provider firm and its quarterly sales budgeting process for a network of 400 branches over a 5-year term, contingent on firm culture (authoritarian or participative).

Results and discussions: Findings show that authoritarian firms generated fair more sales with similar managerial human capital and market, under increasing strong demand; authoritarian firms paid more bonuses as part of their reward system. In general, an authoritarian culture may benefit in a stronger demand scenario than participative firms, potentially due to budgetary slack form negotiation. On the other hand, authoritarian forms showed lower levels of happiness and engagement among their managers.

Contributions: Contributions are threefold, pointing to (a) management accounting practice and research (with parameters and conditions under the ABM framework, the study contributes to explain the role of authoritarian culture from micro-level, agents up to the macro-level firm performance); (b) science and research strategy (confirming the potential of computational accounting, based on successful Python and Mesa implementation of ABM simulation, and stressing a line of research that could be further adopted in topics of behavioral modeling dealing with potentially unavailable data), and (c) accounting education (offering stimulus undergraduate or graduate programs and continued professional education, highlighting highly-demanded data analytics and modeling-oriented solutions).

Keywords: Agent-Based Model, Budgeting, Management Accounting, Computational Accounting, Negotiating Agents.

Introduction

Management accounting, as a field of practice and research, is constantly exposed to challenges and opportunities to evolve (Appelbaum et al., 2017), directly affecting scholars and practitioners. While studying and coping with challenges, management researchers and practitioners, also in the management accounting field, witnessed numerous solutions appear and disappear shortly after, leaving room for disappointment: the so-called management fads.

Setting focus on management accounting, Cokins (2013) explore a framework of six eras, with respective time reference: (a) ancient (20,000 BC), (b) medieval (1494), (c) industrial age (1911), (d) regulatory compliance (1930), (e) consumer (1980), and (f) predictive analytics (2015). This is an interesting approach to help explain major movements in the field, especially the transition from the traditional descriptive approach to a more forward-looking, predictive accounting, in light of recent new managerial demands of innovative business models and organizations, revealing a "transition from management accounting for reporting costs and profits to managerial economics for decision support and analysis that impact the future" (Cokins, 2013, p. 29).

In similar lines, Lawson (2018) links the evolution of management accounting, in terms of line of sight (e.g., oversight, hindsight, insight, foresight) and required skill set, to the value of the profession, from descriptive, to diagnostic, predictive, prescriptive, and adaptive analytics. All this clearly endorses a strong dependency on technology and analytics along with the need for capacity building (Samuel, 2018).

Based on both intrinsic and extrinsic factors affecting management accounting, Cokins (2013) suggests major trends in the field: (a) expansion from product to channel and customer profitability analysis, (b) management accounting's expanding role with enterprise performance management (EPM), (c) the shift to predictive accounting, (d) business analytics embedded in EPM methods, (e) coexisting and improved management accounting methods, (f) managing information technology and shared services as a business, and (g) the need for better skills and competency with behavioral cost management.

Considering these trends, which are reinforced by the specialized literature, the need to advance critically in both theoretical and practical realms of management accounting is clear. Taking the shift to predictive accounting and the increasing data and technology presence, it becomes reasonable to anticipate "dramatic changes in the skills management accountants need in this area" (Lawson, 2018, p. 42) to provide an important value in optimizing organizational performance.

With regards to this organizational and management accounting scenario, lies an important potential still to be explored. In this paper we explore the suggested research gap (Bushman et al., 1995; Davis, 2007; Wall, 2016) between analytical and empirical studies in management accounting, with a fresh approach to interpret culture-contingent managerial behavior and budgetary constraints affecting organizational performance, within the Agent-Based Model (ABM) paradigm. We acknowledge ABM as a key "approach to modeling systems composed of … interacting agents" (Macal & North, 2010) and, as stated by Davis and Pesch (2013), "a relatively new [method] in accounting research … designed to study the emergence of macro-level phenomena from micro-level interactions" (p. 470).

Satra (2017) acknowledges ABM as a relatively new method in social sciences with a timid presence, but not without mentioning its potential, especially in situations where elements linked to the phenomenon of interest may be difficult to discover or observe directly. The potential of ABM in managerial science studies is also addressed by Wall (2016), highlighting the richness of the method to present theoretical insights where current and traditional empirical datasets may not be available (e.g. data collection limitations or management restrictions in unveiling strategy or sensitive data). Moreover, Davis et al. (2007) consider ABM as a useful alternative (or, as registered by them, "a sweet spot") when considering case studies, formal modeling and theory-testing with statistical analysis.

Hence, our study aims at creating a model to simulate managerial behavior within a budgetary process and analyze the evolving overall performance and specific behavioral attributes, at both firm- and manager-level.
The agent-based model (ABM) created in this research adopts a Consumer Service Provider firm and its quarterly sales budgeting process for a network of 400 branches over a 5-year term, contingent on firm culture (authoritarian or participative). The agents are branch managers, each one responsible for the respective branch performance. Firm-level (e.g., culture, provided services, reward system, branch location and potential demand,

and sales) and manager-level (e.g., ambition, goals, happiness, engagement, bonus, and budget beat-miss) attributes coexist. Model rules involve operational (e.g., forecasting and actual sales) and behavioral (e.g., sales goal negotiation, happiness, and engagement) functions.

The ABM literature typically considers distinct agent types. For this study we worked with the first agent type from Chen's (2012) typology, which includes: (a) simple (programmed) agents, (b) autonomous agents, and (c) human-like agents. In this study, agents have both trait attributes (held constant along the simulation) and state (variable along the simulation) that are explored and analyzed.

Beyond the model, we relied on data analytics to treat the results based on intense model simulation, dealing with over 19 million main data points. Simulations may serve distinct purposes, such as prediction, performance, training, entertainment, education, proof, and theory discovery (Axelrod, 2006). In this study, we focus on prediction, which according to Dooley (2002) is when "simulation takes a model, composed of a structure and rules that govern that structure and produces output (observed behavior). By comparing different output obtained via different structures and governing rules, researchers can infer what might happen in the real situation if such interventions were to occur" (p. 830).

Contributions of this study are threefold, pointing to (a) management accounting practice and research, (b) science and research strategy (method), and (c) accounting education. Such contributions are presented in detail along with the conclusion of this paper.

Literature Review

Computational Accounting and Management Accounting Studies

Management accounting and computational accounting are the main elements of the literature review of this study. We use the term computational accounting as a mirroring computational economics, which is considered a research discipline at the interface of computer science, economics, and management science (ACE, 2018; Amman, 1988; SCE, 2019).

Hesford et al. (2007) conducted a bibliographic study with 10 journals[1], covering a 20-year period, from 1981 to 2000, targeting 916 management accounting articles, none of which presented direct or indirect mention to agent-based models or

simulations.

After conducting a current search with the term "agent-based model" across the same 10 journals, we found a total of five articles matching the term: four in AOS and one in TAR. It is noteworthy that (a) just one scholar (Dr. Jon S. Davis) is authoring three out of these five articles and (b) the main areas covered are Fraud, Capital Markets, Assurance, and Numerical Experiments. Thus, leaving a literature void to be filled in the area linking management accounting and computational accounting, especially agent-based modeling.

Management Accounting

It is clear that management accounting is facing a dynamic moment in recent history due to increasing changes in business and organizations (Cokins, 2013; Lawson, 2018). Traditional solutions may leave room for advances, especially those offering forward-looking and insights to managers as a way of optimizing performance and mitigating risks (Appelbaum et al., 2017).

Characteristics of humans performing as managers and controllers tend to affect the outcomes, so capacity building is a key factor in advancing this field, focusing on areas such as coordination, cost and control (Samuel, 2018). Historically, the rationality of managers when dealing with internal or external pressures (Lambert, 2001) with regards to setting goals and going after those goals has been challenged by many fields (Becker, 1962), leading the important debates such as in economics and psychology, all influencing management accounting.

Manager styles and firm policies and performance were treated by Bertrand and Schoar (2003) with evidence supporting their interaction controlling for significant heterogeneity across managers.

Organizational culture: authoritarian and participative

Schein (2004) proposes an approach to organizational culture as a set of basic premises that a group has invented, discovered, or developed by learning how to deal with the problems of external adaptation and internal integration, and explored various dimensions of organizational culture to demonstrate that it is essentially based on how organizational members deal with the issues of external adaptation and internal integration.

In a seminal work, Likert (1967) alluded to organizational culture in framing management systems like (a) authoritarian-strong, (b) authoritarian-benevolent, (c) participating-advisory,

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1 Accounting, Organizations and Society (AOS), Behavioral Research in Accounting (BRIA), Contemporary Accounting Research (CAR), Journal of Accounting and Economics (JAE), Journal of Accounting Literature (JAL), Journal of Accounting Research (JAR), Journal of Management Accounting Research (JMAR), Management Accounting Research (MAR), Review of Accounting Studies (RAS), and The Accounting Review (TAR).

and (d) participating-team. Based on these perspectives, elements of an authoritarian culture may include a top-down approach to defining goals, greater process agility, a more rigid environment, difficult perception of a "comfort zone", which may lead to weaker engagement and happiness. On the other hand, elements of a participative culture may include more negotiated goals, a slower process, a more flexible environment, perception of a "comfort zone", which may lead to stronger engagement and happiness. All these elements affect the process under management control, with special attention to budgeting, the focus of this study.

In terms of participative budgeting, Shields and Shields (1998) developed a study showing results indicating that participative budgeting is the most important for planning and control, especifically vertical information sharing and coordinating interdependence. On the other hand, Chong and Syarifuddin (2010) examined the effects that obedience pressure and the personality trait of authoritarianism have on managers' project evaluation decisions. According to the results, in general, project managers with low authoritarian demand exhibited a greater tendency to continue with a failed project, while greater authoritarian pressure reduced the maintenance of failed projects, which indicates that authoritarian pressure may lead the manager to decide in favor of better projects.

As stated by Grant et al. (2007), the happiness and engagement of managers tend to be intrinsically related to the managerial process, influencing it and being influenced by it, with potential effects on firm performance. The authors conclude by stating that "managerial practices often have unintended consequences for employee well-being, resulting in tradeoffs that prevent these practices from achieving intended objectives" (p. 59).

Budgeting: A management accounting instrument

Management accounting literature has indicated the relevance of behavioral aspects of managers and executives naturally involved in the business cycle, with a certain emphasis. In this ABM study, we relied on findings from the literature stressing state and trait aspects of humans and their connection with business processes and accounting, notably in budgeting. Macinati and Rizzo (2014) analyzed the motivational role of budgetary participation and the intervening role of individuals' mental states and behaviors in influencing the relationship between budgetary participation and performance. Kihn (2010) conducted a study about how and why interpretations of budget targets differ from one person to another, even in the same business unit, suggesting that organizational budgetary processes do not provide a similar understanding of budget targets for each person.

In this line, Church et al. (2018) investigated how managers' budget reporting behavior is influenced by two important features of the budgeting system: (a) the measurement basis used in budget preparation and (b) managers' slack benefits in budget execution. Brink et al. (2018) analyzed participative budgeting and how the role of the superior affects budget outcomes, subordinate behavior, and in some cases superior behavior, demonstrating the superior type influences economic and behavioral predictions, and likewise affects budgeting outcomes and the interpretation of the results.

Concerning the impact of participative strategic planning on manager's creation of budgetary slack, Baerdemaeker and Bruggeman (2015) found that increased participation in strategic planning leads to lower budgetary slack creation through the suggested path of heightened affective organizational commitment, as well as that budget participation decreases the creation of budgetary slack through the mediating effect of autonomous budget motivation, suggesting that both elements of the organizational planning process are related to the creation of budgetary slack.

In Brazil, the study by Souza et al. (2021) showed a complete analysis of the profile of scientific articles on corporate budgeting. The results pointed to an increase in publications compared to the last two decades, with the predominance of male authors. A total of 299 authors were analyzed (Lavarda and Frezatti are the authors with more publications in the period), whose approaches involved more financial or quantitative indicators. In these studies, there is no emphasis on technology.

Rewards and Negotiation

In this regard, one of the subjects commonly dealt with in the literature is the budgetary slack, which includes budget, negotiation, and goals. In this line, Yuen (2004) examined the relationship between several goal characteristics and the propensity of divisional managers to create budgetary slack. The communication and reward systems are affected by the influencing power of managers, required explanation of budget variance, budgetary feedback, peer relations, and the relationship between superiors and subordinates. In addition, the author concluded that clear communication and reward systems can result in goal clarity and may help solve budgeting problems under difficult goal situations. Altoé et al. (2018) concluded that transactional leaders are associated with the use of culture, cyber, and rewards controls.

As we deal with budget negotiations, we highlight results from Arnold and Gillenkirch (2015) who found that when budgets are used for both planning and performance evaluation,

they increase the subordinate's budget proposals during the negotiation and his/her performance after the negotiation.

We used findings from the revised literature in supporting the definition of attributes and rules of our agent-based model. Our model deals with both trait and state agent attributes (aiming to mimic specific elements from the literature), such as ambition (trait), happiness (state) engagement (state), that will reciprocally interact with other themes and rules of the model (e.g., negotiated goals are a function of manager engagement). We align the characteristics of the managers, for instance, with literature about the subject (Mitchell, 1974, and Pritchard & Campbell, 1977 - rewards and motivation; Keirsey & Bates, 1984 - character and temperament; Tosi et al., 1995 - behavior; Ryan & Deci, 2000 and Vroom, 2015 - motivation and engagement, among others referenced in this the paper).

Computational Accounting and Agent-Based Model

Many areas of expertise, with distinct needs and conditions, are benefiting from alternative approaches when dealing with explaining and predicting specific phenomena, supporting theory and practice altogether (Abar, 2017; Dooley, 2002; Russell & Norvig, 2010; Sappleton, 2013).

In many senses, computers represent an important research tool affording conditions not easily found elsewhere (Chamanlal, 2014; Dooley, 2002; Sappleton, 2013), so researchers can improve their process, be more creative, assertive, and capable of dealing with more complex issues, in all scientific fields, including social science (Lazer et al., 2009). In social sciences, the focus on society and individuals imposes specific challenges for both theoretical and empirical studies, with traditional research methods and sources of evidence offering sound limitations.

More recently, Agent-Based Model (ABM), "a computational method that enables a researcher to create, analyze, and experiment with models composed of agents that interact within an environment" (Gilbert, 2008, p. 2), has emerged as a new research and management paradigm supporting organizational theory (Wall, 2016) and a "powerful simulation technique that has seen a number of applications in the last few years including applications to the real-world business problems" (Bonabeau, 2002, p. 7280). As stated by Axelrod, "a young rapidly growing field in the social sciences" (2006, p. 90).

With the ever-expanding access to stronger computational power, the agent-based model approach is gaining even more prominence in several areas where the bottom-up micro-scale

behavior can help comprehend the dynamics of complex systems and macro-phenomena (Andrade, 2010; Conte & Paolucci, 2014). That is the case in economics and business when targeting agent behavior in a specific market and financial conditions (Mignot & Vignes, 2020). Also, ABM is acknowledged for its benefits in the formalization of specific systems and parameters (Waldherr et al., 2021) assuming its bottom-up approach to modeling complex systems.

Wall (2016) presents and discusses the potential contributions of ABM for research in management accounting: (a) agent-based models allow the investigation of management accounting issues in rich organizational contexts, (b) ABM could help to study the effects of different errors in accounting numbers, (c) when procedural aspects of management accounting are of interest agent-based models allow us to study the relevant processes into detail, (d) the "micro-macro" interaction as incorporated in agent-based models enables researchers in management accounting to derive consequences for the system's overall performance which result from the use of accounting techniques on the micro level, and (e) ABM might allow us to investigate to what extent findings of principal-agent models hold if some of the underlying assumptions are relaxed.

Another contribution in the realm of ABM and decision making is related to Negotiation, carrying a potential value for management accounting. According to Jonker et al. (2012) "negotiation is a prime example of a task for which the human mind is but partially equipped, and for which artificial intelligence (AI) can provide assistance" (p. 79). Studies on Negotiation Agents typically require the adoption of the BDI (Belief-Desire-Intention, or model of practical reasoning) approach toward the respective utility function when developing cognitive agents within the model (Radu, 2017; Luna-Ramirez & Fasli, 2018). Existing examples from the literature are ANA (Automated Negotiating Agents), discussed by Jonker et al. (2012), and GENIUS (General Environment for Negotiation with Intelligent multi-purpose Usage Simulation) system (Genius, 2022).

Focusing on management, Wall (2016) offers strong evidence showing the state of the use of ABM, simulations, and computational models. Also, the literature review conducted by Barbati et al. (2012) on operational research and management science, yielded important results indicating the benefits of ABM solutions to support optimization problems, including a growing number of papers using ABM, suggesting the potential of the field and inviting more studies in this area. Similar claims are registered by Fioretti (2012) with regards to ABM and simulation in management. As stated by Wooldridge back in 2002 "multiagent systems do provide an

interesting and novel new tool for simulating societies" (2002, p. 8).

However, despite a very intense and fast development in other areas of expertise in the last years, ABM presence in management and accounting is still shy, "leaving its potential to manage organizations far from realized." (Gómez-Cruz et. al., 2017). Regardless of a timid adoption of ABM in accounting (as aforementioned, related to search across 10 top journals), we are still able to find ABM studies aiming at auditing, financial markets, auctioning, logistics, risk, continuous auditing, and fraud detection (Chesney et al., 2017; Prawesh, 2013; Dosi et al., 2018).

Based on the development status of agent-based model and management accounting, from the scarce literature, there is plenty of space for such a research approach to experience an increasing use. First, assuming the social and behavioral dimension of processes and transactions involving managers with effects on managerial accounting. ABM offers a natural opportunity for building representations of complex systems based on the behavior of micro-level agents operating in a synthetic environment (Wall, 2016; Mignot & Vignes, 2020). This modeling is capable of interactively support researchers and practitioners to test a greater variety of subtleties and make stronger assumptions (Conte & Paolucci, 2014; Wall, 2016).

Second, as organizations are experiencing multiple advances in management, which typically requires new ways of combining resources (e.g., people, money, machines, information). Management control systems (MCS) have many theories and claims to explore the embedded complexity of organizations, including a management accounting orientation (Merchant & Van der Stede, 2017). ABM offers the potential to rationalize this system thinking, formalize such elements (variables, parameters, and functions), understand the dynamics, explain the results, and help with the prediction and exploration of such elements (Waldherr et al., 2021). Thus, the highly-demanded predictive function (Lawson, 2018) of management accounting can be supported by the ABM framework.

It is noteworthy that beyond the natural interest in the individual agent behavior, within the ABM approach there is a significant potential for management accounting in modeling and building representations of complex systems, using interactions of variables based on parameters set. Thus, by following the evolution of such variables in an ABM simulation, both researchers and executives may identify elements potentially guiding new actions or even new strategies to improve the business model. This should not be taken for granted, as

the bottom-up micro-level focus of ABM may pose as a very insightful resource helping to perceive subtle interactions, even more in such complex systems, like those explored by management accounting.

Method

This study, within the proposed computational accounting approach, uses the agent-based model method, an analytical method (Gilbert, 2008), supported by simulations (David et al., 2005) and implemented with computational techniques. From a theoretical standpoint, ABM and its simulation processes can be considered another way of approaching reality, along with induction and deduction (Axelrod, 2006).

Sustained by the agent-based model method, the model used in this study is implemented in Python programming language and relies on the Mesa framework, a growing ABM framework in the scientific community. According to the Project Mesa Team (2018, p. 1) "Mesa is an Apache2 licensed agent-based modeling (or ABM) framework in Python."

The structure of the agent-based model used in this study is aligned with Macal & North (2010) and composed of (a) an environment (firm and market setting and agents organization), (b) agents (firm, branches, and managers, with respective traits and states), and (c) relationships (rules and methods of interaction, behaviors), in a fixed grid agent space topology.

The model is set to explore Management Accounting and ABM interaction adopting the perspective of a Consumer Service Provider (firm) quarterly revenue budgeting process for a network of 400 branches, with their respective managers (agents), over five years or 20 quarters (ABM steps), focusing on both firm- and individual-level attributes and a set of rules representing the cycle of planning, execution, and control. Branch managers (agents, at the individual level) are of particular interest, as we explore their behavior dynamics contingent on firm culture. The ABM simulation explores (via variables, see Table 1, and parameters, see Table 2) micro-level agent dynamics by setting budgetary goals (negotiation) and beating (or missing) such targets over the analyzed period, based on simulated interactions with both the market (demand) and salespeople in their branches.

Model Rationale

Our model is a micro organizational world representing the selected Consumer Service Provider (CSP) business and its quarterly sales budgeting process across all branches. The model assumes a strong demand environment, based on a

recent report from a marketing research company (hired for this specific consulting engagement), estimating a minimum of 600 thousand and a maximum of 900 thousand contracts per year for the CSP Firm. As part of the reward system, the CSP Firm offers salespeople a 5 percent commission (USD 30) of the year amount (contract price per year of service is USD 600, or 12 installments of USD 50) for each contract sold. On top of that, for beating the budgetary goal both the branch salespeople (2.5 percent) and the manager (2.5 percent) receive a bonus on the total sales amount. For this study, we focused just on the branch manager (not salespeople).

In this model, the firm has a single relevant attribute, firm culture: authoritarian or participative. The authoritarian culture imposes a top-down approach when establishing the sales goals, leaving no room for actual negotiation with branch managers. On the other hand, the participative culture considers the negotiation of sales goals with branch managers.

Immutable traits affecting the sales budgetary process: (a) each manager agent has an inherent ambition trait (35-65, on a 100-point scale) and (b) each branch has a demand potential (heat map from the grid, 40-60, in a 100-point scale), fixed for the simulation. In addition to this, as the variable states, we have (a) sales history of each branch and (b) engagement level (ambition combined with happiness on a 100-point scale) of each manager affecting the actual quarterly sales. The sales budgetary goal has (a) a floor, sales history (12-month average or 4 quarters), and (b) a ceiling, up to about 10 percent more (based on the strong demand from the market research report).

Firms with an authoritarian culture will set the goal (top-down) closest to the ceiling. Firms with a participative culture will negotiate the goal with branch managers adopting this floor-ceiling range. Managers' happiness will influence engagement improving their negotiation power. Missing or beating the goal will affect managers' happiness, influencing their engagement, and, as a result, the negotiation power. In this model, we did not implement consequences for managers consecutively missing the sales goal. Managers are expected to improve their behavior toward the reward attached to beating the goals.

In our model, agent attributes (firm- and individual-level) for all

400 branches and all 24 quarters (4 past quarters to inform sales history plus 20 quarters, 5 years) include the following: (a) sales, (b) sales goals, (c) ambition, (d) happiness, (e) engagement, (f) branch demand, (g) manager bonus, (h) beat-miss (sales budget). Specific rules for each theme and condition are a critical part of the model.

The functional flow of the ABM simulation involves (a) instantiating branches (ABM grid), managers (agents and their traits), and salespeople, (b) branch geographical, operational, and financial initial attributes, (c) agent dynamic states and negotiation of budgetary goals for each quarter, (d) validation of budgetary targets (according to cultural attribute), (e) simulation of each quarter process, with operational, financial and behavioral (manager states) consequences, and (f) simulation closure, including auditing tracks and analytical procedures.

Table 1. ABM Selected Variables

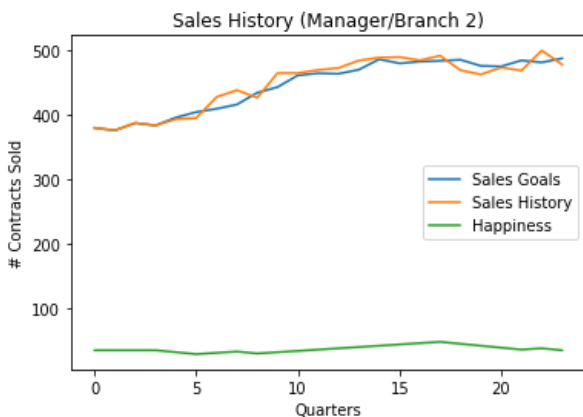| Theme	Variable
Performance	V_1 Total Sales (total of all branches)
Reward	V_2 Bonus Expenditure (total of all managers)
Sales Efficiency	V_3 Sales / Bonus Ratio (average of all branches)
Negotiation Power	V_4 Sales Ceiling - Sales Goal (total of all managers)
Budgetary Efficiency	V_5 Beat / Miss Ratio (average of all branches)
Location Advantage	V_6 Branch Heat (average of all branches)
Managerial Human Capital	V_7 Ambition (average of all managers)
Overall Morale	V_8 Happiness (average of all managers)
Overall Engagement	V_9 Engagement (average of all managers)
Sales Goals	V_{10} Sales Goals (total of all branches)

Beyond these attributes, specific parameters to support the stochastic process are used, such as (a) sales booster (influencing sales estimates over the past 12 months), (b) sales negotiation seed (the basis for negotiation), (c) actual sales seed (influencing actual sales for each quarter), (d) ambition range, (e) happiness range, (f) happiness seed up (seed to increase manager happiness when beating the target), (g) happiness seed down (seed to decrease manager happiness when missing the target), (h) engagement seed (trigger for manager engagement influencing actual sales), (i) negotiation bias up (trigger for setting goals above the sales target ceiling), (j) negotiation bias down (trigger for setting goals below the sales target floor), and (k) manager reward (bonus percentage). Table 2 contains the parameters used to set the model for simulations.

Table 2. ABM Parameter Settings

Theme	Parameter
Firm Culture	0 = Authoritarian (no goal negotiation), 1= Participative
Base Sales	380 (initial sales base, contracts per quarter)
Contract Price	600 (USD amount for one contract)
Sales Booster	5.00 (percent increase over the past quarter)
Sales Negotiation Seed	2.50 (stochastic seed, +/- percentage for negotiation, between floor and ceiling)
Actual Sales Seed	3.00 (stochastic seed, +/- percentage for negotiation, between floor and ceiling)
Ambition Range	15.00 (stochastic seed, 50 +/- seed: from 35 to 65)
Happiness Range	15.00 (stochastic seed, 50 +/- seed: from 35 to 65)
Happiness Up	2.00 (happiness increase factor for beating quarterly goal)
Happiness Down	3.00 (happiness decrease factor for missing quarterly goal)
Negotiation Bias Up	0= Sales Goal stops at ceiling (good for the manager), 1= no limit (default is 0)
Negotiation Bias Down	0= Sales Goal stops at floor (good for the Firm), 1= no limit (default is 1)
Engagement Seed	0= Actual Sales not affected by Engagement levels 1= Actual Sales are affected by Engagement levels (default is 1)
Manager Bonus Percentage	2.50 (manager bonus percentage for beating the quarterly goal)

A graphical representation of the micro-level simulation of this CSP agent-based model is presented below. It is intended to support comprehension of individual-level (specific branch, specific manager) dimension of the model, including quantities of contracts budgeted and sold, as well as levels of the manager's happiness during the 5-year term.

CSP Model Sample Manager/Branch Results

This graphical representation shows for a single branch, as an example, three main variables of the model for all the 24 quarters (4 containing historical data and 20 for the 5-year simulated period): (a) sales goals (number of contracts), (b) actual sales (becaming, sales history), and (c) the manager's happiness level. This is intended to support comprehension of

micro-level simulation of the CSP agent-based model created.

Protocol

We created a micro organizational world to model the Consumer Service Provider (CSP) operation as an agent-based model (ABM) using Python 3.6.5 (as a programming language), Mesa 0.8.5 (as the ABM package), and Jupyter 5.7.4 (as the coding and testing environment). After planning, driven by the specific needs of our model, we decided to develop our data collectors and analysis tool (not using those provided by the Mesa package). We worked with four main Mesa classes: (a) Model (b) Agents, (c) Time (BaseScheduler), and (d) space (SingleGrid).

The Model class was implemented to control the model-level attributes and set up the agents and branches. The Agent class was implemented to initiate and control all branch managers, as well as to define the rules to be executed in each step of the simulation (e.g., budgetary negotiation, engagement, and sales). The BaseScheduler class was implemented to control the set of agents and their activation during all steps. The SingleGrid class was used as a spatial container for the branches, virtual locations where they stayed during the entire simulation.

The code has four main parts: (a) CSP imports (calls all external modules and packages used), (b) CSP data collector

container setup, (c) CSP model (the main program to set up the agent-based model, defining attributes and rules for the firm and the agents, including their classes, methods), (d) CSP run (executes a single or a batch run, the data collector and performance tracking, generating several detailed matrices and a summary multidimensional matrix with all data points from the simulations), (e) CSP auditing (generates MS-EXCEL files with sample data and summary results for model auditing purposes), and (f) CSP stats (computes all model statistics, including descriptives, normality tests, comparison tests, and graphs based on datasets in the main data collector matrices).

Over 19 million main data cells were used to reach these results. We executed a set of 100 runs for each firm culture scenario, with 400 branches (each with one branch manager) during 24 quarters (4 quarters for sales history information and 20 more representing 5 years of the quarterly budgetary process). In this format, a single model contains about 96,000 main data cells (10 themes with 9,600 points each), reaching 9.6 million main data cells after 100 runs (19.2 million main data cells, as the model is executed twice: for authoritarian and participative modes). In other words, this is equivalent to having five years of quarterly data (10 themes) from 200 companies. We collected selected results using a set of Numpy 1.14.5 two-dimensional matrices, in the interest of performance, and were able to export summary results to MS-

Excel using Pandas 0.23.1. Statistical descriptives, tests, and aggregating computations were performed with SciPy 1.2.0 and graphic reports generated both in Matplotlib 2.7.3 and Seaborn 0.9.0, all supporting both detailed and consolidated analyses.

Proposed Data Analysis and Study Hypotheses

The goal of our study is to create a model to simulate managerial behavior within a budgetary process and analyze the evolving overall performance and specific behavioral attributes, at both firm- and manager-level. So, first, we will analyze the details of the created model and all simulation processes, as this is an important outcome of the study. Also, we plan to analyze the results of intense simulation by looking at aggregated data, relying on descriptive statistics, and test selected hypothesis to evaluate the potential of the model.

We expect to embed descriptive statistics outlets in the model, taking advantage of Python, Numpy, Scipy, Pandas, Matplotlib, and Seaborn, on the ABM selected variables (see Table 1) and analyze the results in light of the elements from the literature review. In addition, we established the following set of ten statistical hypotheses to compare data controlling for organizational culture (authoritarian vs. participative), based on the literature review and model expectations.

H_1 – Performance (Total Sales))
H_2 - Reward (Total Reward)
H_3 - Sales Efficiency (Sales/Bonus)
H_4 - Negotiation Power (Ceiling-Goal)
H_5 - Budgetary Efficiency (Beat/Miss)
H_6 - Location Advantage (Branch Heat)
H_7 - Managerial Human Cap. (Ambition)
H_8 - Overall Morale (Happiness)
H_9 - Overall Engagement (Engagement)
H_{10} - Sales Goals (Goal)

H_1: μ(authoritarian) > μ(participative)
H_2: μ(authoritarian) < μ(participative)
H_3: μ(authoritarian) > μ(participative)
H_4: μ(authoritarian) < μ(participative)
H_5: μ(authoritarian) < μ(participative)
H_6: μ(authoritarian) = μ(participative)
H_7: μ(authoritarian) = μ(participative)
H_8: μ(authoritarian) < μ(participative)
H_9: μ(authoritarian) < μ(participative)
H_{10}: μ(authoritarian) > μ(participative)

As observed, the hypotheses are all directional, except H6 and H7 (which assumes no differences distributions of immutable attributes of the branch (location advantage) and manager (ambition as a trait, considered as a proxy for managerial human capital). All tests are conducted at the .05 alpha level.

Data Analysis and Findings

As we created the model, we executed it several times until sound stabilization and performance optimization, due to its complexity and dataset expectations. The decision about creating our solution for the data collector (instead of using the one in Mesa) was made based on performance and flexibility. First, we executed the CSP agent-based model simulation in a single run, which involves the computation of 4 quarters of sales history, plus the simulation of 20 quarters (five years) for each of the 400 branches with the 10 themes and all additional variables. Python with Numpy, computer memory, and solid-state disks contributed to sound simulation performance with a typical computer (iMac 3.4 GHz Intel i7 with 32Mb RAM and a solid-state drive running Mac OS 10.13.6). On average, a single run (400 branches, 24 quarters, 10 main themes, or about 96,000 main data cells) is performed in about 0.3 seconds.

However, in the interest of the potential benefits of ABM to management accounting claims, instead of using just a single run (already bringing relevant evidence to support expected claims), equivalent to five years of data (behavioral, operational and financial, budgeted, and actual) of one company (with one culture attribute) and its 400 branches and managers, we decided to take advantage of the ABM framework and simulation potential to have two separate sets of data coming from 100 runs for each of the two selected organizational cultures. This approach has proved beneficial, as we were able to claim the robustness of the model (based on many more data and conditions running through the system and stressing its classes, methods, parameters, and rules). Moreover, this was possible due to the overall performance of the Python solution. A full simulation with two batches (two cultures) with 100 runs each takes about 60 seconds, and execution of the auditing and statistics modules takes 10 seconds, on average, of additional processing time.

Model Descriptives

The summary of all main variables (themes) yielded results that are aligned with our overall expectation and anticipated dynamics of the ABM intense simulation. Table 3 presents the summary bulk results (e.g. each cell of the table refers to 100 firms with 400 branches each for 20 quarters - we disregarded the four sales historical quarters, for reporting purposes).

Table 3. Summary Bulk Results (200 runs of the model)

	Participative Culture Firms	Authoritarian Culture Firms
5-year Combined Goal ($)	2,133,147,948.34	2,279,945,908.44
5-year Firm Sales ($)	2,148,252,620.18	2,285,233,066.20
5-year Combined Bonus ($)	32,195,010.27	32,530,218.75
Sales/Bonus Ratio	66.9446	72.4164
Ceiling - Goal ($)	40,942,587.63	-
Beat/Miss Ratio	1.3565	1,1901
Branch Heat	50.0343	50.0055
Ambition	49.9689	49.9697
Happiness	48.3921	45.1657
Engagement	49.0288	47.4604

Starting with important information for this model (which focuses on budgetary process and manager behavior) is actually related to sales. Both budgeted and actual sales behaved according to the parameters mirroring the rationale (or business case). The elements of coordination and control, as in Samuel (2018), were modeled. The strong demand (10 percent per year increase) could yield about USD 2.2 billion of accumulated revenues (keeping the USD 600 price constant in the period) in five years. Cumulated sales goals (V10) for participative (M= 2,133.1480 million, SD= 14.2576 million) and authoritarian (M= 2,279.9459 million, SD= 12.260 million) were close to the demand from the marketing research report. That was also the case with actual sales from the simulation (V1) for both participative (M= 2,148.2526 million, SD= 15.2687 million) and authoritarian (M= 2,285.2331 million, SD= 13.9503 million) cultures. This is aligned with the literature on culture effects (Likert, 1967) and internal policies (Bertrand & Schoar, 2003) on firm performance.

The "ceiling-goal" indicator was defined as a proxy for negotiation power. Negotiation is modeled in the CSP model only for firms with participative culture. Thus, the indicador does not exist for authoritarian firms. The "ceiling-goal" indicator (V4) for participative firms (M= 40.9426 million, SD= 1.4722 million) reached 1.9% of the overall sales goals (V10), meaning that branch managers were able to negotiate an average of 1.9% bellow the initial budgetary ceiling, as the sales target, directly affecting their potential bonus (when reaching the target). This result is aligned with the work of Lambert (2001) addressing internal and external pressure affecting managers and firm performance.

Accordingly, these simulated firms with a participative culture rewarded (V2) their managers (M= 32.1950 million, SD= 0.5333 million), on average, with 1.5% of sales, while their authoritarian counterparts rewarded their managers (M= 32.5302 million, SD= 0.5498 million), on average, with 1.4% of sales. With an inverse thinking, the proxy "sales/bonus" (V3) was created to keep track of sales efficiency. In this case, firms with an authoritarian culture (M= 72.4164, SD= 1.1996 million) achieved more sales per dollar rewarded as bonus, when compared to firms with a participative culture (M= 66.9446, SD= 0.7259).

Linked to this, the "beat/miss" ratio (the amount of times managers beat their targets versus the amount of times they missed them) yielded complementary results. As our model established no target negotiation with managers in firms with an authoritarian culture, it was expected that beating their targets would be harder. In fact, the "beat/miss" ratio (V5) of firms with an authoritarian culture (M= 1.1901, SD= 0.0331) was smaller than the ratio of the participative firms (M= 1.3565, SD= 0.0352).

Analyzing the results of the branch demand heat (V6), the model proxy (100-point scale) for location advantage (fixed for the branch throughout the simulation), converged to the mean for both authoritarian (M= 50.0055, SD= 0.2654) and participative (M= 50.0343, SD= 0.3034) cultures represented in the model. Thus, we can infer that branches were, in aggregate terms, in locations that did not favor either culture, in bringing more or less demand.

On the behavior side, the model has a proxy for managerial human capital, which is tracked (100-point scale) by the variable ambition (V7), a proxy for the manager's trait, fixed for the manager throughout the simulation. Ambition also converged to the scale midpoint in both authoritarian (M= 49.9697, SD= 0.4538) and participative (M= 49.9689, SD= 0.4835) cultures, suggesting that firms all shared similar levels of managerial human capital.

With regards to manager's states, happiness, a proxy for overall morale of the firm, was modeled as a variable (V8) being affected by beating or missing goals and responsible for indirectly influencing the goal negotiation process. Managers in authoritarian settings presented lower levels of happiness (M= 45.1657, SD= 0.3814) when compared to their counterparts working in firms with a participative culture (M= 48.3921, SD= 0.4056). This is likely a result of goals that were not negotiated (in authoritarian firms), consequently harder to beat (as shown in the "beat/miss ratio" analysis).

Lastly, engagement (V9) levels (a combination of ambition and

happiness), with direct influence over negotiated goals and actual sales in participative settings, reflected the movement of happiness (as a traint, ambition was held constant), and were lower in authoritarian (M= 47.4604, SD= 0.0873) settings when contrasted with participative (M= 49.0288, SD= 0.1305) ones. These emotional effects (Likert, 1967) interacting with firm performance are clearly addressed as a concern in the literature (Grant et al., 2007), presenting an actual challenge to organizations: the tradeoff between performance (e.g., short-term) and engagement (e.g., long-term), as clearly presented as a result of this ABM simulation.

Authoritarian vs. Participative Cultures

Using the statistics and graphical solutions (based on Numpy, Scipy, Pandas, Seaborn and Matplotlib) embedded in our model for all the ten proposed hypotheses, we tested the two samples (samples coming from authoritarian and participative cultures datasets) and compared their means using t test at the .05 alpha level. The normality requirements were checked with D'Agostino normality test and evaluated graphically with the distribution plots of the sampled variables.

The first hypothesis (H1 - Performance) anticipated that overall sales performance would be stronger among authoritarian firms and results ($t(198) = 66.2318$, $p < .0001$) are enough to reject the null (equal means) hypothesis, so, we support the claim that sales of authoritarian firms are higher. This may be explained by higher levels of sales goals present among authoritarian firms (lack of manager negotiation) and strong demand trends in the model.

For the second hypothesis (H2 - Reward) we expected that firms with a participative culture would reward more (bonus) to their managers, based on the lower sales goals due to negotiation (not present in authoritarian firms), with lower targets being easier to beat. Results ($t(198) = 4.3766$, $p < .0001$) are strong enough to reject this null (equal means) hypothesis, however in the opposite direction: higher reward paid by authoritarian firms. This could be explained by the strong demand trend present in the model. The third hypothesis (H3 - Sales Efficiency) assumes authoritarian firms are expected to have more sales per bonus dollars paid. We actually could confirm this, as the test yielded results ($t(198) = 39.0238$, $p < .0001$) rejecting this null (equal means) hypothesis.

Hypotheses dealing with budgetary goal setting were created (H3 - Negotiation Power and H10 - Sales Goals) anticipating higher sales goals among authoritarian firms and, of course, lower negotiation power among them, as the model did not allow budget negotiation for managers of these firms. Results ($t(198) = -278.1060$, $p < .0001$), of course, reject the null

(equal means) hypothesis of negotiation power and they also rejected (t(198) = 78.0669, p < .0001) the null (equal means) hypothesis of sales goals, supporting the claim that authoritarian firms were able to set higher sales goals, based on the budgetary process.

Another way of analyzing this is that participative companies, by offering a negotiated budgetary process, gave their managers a chance to lower their targets. As for the "beat/miss" hypothesis (H5 - Budgetary Efficiency), we considered managers of participative firms able to have more beats than misses in the business cycle, for similar reasons already mentioned: lower targets due to presence of negotiation. Results (t(198) = -34.4497, p < .0001) are strong enough to reject the null (equal means) hypothesis, supporting the claim of a higher "beat/miss" ratio among participative firms.

The location advantage hypothesis (H6) was tested with the branch demand heat indicator, and we assumed that no significant difference would appear, showing that in aggregate terms the same sales demand potential would be present in the branch geographical distribution. Results of the test (t(198) = -0.7151, p = .4754) failed to reject the null (equal means) hypothesis, supporting the claim of no overall location advantage for branches.

Ambition, a manager trait, was used as a proxy for managerial human capital of the firms and served as the basis for the seventh hypothesis (H7) tested. We assumed that managerial human capital would be evenly found across firms, regardless of their cultural aspects. Results (t(198) = -0.0113, p = .991) failed to reject the null (equal means) hypothesis and supported the claim of similar ambition levels among all managers.

We also tested the overall morale hypothesis (H8), linked to the levels of happiness experienced by the branch managers, assuming that managers working in participative firms would experience higher levels of happiness. Results yielded by the test (t(198) = -57.9463, p < .0001) sustained our expected claim, indicating significant greater levels of happiness among managers in firms with a participative culture. Lastly, we were able to test the hypothesis on engagement levels (H9). Test results (t(198) = -99.8869, p < .0001) supported our expected outcomes that engagement levels would be higher in firms with a participative culture, which in part is due to the nature of the behavioral rules present in the model, where engagement is set based on the combination of ambition (a trait, constant) and happiness.

Conclusion

What would it take to gain access to 200 companies, fairly representing two types of organizational culture, collect data from 400 managers of different branches (in distinct locations), and evaluate their behavioral movements according to an established budgetary process, in light of specifics of reward systems: all this, for 5 years?

Our study showed that this is possible when you create your model, portraying attributes, methods, and rules of a synthetic environment, its "living" constituents (agents), their states and traits, spatial distribution, reference of time-reference, and ancillary solutions to collect, keep, treat and report large amounts of data. Or when you rely on the agent-based model method and simulations. The goal of this study was to create a model to simulate managerial behavior within a budgetary process and analyze the evolving overall performance and specific behavioral attributes, at both firm- and manager-level. It is legitimate to state that we reached the goal.

Management accounting literature used in this study points to a research gap between analytical and empirical studies, beyond the lack of studies adopting the ABM framework, and we were able to contribute with the model construction and reporting respective results of the ABM simulation. It is noteworthy that no equivalent or similar study was found, making this an important innovation to the field.

Two important findings must be registered. First, the reality of creating an agent-based model in management accounting and improving it to incorporate gradual complexity of rules and methods, generating a strong representation of the phenomena under investigation. Secondly, evidence of manager's behavior participating in a budgetary process, in light of specific organizational culture types, were found with support of the ABM method, sustaining, or not, anticipated claims (hypotheses).

On this, we want to highlight two findings from our study. First, authoritarian firms generated far more sales with similar managerial human capital (H7 - Ambition) and market (H7 - Location Advantage), under the same external environment conditions (increasing strong demand). Second, despite having higher sales goals, due to lack of manager negotiation, authoritarian firms paid more bonuses (for beating sales targets) as part of their reward system, with the same commission (2.5%) percentage of participative firms. In general, our study provided evidence that an authoritarian culture may benefit in a strong demand scenario, presenting better performance and financial results than participative firms, potentially due to budgetary slack from negotiation. But this comes at a price: authoritarian firms showed lower levels of happiness and engagement among their managers.

From our experience with this study, despite the series of advantages and disadvantages of ABM that can be found in the relevant literature, it is fair to state that the ABM method used in our study offers important advantages or opportunities over traditional research methods, including (a) handling complexity, (b) scalability (smooth growth), (c) faster speeds, (d) safer environment for testing hypothesis, (e) alternative to subjectivity of perception-based evidence, (f) sources of evidence (overcoming challenges of sampling participants, both in quantity and quality, an important natural limitation in the real world), and (g) micro-world sensitivity to indirect or hidden relations or interactions.

On the other hand, as challenges, we may refer to the (a) amount of specific knowledge on problem-dependent key fields (e.g., economics, management science, computer science, decision-making, psychology, behavioral misconceptions), (b) access to certain technologies (e.g., hardware and software), (c) required modeling mindset and attitude, (d) level of focus on details of the model environment, agents, rules and attributes, and (e) the need for updating on frameworks and techniques for model construction, data collectors and analytics.

Our initial investigation offers insights to several opportunities for future research in management accounting, by exploring problems and environmental conditions that cannot be easily explored from a typical research approach. Issues of control, costs and risks may benefit from the ABM method.

Contributions

Contributions of this study are threefold, pointing to (a) management accounting practice and research, (b) science and research strategy (method), and (c) accounting education. First, for management accounting, the design and development of a model, in light of the ABM paradigm, is innovative (as observed in the literature review) and provides conditions to afford analysis of relevant managerial behavior phenomena by means of controlling parameters and rules to support claims, very difficult to do otherwise. In this particular case, it is noteworthy to stress our main contribution to the managerial accounting debate on organizational culture and its interaction with firm performance. With the adoption of performing agents (ABM) the study was able to show more performance linked to an authoritarian culture and address tradeoffs with emotional effects of managers, both in terms of trait (ambition) and state (happiness), as well as their combination (engagement). This should make for an intense debate even more in a context and moment of societal changes, distinct generations, and diverse innovation levels across industries and organizations. Second, for science and research strategy, the model created and used here is based on the ABM paradigm, another approach to induction and deduction, according to the literature, offering potential to be explored in business, specially in accounting. The CSP model is implemented in Python and Mesa, also offering a contribution to scholars interested in expanding methodological alternatives to support advances in the field, mainly those fit for behavioral studies. This is also aligned with observable changes in how organizations adopt technology to explore scenarios and test alternatives seeking improved performance over time. Lastly, for accounting education, the study addresses a potential gap between formal current curriculum (undergraduate, graduate or continuing professional education) and needed skills from the workplace. It offers insights on specific skills by adopting computer science and decision systems elements applied to management accounting (e.g., ABM, behavioral modeling, simulation) with opportunities to either improve the curriculum or as topics for continuing education, including robust programming languages and data analytics packages (e.g., Python, NumPy, Scipy, Pandas, Matplotlib and Seaborn), as well as modeling-oriented solutions (e.g., Mesa).

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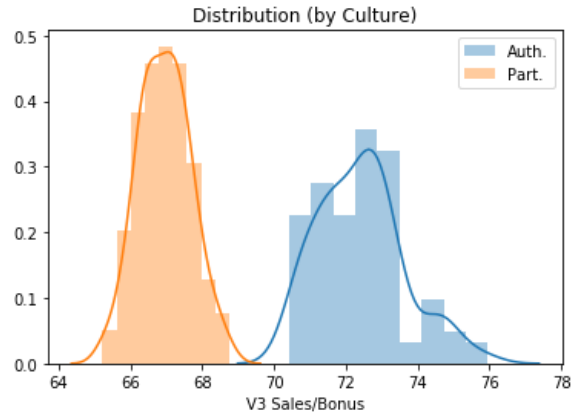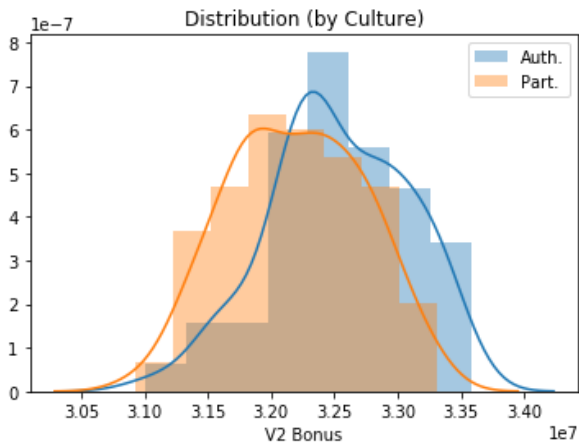
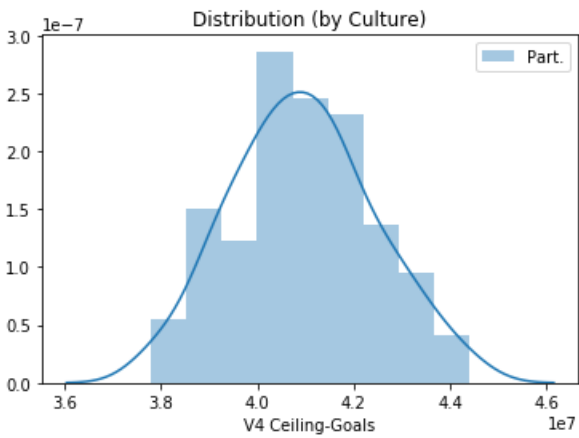# Appendix 1

CSP Model Descriptives (Bulk Results)
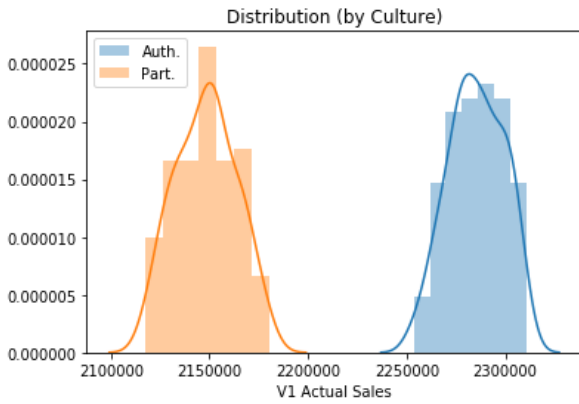
Distribution (by culture) = Distribuição (da cultura)
Actual Sales = vendas atuais
Auth. = autoritária
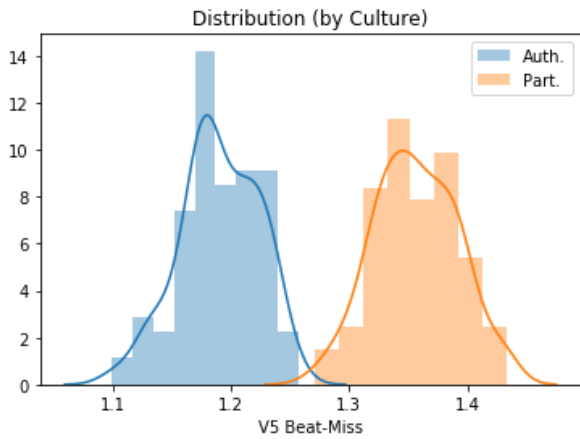Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
Sales/Bonus = vendas/bônus
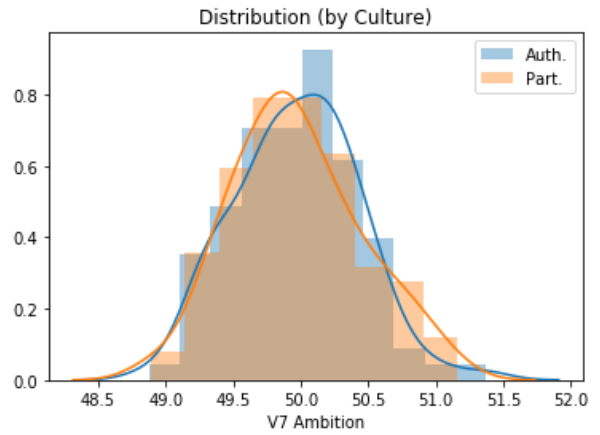Auth. = autoritária
Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
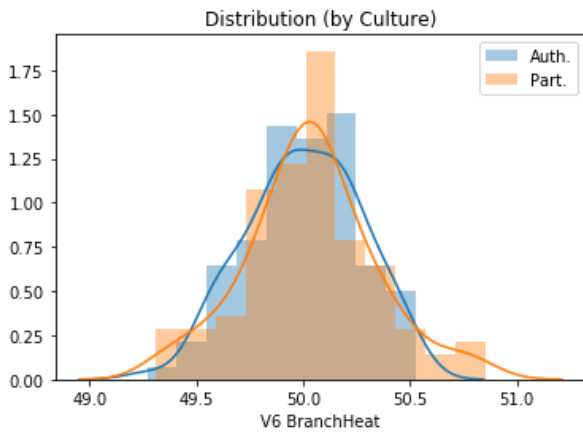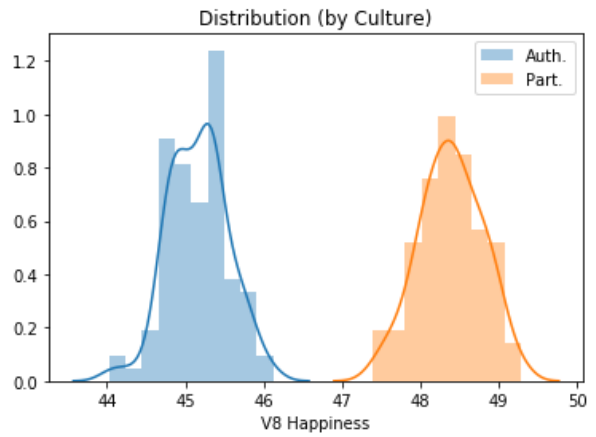Bonus = bônus
Auth. = autoritária
Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
Ceiling-Goals = meta-teto
Auth. = autoritária
Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
Beat-Miss = Índice de meta batida sobre não alcançada
Auth. = autoritária
Part. = participativa

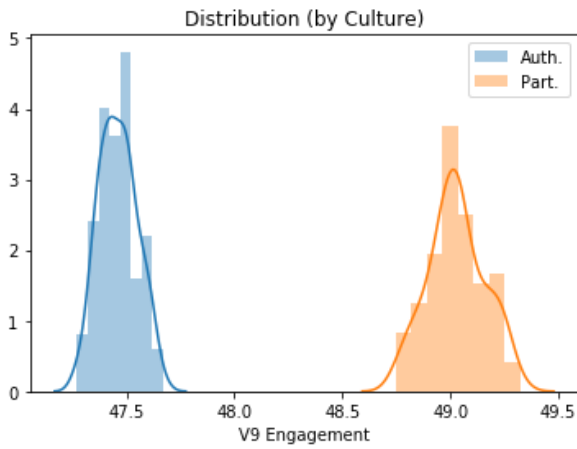Distribution (by culture) = Distribiução (da cultura)
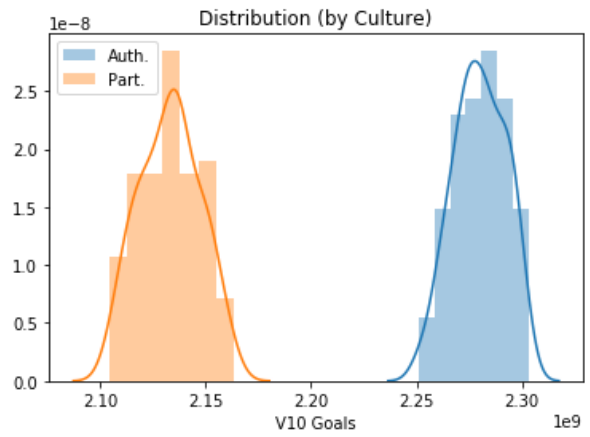Ambition = ambição
Auth. = autoritária
Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
BranchHeat = Mapa de Calor
Auth. = autoritária
Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
Happiness - felicidade
Auth. = autoritária
Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
Engagement = engajamento
Auth. = autoritária
Part. = participativa

Distribution (by culture) = Distribuição (da cultura)
Goals = metas
Auth. = autoritária
Part. = participativa