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The minority game in product strategy

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Abstract:	The competitive interaction among product strategies in complex markets is an evolutionary game, where players engage using strategies that are forced to differ and there is no optimum solution. It is a network of multiple nonlinear relations, operating at the edge between stability and instability. Information is incomplete, settings change continuously, and outcomes in the long run are unpredictable. However, it is possible to understand patterns of behavior to make better decisions. Winners are the minority players, exhibiting differing strategies but also common patterns – despite flickering settings and constraints. This paper proposes a framework to understand competitive product strategy behavior, illustrating with a case from the automobile industry, validated by an artificial neural network model. Categorical principal component analysis (CATPCA) was used to analyze relations among the attributes. The experiment yielded meaningful results, showing the framework provides valuable insights for deciding how and where to focus in product strategy.
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Abstract

The competitive interaction among product strategies in complex markets is an evolutionary game, where players engage using strategies that are forced to differ and there is no optimum solution. It is a network of multiple nonlinear relations, operating at the edge between stability and instability. Information is incomplete, settings change continuously, and outcomes in the long run are unpredictable. However, it is possible to understand patterns of behavior to make better decisions. Winners are the minority players, exhibiting differing strategies but also common patterns – despite flickering settings and constraints. This paper proposes a framework to understand competitive product strategy behavior, illustrating with a case from the automobile industry, validated by an artificial neural network model. Categorical principal component analysis (CATPCA) was used to analyze relations among the attributes. The experiment yielded meaningful results, showing the framework provides valuable insights for deciding how and where to focus in product strategy.

Keywords

Product strategy; evolutionary game; competitive strategy; minority rule; machine learning; CATPCA.

1. Introduction

In Cost Rica, choruses of male frogs sing to attract females, despite the risk of being caught by frog-eating bats. It is a competitive game, by advertising to attract mates away from rival males. If a frog sings louder than its competitors, it increases its chance of mating but decreases its odds of survival; the reverse is true also. If most males are quiet, a male is better off being louder. If most rivals are loud, it benefits from being quiet. Over time, the strategies tend to convergence towards the same volume for all males.

(adapted from Vincent and Brown, 2005)

Product strategy in dynamic markets is a challenging endeavor, with uncertainty about both customers and competitors (Sorenson, 2000a). Competitive dynamic markets are characterized by multiple players, complex strategies and incomplete information, with variables changing over time. Most firms have leeway to choose among different product strategies. However, there are many constraints - from the market, technology, economics, corporate policy, history, tradition, legislation - making it difficult to yield optimal strategies. In addition, the best strategy does not depend only on what a firm does, but also on what competitors do. The *minority rule* states winners play differing strategies, achieving a superior balance in attributes despite the constraints (Devetag et al. 2014). This paper explains how the minority rule works in competitive product strategies and how it can enhance decisions in complex environments. The framework is illustrated with an automobile industry case. A database is engineered as the repository of market history, contemplating customers, product attributes, competitors, pricing, and brands. The strategy space is hard to map mentally or heuristically; hence an artificial neural network traces those relations. The experiment confirms winners adopt distinctive strategies, command higher than average market share and enjoy stability; but they also exhibit common patterns. The proposed framework and method are original contributions to understand competitive product markets and provide practical insights for managerial decision-making.

2. Theoretical background

Evolutionary game theory was formulated by Smith and Price (1973, 1976, 1982) and elaborated further by Vincent and Brown (1985, 1987, 2005, 2011). A game is a model of the interaction among players using strategies, in pursuit of payoffs (Sharif and Heydari 2013). Evolution implies changes in the strategies over time, under selection and adaptation to the current situation (Li et al. 2019). Evolutionary games are composed of players, strategies, payoffs, and a solution concept (Vincent and Brown 2005; Vincent et al. 2011). Players are sets of individuals with the same strategies and payoffs. A strategic group is a set of players who perceive themselves as being part of the same game (Camerer 1991). Strategies are unique and inheritable sets of attributes; different players act with different strategies. A *product strategy* is a set of attributes, mapped to customer value (Simon 1996, Woodruff 1997). Value is the expression of benefits perceived by customers (Woodruff 1997).

A strategy set comprises all evolutionary strategies that are feasible for a player. Possible strategies are constrained by genetic, physical, and environmental factors. Other constraints can be derived from inter-dependencies among the attributes. Some attributes are fixed, or *invariants*; others are changeable. Companies are constrained in the range of feasible product strategies; but they still enjoy significant leeway, depending on perceptions and resources. Ratneshwar et al. (1999) recommend a broad vision of strategic groups, since product innovation and changes in pricing policies may reshape the market and affect consumer considerations.

Payoffs are expressions of fitness - the relative presence of a strategy at a particular time (Vincent et al. 2011). While classical games focus on strategies to optimize payoffs, evolutionary games look for persistence in time. The *solution concept* is a function that maps the strategies to fitness. Since fitness results from the interaction of strategies, evolution by natural selection is an emerging evolutionary game (Vincent and Brown 2005). Natural selection is an optimization problem, seeking the best fitness in a given time and space. But optimum is an unstable state. By seeking persistence of strategies, evolution is a game - not just a problem of optimization. Players may disappear, but strategies persist through inheritance. New strategies occasionally emerge through mutation or invasion. The former is a heritable change in the attributes; the later occurs when a new player enters the strategic group.

Sorenson (2000b) observed competition and legitimation are the two forces that shape a market; the number of players (fitness) is their measurement. Legitimacy happens when a player is taken for granted in an industry, the degree of acceptance by both customers and industry peers. It determines a player's resilience in the market; once established legitimate players tend to exhibit a certain inertia in the market – expressed by a steady market share. New

entrants have a hard time to acquire legitimacy. The complexity (number of interactions) of a market grows by the square of its density (number of players). Competition will increase with the number of players, unless the market expands at the same rate as the number of interactions (Sorensen 2000b).

The "El Farol bar" model is a game of adaptive players with incomplete information. Players win by being in the *minority*: going to the bar, if it is relatively empty; staying home, if it is crowded (Arthur 1994, 1999). Nobody knows what others are doing but they have information about past attendance. Players learn by inductive reasoning. Attendance converges to a threshold value over time; but it is dynamically unstable, continuously fluctuating around that value. The *El Farol* problem was mathematically solved by Challet, Zhang and Marsili (1997, 1998, 2001, 2004, 2005), in the *minority game*. Convergence itself is a consequence of the law of large numbers (Challet et al. 2004). But there is no winning strategy – if there were such a strategy, all players would adopt it and then they would all lose (Casti 1996; Ranadheera et al. 2017). Strategies are forced to differ, to fluctuate, and to evolve quickly (Casti 1996; Bischi and Merlone 2017). A larger minority or a variety of differing strategies imply smaller fluctuations and a more efficient overall system (Bottazzi and Devetag 2007; Ranadheera et al. 2017). Success in real life situations, as in financial trading, is often a composite of majority and minority decisions (Bischi and Merlone 2017). Up to a point, it is convenient to follow trends - players tend to be conservative and there are benefits from collective experience (Sharif and Heydari 2013). But deviating at the right time is a successful strategy (Devetag et al. 2014; Challet, Marsili and Zhang 2005).

Game theory models the competition among alternative strategies, attempting to predict the actions of rival players (Kleindl 1999). Competition is the pursuit of market space by players with strategies contending for similar target customers (Hoffmann et al. 2018). Despite its name, game theory is a set of tools for disciplining model construction, not a substantive theory by itself (Postrel 1991; Kleindl 1999). It is neither normative nor descriptive; it is analytic, seeking the implications of strategic situations (Camerer 1991). Strategic settings are complex nonlinear networks that operate at the edge of stability and instability, exhibiting both at the same time. They are unpredictable in the long-run and the task of strategy making is to understand behavior patterns, not outcomes by themselves (Stacey 1995). Business strategy is a practical field and game theory comes into existence by being applied to real strategy situations (Camerer 1991; Saloner 1991; Stacey 1995). Chatterjee (1986) urged the confluence of abstraction from game theory and empiricism of marketing science, to design robust competition models with practical reach. To gain legitimacy, game theory needs a corroborating case-specific theory. It links supporting theory and managerial actions,

providing a decision framework for choosing strategies based on predictions of competitor actions. Since strategy implies a view of the future, some form of prediction is necessary (Wilson 1999). Prediction should not be understood as forecasting, but as the construction of hypotheses and the analysis of their sensitivity to theory and data (Simon 1996). From Mintzberg (1994), strategy making is a process of learning from all available resources – including experience and data – and synthesizing them into a vision of the future.

Porter's *five forces* (customers, suppliers, existing competitors, new entrants, and substitutes) are a well-known framework (1979, 2008). The *minority game* implies intense rivalry and positioning for differentiation from competitors. Among the reasons for intense rivalry, Porter cites multiple committed competitors and imperfect information. This investigation elaborates on the interactions among heterogenous and complex strategies, contending in evolving markets. It confirms winners are the minority players. Although all players are forced to differ in their strategies, minority players exhibit some common patterns. The framework assists decision-makers to both understand the product strategy game and to guide their actions.

3. Method

This study is grounded on theoretical review, conceptual framework, and a case study with simulation. Key constructs were defined, and a conceptual framework was built. In the experiment, an artificial neural network (ANN) simulated and validated the competitive strategy dynamics of an automobile segment. Attribute dimensions were identified using a *nonlinear principal components analysis* (PCA) technique. The investigation is based on a single industry and does not seek statistical generalization. However, from Eisenhardt (1989), a case study can provide in-depth understanding of a particular phenomenon, providing explanation and prediction. Slater (1995) extolls the control of market influences in single industry research, enhancing internal validity. It is preferable to go narrow and deeper in the investigation, relating it to a specific performance criterion.

Case study

Small SUVs are the fastest growing automobile segment in Brazil, currently accounting for 30% of the market (Fig. 1). Although there were small *off-road* vehicles in the market before, the Ford Ecosport is recognized as the product that inaugurated the segment in 2003 (Bazanini and Berton 2011). In its first year of production, the Ecosport held 2% of the general automobile market, growing to almost 3%, a couple of years later – significant figures for a single model. It remained without a strong direct competitor until 2011, when Renault launched the Duster. Currently, there are twenty-seven players in the small SUV segment.

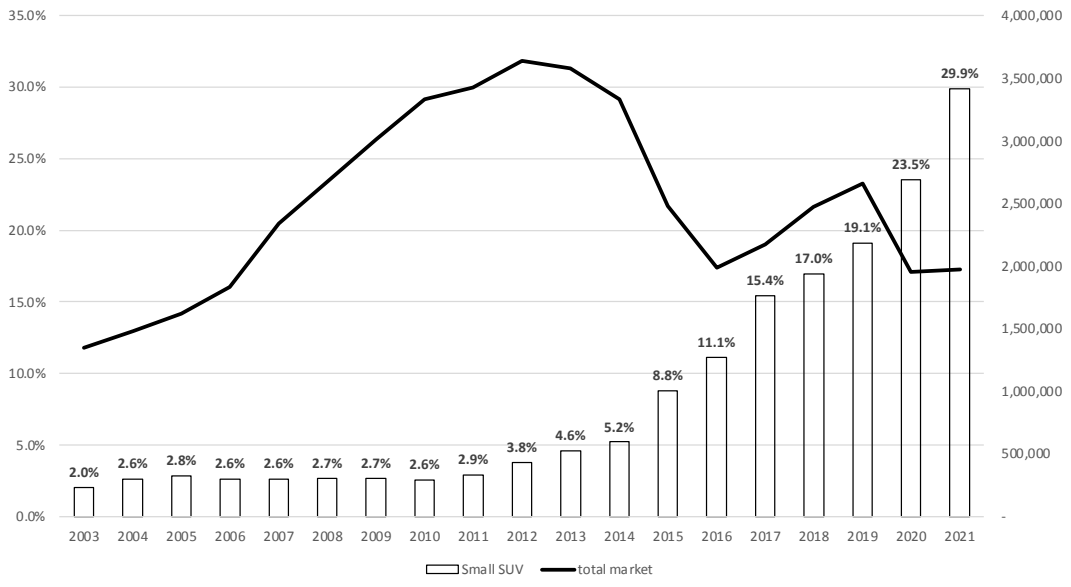

Fig. 1 Total automobile sales and small SUV market share in Brazil. Source: FENABRAVE.

Modeling and simulation

A database summarizing product strategy in the small SUV segment, from years 2003 to 2020, was crafted. Year 2021 was not included in the model due distortions from the Covid-19 pandemic, which affected the supply of electronic components and sales of several vehicles. We relied on specialized publications, customer evaluation websites (Quatro Rodas 2021; UOL Carros 2021), and industry experience to identify the key product features (customer attributes). The initial feature assessment yielded sixteen product attributes, which were then confronted with the prescriptions from Weber's automobile development text (2009) - for validation. *Novelty, brand, style, robustness, space, trunk, comfort, agility, convenience, finish, equipment, infotainment, performance, economy, safety, and price* were the selected features. There is a parallel between strong product attributes and USPs - *unique selling propositions* (distinctive innovations for product marketing) (Weber 2009). Although USPs are tools for advertising and attributes are elements for strategy, they are aligned since the later are mapped to customer value.

Market share is the fitness indicator adopted in this study to anchor the model to reality and to validate its accuracy. It is a proxy for *customer value*, as customers vote with their pockets. Monthly sales data (vehicle registration figures) were collected from the Brazilian Federation of Vehicle Distributors website (FENABRAVE 2021), generating 1,571 observations (Yamamura 2022). Market share is the ratio between product sales and market size. Using market share instead of straight sales figures purges market seasonality and effects of fluctuations in the economy, when comparing data from different moments. As the SUV market has been growing continuously and it is receiving new entrants, share of the overall automobile market was adopted, instead of share of the SUV segment.

A product strategy is a vector of features (product attributes). Each attribute in the observations was evaluated to synthesize the vectors in the matrix database. Most sample vectors are recursive as their attribute values are constant over time. However, some attributes may differ for the same product in different moments of time. For instance, one point was deducted in *novelty* for every year from launch time to account for product ageing. It recovers one or two points if it receives a styling update, depending on the intensity of the refreshening action. Product specifications may also be updated, receiving improvements along its life cycle. An automobile manufacturer would rely on sources like expert knowledge, proprietary research, static and dynamic testing, competitor *benchmarking* and *tear down*, to evaluate products. For this experiment, customer evaluations from a website (UOL Carros 2021) and reviews from a specialized automobile magazine (Quatro Rodas 2021) were used. The objective was to find *satisficing* solutions, not

necessarily optimal ones (Simon 1996), not numerical precision but adequate representations for information processing. A discreet scale of values from one to five was used to evaluate the attributes.

The second stage of the process is to find a *fitness generating function* (Vincent and Brown 2005), modeling game rules and minimizing the conditional probabilities of error. A shallow artificial neural network (ANN) was chosen because of its capacity to handle variables in complex, nonlinear and hierarchical levels of abstraction. It is a two-stage hierarchical function that maps linear combinations of input features into nonlinear representations of target values. Data is processed by inputting feature data and adjusting the parameter weights in the connections through layers of hidden nodes. Errors are calculated in a loss function and learning occurs by *feed-forward* and *back propagation* iterations, minimizing errors by seeking global minima through stochastic gradient descent. As data moves through higher layers, more abstract representations are processed through the network.

Data was split among training, validation, and testing sets in 70:15:15 ratios. About the number of neurons in the hidden layer, the best result was achieved with ten units - activated by the hyperbolic tangent function $g(z) = tanh(z)$. Target values are activated by the *rectified linear unit* (ReLU) function $f = max (0, x)$. For optimization, the Levenberg-Marquardt method was used to find the minimum of the sum of squared errors in the functions (Marquardt 1963). Predictions were compared with real market share data (target values) and a correlation $R = 0.96$ was obtained (Fig.2), showing a high level of explanation. Those figures suggested the model was an adequate representation of competitive product strategies mapped to fitness. It was run on MATLAB™ R2021a, in a MacBook™ with 1.2 GHz Intel™ Core M processor.

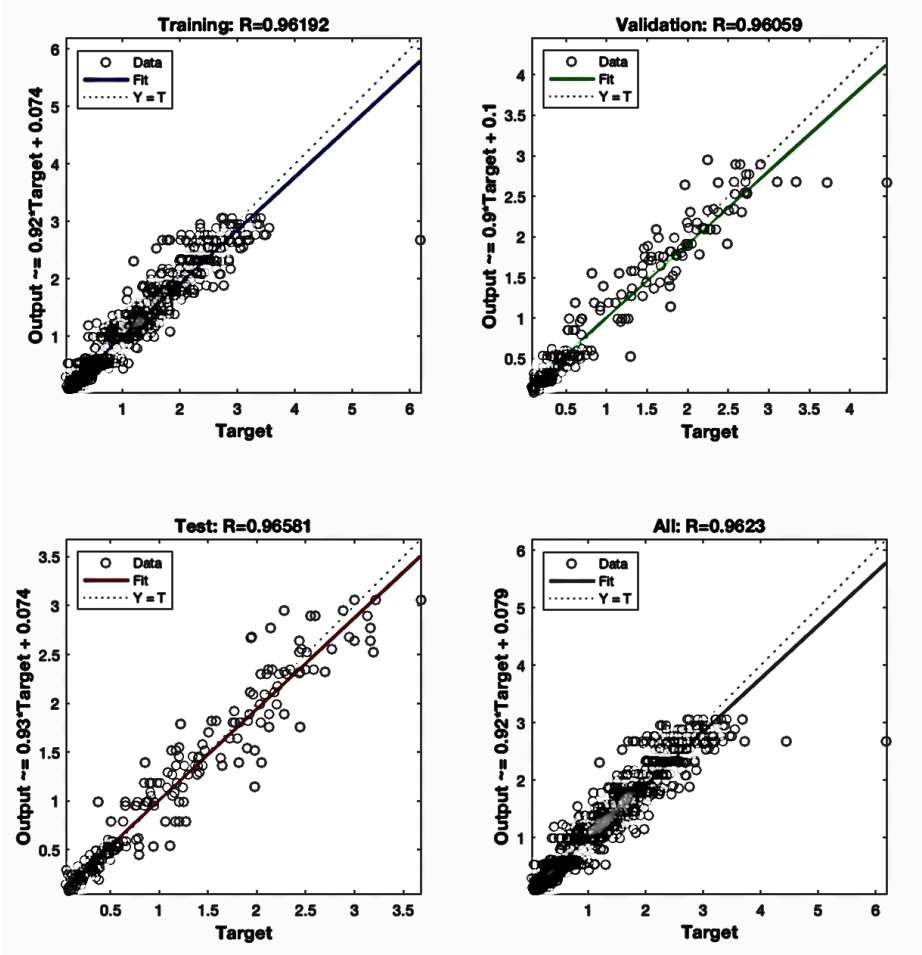

Fig. 2 Correlation between real data and predictions - 0.96 (MATLAB™).

For the analysis of attribute clusters, the *categorical principal component analysis* (CATPCA) was performed, which reduces data dimension assigning metric values to non-metric variables in a dataset with different levels of measures and nonlinear relations. The *ordinal level of optimal scaling*, v*ariable principal normalization* and *varimax rotation* methods were selected for the analysis (IBM 2020). Dimensions were defined according to the *Kaiser Criterion* (eigenvalue greater than 1), total variance explained and interpretability. For technical information, see Kuroda et al. (2013), Linting and Van Der Kooij (2012), Campos et al. (2020) and Linting et al. (2007). Analysis was run in the IBM SPSS 25 statistical software package.

The framework used for evolutionary product strategy analysis is summarized in Fig. 3.

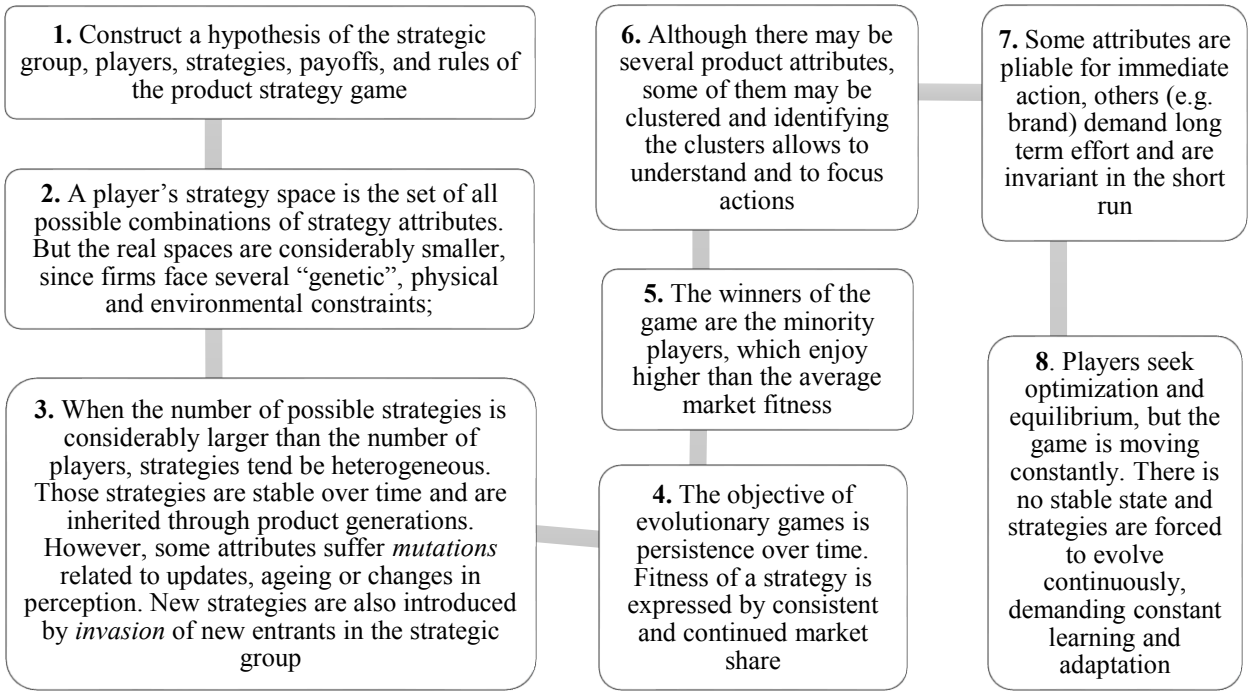

Fig. 3 Evolutionary product strategy framework.

4. Results

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	avg
Ecosport	**2.02**	**2.61**	**2.80**	**2.38**	**2.01**	**1.65**	**1.45**	**1.29**	**1.12**	**1.05**	**1.85**	**1.63**	**1.37**	**1.41**	**1.44**	**1.40**	**1.29**	**1.23**	**1.67**
Tucson			0.03	0.19	0.53	0.74	0.96	0.84	0.53	0.58	0.45	0.55	0.46	0.56	0.23	0.21	0.13	0.12	0.44
Sportage			0.01	0.02	0.09	0.27	0.26	0.22	0.24	0.25	0.26	0.31	0.27	0.23	0.17	0.23	0.16	0.08	0.19
iX35								0.20	0.40	0.30	0.29	0.46	0.59	0.51	0.47	0.35	0.22	0.13	0.36
ASX								0.01	0.32	0.30	0.28	0.36	0.39	0.24	0.23	0.22	0.14	0.06	0.23
Duster									0.27	**1.29**	**1.40**	**1.47**	**1.39**	**1.28**	0.81	0.95	0.98	1.00	**1.08**
Tracker											0.07	0.43	0.45	0.43	0.56	1.06	0.61	2.53	0.77
HRV													**2.07**	**2.81**	**2.20**	**1.94**	**1.86**	**1.67**	**2.09**
Renegade													**1.58**	**2.60**	**1.76**	**1.88**	**2.58**	**2.91**	**2.22**
2008													0.25	0.54	0.49	0.39	0.33	0.24	0.37
Kicks														0.54	**1.54**	**1.89**	**2.11**	**1.87**	**1.59**
Compass															**2.26**	**2.44**	**2.27**	**2.71**	**2.42**
Creta															**1.92**	**1.98**	**2.16**	**2.45**	**2.13**
WRV															0.71	0.60	0.46	0.54	0.58
Captur															0.63	1.07	1.08	0.56	0.84
Tiggo																0.21	0.24	0.24	0.23
Cactus																0.14	0.62	0.49	0.41
TCross																	**1.78**	**3.08**	**2.43**
Tiggo5X																	0.32	0.45	0.39
Tiggo7																	0.15	0.13	0.14
Eclipse																	0.09	0.13	0.11
Nivus																		0.83	0.83
Territory																		0.08	0.08
avg	2.02	2.61	0.95	0.86	0.88	0.88	0.89	0.51	0.48	0.63	0.66	0.74	0.88	1.01	1.03	1.00	0.93	1.02	**0.94**

Table 1 Market share (%) by model, between 2003 and 2019. Source: FENABRAVE.

The small SUV market model is an evolutionary game with twenty-three distinct players in 2020 (Table 1). Strategies are vectors of sixteen product attributes, each with five score levels; hence each player has a potential strategy space of 5^{16}, or S = ~ 1.5×10^{11} possible strategies. In principle, the probability of someone playing a certain strategy is $\frac{1}{1.5\times10^{11}}$. However, effective strategy space is smaller because of firm and environment constraints. Still, the probability of two players playing the exact same strategy is very low, if the strategy space is considerably larger than the strategic group size ($S \gg N = 23$). The examination of strategies in the small SUV model, confirms there are no players with identical strategies (Table 2).

model	new	brand	style	robust	comf	space	trunk	conv	finish	equip	info	econ	perf	agile	safe	price	mkt%
TCross	**5**	**4**	**4**	**4**	**4**	**4**	2	**4**	**4**	**5**	**5**	**4**	**5**	**5**	**5**	3	**2.43**
Compass	3	**5**	**5**	**5**	**5**	**4**	3	**4**	**5**	**5**	**5**	1	3	**4**	**4**	1	**2.42**
Renegade	1	**5**	**5**	**5**	**4**	2	1	**4**	**5**	**4**	**5**	1	1	3	**4**	3	**2.22**
Creta	2	**5**	3	**4**	**4**	3	**4**	3	3	3	**4**	2	2	**4**	2	**4**	**2.13**
HRV	2	**4**	**4**	3	3	3	**4**	**5**	3	1	2	**4**	3	**5**	5	3	**2.09**
Ecosport	1	3	2	2	3	1	2	3	**4**	**4**	**5**	3	2	**5**	3	**5**	**1.67**
Kicks	2	3	3	2	1	2	**4**	2	2	2	1	**4**	**4**	**4**	3	**4**	**1.59**
Duster	3	2	2	**5**	2	**5**	**5**	2	2	2	**4**	1	2	2	2	**5**	**1.08**
Captur	2	2	4	5	1	5	4	2	1	2	3	1	1	2	3	4	0.84
Nivus	5	4	5	3	3	2	3	3	4	5	5	4	5	5	5	4	0.83
Tracker	5	4	4	3	4	2	3	4	3	5	5	3	5	5	4	3	0.77
WRV	3	4	1	3	2	2	2	5	2	1	1	4	3	4	4	5	0.58
Tucson	3	5	4	4	5	5	5	5	5	5	4	3	5	3	5	1	0.44
Cactus	4	1	2	1	4	2	1	2	3	4	3	2	2	2	2	5	0.41
Tiggo5X	4	1	3	1	3	3	1	2	3	4	4	3	4	1	2	3	0.39
2008	2	1	1	1	3	1	2	1	1	3	3	3	1	4	3	4	0.37
iX35	1	5	3	3	4	4	5	2	4	3	4	1	3	1	2	2	0.36
ASX	1	3	2	5	2	4	3	3	2	2	3	1	3	2	3	3	0.23
Tiggo	3	1	2	1	1	1	3	1	1	2	2	1	1	2	1	5	0.23
Sportage	3	2	5	4	5	5	5	5	5	3	1	1	4	3	5	2	0.19
Tiggo7	4	1	4	1	5	4	3	3	4	5	5	3	4	1	2	2	0.14
Eclipse	4	3	5	3	5	4	5	5	5	2	3	1	5	3	4	1	0.11
Territory	5	3	2	2	3	5	3	3	4	5	4	2	3	3	3	1	0.08
																avg	**0.94**

Table 2 Product strategies and average market share. Sources: FENABRAVE; Quatro Rodas; UOL Carros; the authors.

In biology, strategies are called *phenotypes* and they are constrained by genetic, physical, and environmental factors. In business, "genetic" constraints are linked to a firm's history, culture, brand policy and image. For instance, styling decisions are influenced by a firm's *DNA* (identity) and history. Physical constraints are related to the possession of material, technical, and economic resources. Environmental restraints can have legal, social, ecological and market origins. Some attributes are harder to change in the short run. For instance, brand building demands continuous and long-lasting technical and marketing efforts – it is a short-term invariant. On the other hand, prices can be adjusted in a relatively short time.

Strategic attributes are elements of a product's *phenotype,* they tend to be stable over its life cycle, and are transmitted by *inheritance*. But some attributes can suffer mutations, like modifications or updates in product content. Some mutations are almost imperceptible – e.g., model-year detail updates, small running changes; others have significant impact in market fitness, like mid-life actions with substantial changes in styling and content. The Ecosport, launched in January 2003, was strong in attributes like *novelty, styling, agility*, and relatively affordable *price*. It received a mid-life facelift in October 2007, changing its front styling. In September 2012, a second generation was launched - a descendant that superseded the previous Ecosport. Most attributes, like *comfort, convenience, agility,* and *price* positioning, were inherited. The first generation disappeared as a player, but strategy persisted in the next generation. However, the styling was *mutated,* and its impact was enough for a 75% increase in market share, from

2012 to 2013 (table 1). A mid-life update in August 2018 brought a significant mutation in several previously weak attributes - *equipment, finish*, and *infotainment* technology –to face the *invasion* of new entrants in the strategic group (Honda HRV, Jeep Renegade, Nissan Kicks, and others). The Ecosport was discontinued in 2021, becoming extinct in the marketplace.

Fitness is the relative density of a product strategy and is expressed by stable and persistent market share. Competition for customer preference is the *natural selection* mechanism that determines fitness. The small SUV segment has been growing continuously and the entrance of new players have expanded the segment size - participation in the automobile market has been roughly proportional to the number of players (Fig. 4). However, players do not have an "easy life". The intensity of competition is not a function of the number of players, but of the number of interactions – i.e., it increases by the square of the number of players (N^2) (Sorensen 2000b). This explains some players experiencing significant decline in market share, despite the expansion in the overall segment size (table 1).

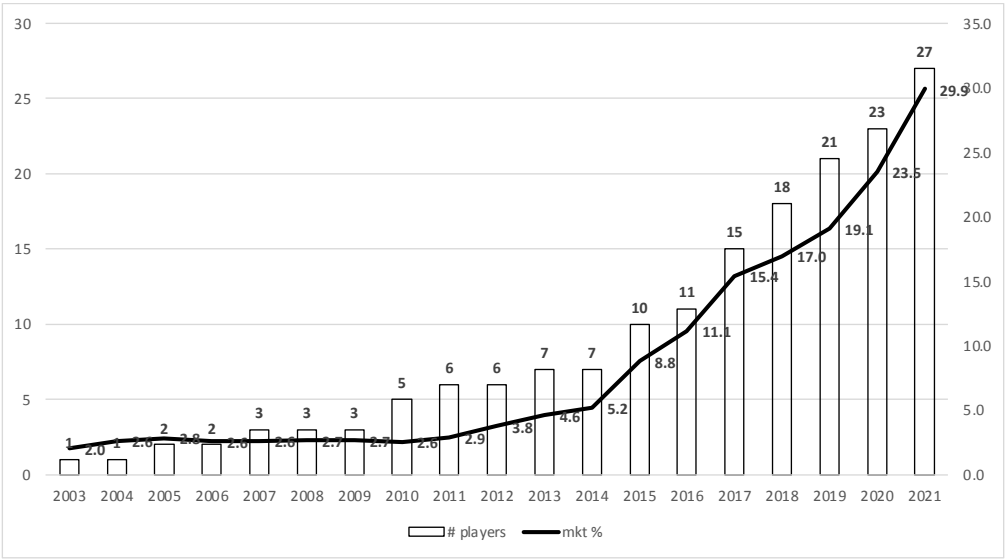

Fig. 4 Number of small SUV models vs market share. Source: FENABRAVE.

If all players adopted the exact same strategies (under the same conditions), market share should be the same for each player. They would all be equal in the *majority*, with individual market share $ms = \frac{m}{N}$ (*ms* = market share; *m* = market size; *N* = number of players). Historical data shows a small SUV holds 0.94% of the automobile market on average (Table 1). Players acting with different and advantageous strategies should enjoy $ms > 0.94\%$. From table 1, winners in the small SUV game (the *minority*) are Ecosport, Duster, HRV, Renegade, Kicks, Compass, Creta, and TCross.

Strong attributes are scored four or five points in the simulation. Close examination of minority strategies reveals differentiation, but also common traits. The CATPCA analysis resulted in attributes clustered into three major dimensions (Fig. 5), explaining 76,0% of data variance. Minority players are strong in attributes like *comfort*, *convenience*, *finish*, *equipment*, and *infotainment* (table 2), which are clustered in dimension 1. Equipment and infotainment technology are closely linked and related to price – more expensive vehicles tend to be better fitted. The same is valid for comfort, finish, and safety – distinction in those attributes tends to be followed by higher prices. *Space* and *trunk* go in direction opposite to *economy* and *agility* (dimension 2): small vehicles tend to be more fuel efficient and agile, while losing in passenger and luggage space in comparison to larger products. Those attributes are not particular to minority players. However, combinations of affordable prices, space, and trunk (e.g., Duster), or economy and agility (Ecosport, Kicks), seem to be winning propositions. A strong brand is an expression of legitimacy, and a long time is needed to gain recognition (Sorensen 2000a). Five of the eight minority players exhibit strong brands; small market share is related to less endowed brands (Table 2). *Robustness* goes beyond physical sturdiness, being also related to *brand* image (dimension 3). According to customers in the qualitative survey, robustness is not just resistance to wearing and breaking, or off-roading capability, but it is linked to *reliability* (although the Jeep brand is strongly associated with off-road vehicles). The analysis could go further. However, the above explanation should be sufficient as the objective of the automobile case study was merely to exemplify and to illustrate how the evolutionary game and minority rule frameworks can assist to understand strategic patterns and behavior.

	Dimension		
	1	2	3
finish	**0.961**	-0.074	0.097
comfort	**0.892**	-0.229	-0.083
safety	**0.880**	0.176	0.120
convenience	**0.831**	-0.006	0.286
style	**0.810**	-0.050	0.137
infotain	**0.792**	-0.040	-0.031
equipment	**0.789**	0.104	-0.295
price	**-0.774**	0.411	-0.088
perform	0.543	0.041	0.224
novelty	0.438	0.181	-0.238
space	0.133	**-0.938**	0.193
agile	0.130	**0.933**	0.180
trunk	0.070	**-0.889**	0.193
economy	0.012	**0.841**	-0.160
brand	0.082	-0.127	**0.969**
robust	0.096	-0.160	**0.964**
Cronbach Alpha	0.898	0.784	0.664
Eigenvalue	6.235	3.598	2.335
Variance Explained (%)	38.968	22.489	14.593

Variable Principal Normalization.

a. Rotation Method: Varimax with Kaiser Normalization. Rotation failed to converge in 4 iterations. (Convergence = 0.000).

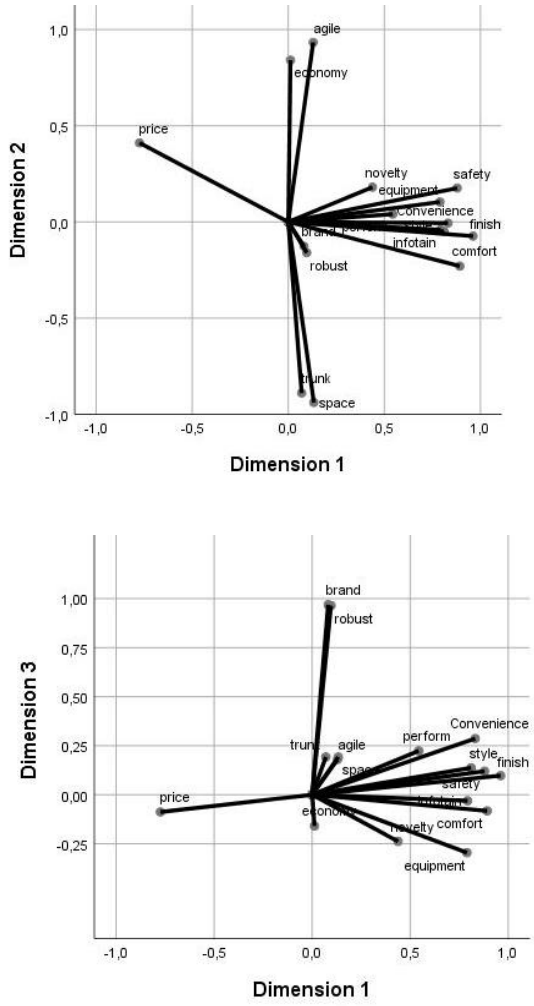

Fig. 5 Categorical Principal Component Analysis (CATPCA) rotated component loadings (left) and dimensions biplot (right).

5. Conclusion and future research

The evolutionary game framework applied to an automobile market case provided valuable insights. Among the several product strategy features, some can be enhanced in short or medium terms, like pricing. Others are much harder – they can be invariant for a single product generation, like styling, interior space, and others. Brand is an expression of legitimacy, not easy to be acquired. Once possessed, it tends to persist. It is worth to invest in an image of robustness – which tends to be associated with reliability – for a firm's long-term product success. Multiple attributes tend to be related in clusters (e.g., comfort, convenience, equipment, and infotainment technology) and – by selecting and focusing on them – firms benefit from synergies and efficient use of resources.

The case study was an illustration of both evolutionary games and the minority rule. It showed the framework is a useful tool to analyze an industry systematically, extracting focal points for product strategy making. It highlights the attributes a firm should pay attention to, in different time frames. Some actions can be specific to a single product, but others will require a continued effort that spans several product generations. It is worth remembering the aim of evolutionary games is the long-run persistence of market fitness.

The investigation was based on a single industry, limiting its capacity of generalization. But it showed the approach – identifying the elements from an evolutionary game perspective and constructing the theoretical framework – is meaningful to assist strategy decisions. Investigations involving other business settings and a variety of other algorithmic tools to generate the fitness functions would be valuable future research contributions.

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