

# Game-Theoretical Approach to Strategic Planning in Regulatory Market Surveillance

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**Abstract**—This paper presents an inquiry into the applicability of basic principles of Game Theory to the field of Market Surveillance. It identifies an optimal market surveillance strategic plan based on the prevailing and the desired market conditions. It further utilises an exponential relationship governing the number of possible outcomes in any n-person game given the number of players and the number of available strategies and its implications from a regulatory point of view, and introduces the idea of the optimal path to equilibrium point as a decision-making tool.

**Index Terms**—Game Theory, Market Surveillance, Planning, Strategy, Nash Equilibrium, Crime, Criminal Behaviour

## I. INTRODUCTION

GAME theory is a systematic study of strategic interactions among rational individuals (Kokesen and Ok, 2007, p. 8). In other words it is the study of the ways in which interacting choices of economic agents produce outcomes with respect to the preferences (or utilities) of those agents, where the outcomes in question might have been intended by none of the agents (Stanford Encyclopedia of Philosophy, 1997).

The mathematical groundwork of the theory of games was laid by von Neumann and Morgenstern in 1944 with the publication of their foundational book on the subject *Theory of Games and Economic Behavior* (Stanford Encyclopedia of Philosophy, 1997). Six years later Nash in his doctoral dissertation extended the theory beyond two-person cooperative games and established a generalisation for any number of persons playing non-cooperatively (Nash, 1950). He further established the idea of an optimal equilibrium point upon which no change in strategy by the players will lead to higher payoffs (Nash, 1950, pp. 48-49). This equilibrium in an any-person game is now called the Nash Equilibrium in his honour.

A pure strategy Nash equilibrium is a profile of strategies such that each players strategy is a best response (results in the highest available payoff) against the equilibrium strategies of the other players (Jackson, 2011, p. 5).

## II. LITERATURE REVIEW

*Market Surveillance* is defined as the activities carried out and measures taken by designated (Market Surveillance) authorities to ensure that products (in the market) comply with the requirements set out in the relevant legislation and do not endanger health, safety or any other aspect of public interest protection (United Nations Economic Commission for Europe [UNECE], 2011, p. 22).

An *Economic Operator* is defined as the manufacturer, the authorised representative (acting on behalf) of the manufacturer, the importer or the distributor of any product in the market (UNECE, 2011, p. 8).

*Quality* means different things to different people. According to feedback from consumers, quality means how well something does what it is meant to do, and is perceived in terms of in terms of construction, durability and performance (Day and Castleberry, 1986). In the context of this paper, quality shall refer to compliance with set product standards and regulations in addition to the aforementioned understanding.

The interactions among Market Surveillance Authorities, Economic Operators and Consumers can be modelled in form of games. Trading in substandard products is a crime in most parts of the world; therefore using the game-theoretical approach by Tsebelis (1990), this form of illicit trade can be examined as a game between the Market Surveillance Authorities on one hand, and Economic Operators and Consumers on the other hand.

Consumers make purchases based on their spending power, and are aware of an existing general relationship between the price of a commodity and its quality. This fact is supported by Day and Castleberry (1986) who reported that consumers correlate the price of a commodity to its quality. Their finding is reinforced by Gavious and Lowengart (2011) who found a positive relationship between price and quality in their analysis of data on paper towels initially reported by *Consumer Reports* in 2009. Blum and Mansour (2018) further established using mathematical modelling techniques that price and quality are linearly related and concluded that price is indeed a stable indicator of quality. These ideas are crucial in analysing trading behaviour and the outcomes of the game scenario presented herein.

*Management by Objectives*, a concept that was brought to life by Drucker in 1954, still underpins management processes and systems to this day (Thomson, 1998, pp. 1-4). Central to this concept is the setting up of objectives that are smart (specific, measurable, achievable, relevant and time-bound). This requirement has been incorporated in quality management system standards such as the ISO 9001.

A sticking point in the field of Market Surveillance is the development, during the planning phase, of a smart grand strategy. A likely reason for this is the number of interconnected inputs that are required to adequately map the process, and the outputs and outcomes which are equally convoluted.

In this paper the idea of the optimal path to the equilibrium point will be utilised. This idea requires analysing the players' behaviour, assuming they are rational decision-makers,

and making a tradeoff between economic gains and market disruptions.

Conventional strategies adopted by Market Surveillance Authorities involve institution of punitive sanctions on market players who flout product quality and safety regulations. However, from a game-theoretical viewpoint, sanctions alone are not an effective deterrent to crime. In general, an increase in the severity of the penalty applicable to a crime has no impact on criminal behaviour at equilibrium (Tsebelis, 1990). A multi-pronged strategy is therefore crucial in ensuring both consumer safety and economic stability.

### III. OBJECTIVE

This paper attempts to answer the following question:

*From the principles of Game Theory and taking into account the prevailing market conditions, can a Market Surveillance Authority develop an optimal strategic plan which ensures that products traded within the Authority's jurisdiction comply with the requirements set out in the relevant legislation and do not endanger any aspect of public interest protection, while at the same time safeguarding economic stability?*

In addition, this paper is going to address a situation in which there are only two possible strategies: trade in quality products and trade in substandard products, both based on price-oriented market positioning with price, at least at the consumer level, being an indicator of quality.

### IV. PLAYERS, AVAILABLE PAYOFFS AND GAME RULES

#### A. Description of Players

Consider a scenario involving three players with characteristics and behaviour described below.

- 1) Market Surveillance Authority (MSA): plays to ensure high quality and safe products are traded in the market with no regard to the price of the products (the MSA relies on technical information on a product with respect to its quality and safety). During this game the MSA conducts various activities such as implementing sanctions and conducting awareness-raising activities, all of which require material and financial resources.
- 2) Economic Operator (EO): plays to maximise profits while at the same time trying to make sure that the EO is not placed under sanctions by the MSA. In maximising profits the EO may choose to offer for sale low price products in order to increase the volume of sales, in most instances at the expense of quality.
- 3) Consumer: plays to get the best deal in purchases. In most cases this involves a tradeoff between quality and price, depending on the Consumer's level of awareness on quality requirements and their purchasing power. Quality-aware Consumers, within the limits of their purchasing power, will go for quality products which may in most cases be reasonably expensive, but safe and durable. Quality-averse Consumers, as a result of either limited purchasing power or low level of awareness on quality requirements, will go for substandard products which may in most cases be reasonably affordable, but less safe and less durable.

#### B. Available Payoffs

In this analysis, three possible payoffs are described in terms of economic gains or losses, with corresponding numerical values for ease of mapping them into the payoff matrix.

The three payoffs are as follows:

- Low Economic Gain - 0
- Medium Economic Gain - 1
- High Economic Gain - 2

#### C. Game Rules

The following rules are necessary for the analysis of this game:

- 1) MSA scores 0 in the event that EO supplies substandard products to both quality-aware and quality-averse Consumers in the absence of monitoring by MSA.
- 2) MSA scores 1 in the event that EO supplies substandard products to both quality-aware and quality-averse Consumers in the presence of monitoring by MSA.
- 3) MSA scores 1 in the event that EO supplies quality products to both quality-aware and quality-averse Consumers in the absence of monitoring by MSA.
- 4) MSA scores 2 in the event that EO supplies quality products to both quality-aware and quality-averse Consumers in the presence of monitoring by the MSA.
- 5) EO scores 1 in the event that EO supplies substandard products to a quality-aware Consumer.
- 6) EO scores 2 in the event that EO supplies substandard products to a quality-averse Consumer.
- 7) EO scores 1 in the event that EO supplies quality products to a quality-averse Consumer.
- 8) EO scores 2 in the event that EO supplies quality products to a quality-aware Consumer.
- 9) Consumer scores 0 in the event that EO supplies substandard products to a quality-averse Consumer.
- 10) Consumer scores 1 in the event that EO supplies substandard products to a quality-aware Consumer.
- 11) Consumer scores 1 in the event that EO supplies quality products to a quality-averse Consumer.
- 12) Consumer scores 2 in the event that EO supplies quality products to a quality-aware Consumer.

### V. GAME OUTCOMES AND THE PAYOFF MATRIX

In every game in which a finite number  $N$  of players have at their disposal a finite number of strategies  $S$ , the number of strategy profiles  $P$  defining the possible outcomes to the game is given by:

$$P = S^N \quad (1)$$

or, in natural exponential form, by:

$$P = e^{kN} \quad (2)$$

where the constant  $k$  is given by:

$$k = \ln S \quad (3)$$

In the situation under discussion, the number of players is known ( $N = 3$ ). Additionally, as previously declared in the

argument section, there are only two possible strategies: trade in quality products and trade in substandard products, therefore  $S = 2$  giving the number of possible outcomes  $P = 8$ .

#### A. Game Outcomes

The following statements of the outcomes and their corresponding 3-tuples of strategy profiles can thus be drawn:

- 1) Ideal situation: The market is saturated with quality products. The MSA activities are centred on maintenance of quality through appropriate monitoring. The EO supplies quality products which have found acceptance with the Consumer. (2,2,2)
- 2) The MSA is focused on enhancement of quality through appropriate monitoring. The EO supplies quality products, which due to their relatively high price, have not found acceptance with the Consumer, who prefers pocket-friendly products which in most cases are substandard. (2,1,1)
- 3) The MSA is focused on enhancement of quality through appropriate monitoring. The EO decides to supply substandard products, due to their relatively low price and high turnover, but these have not found acceptance with the Consumer, who prefers quality products. (1,1,1)
- 4) The MSA is focused on enhancement of quality through appropriate monitoring. The EO decides to supply substandard products, due to their relatively low price and high turnover, and these have found acceptance with the Consumer, due to factors such as low awareness on quality requirements and low purchasing power. (1,2,0)
- 5) The MSA is not focused on enhancement of quality (no monitoring is being conducted). The EO supplies quality products which have found acceptance with the Consumer. (1,2,2)
- 6) The MSA is not focused on enhancement of quality (no monitoring is being conducted). The EO supplies quality products, which due to their relatively high price, have not found acceptance with the Consumer, who prefers pocket-friendly products which in most cases are substandard. (1,1,1)
- 7) The MSA is not focused on enhancement of quality (no monitoring is being conducted). The EO decides to supply substandard products, due to their relatively low price and high turnover, but these have not found acceptance with the Consumer, who prefers quality products. (0,1,1)
- 8) The MSA is not focused on enhancement of quality (no monitoring is being conducted). The EO decides to supply substandard products, due to their relatively low price and high turnover, and these have found acceptance with the Consumer, due to factors such as low awareness on quality requirements and low purchasing power. (0,2,0)

#### B. Payoff Matrix

The corresponding payoff matrix for the eight outcomes described above is presented in Table 1 below. The payoffs in the matrix are indicated in the (MSA, EO, Consumer) format.

TABLE I  
PAYOFF MATRIX

MSA	Economic Operator			
	Quality		Substandard	
	Consumer			
	Quality	Substandard	Quality	Substandard
Quality	1.(2,2,2)	2.(2,1,1)	3.(1,1,1)	4.(1,2,0)
Substandard	5.(1,2,2)	6.(1,1,1)	7.(0,1,1)	8.(0,2,0)

## VI. ANALYSIS AND DISCUSSION

From the relationship  $P = e^{kN}$ , it can be immediately deduced that to mitigate the chaos brought about by exponentially increasing number of possible outcomes as a result of increasing number of players, Governments with the support of the MSAs should ensure that the number of EOs dealing in a particular type of product is kept at a minimum for ease of surveillance, possibly through enactment of regulations requiring formation of cooperatives, consortiums or any other forms of trading associations, while at the same time ensuring that this does not result in non-technical barriers to trade and suffocate the economy.

Likewise the number of MSAs regulating a given product should be kept at a minimum. This is especially important for markets in developing regions which may be deprived of adequate automated compliance assessment technologies.

From the same relationship, it can also be deduced that organising individual consumers into active consumer protection organisations will not only be effective in championing the rights of the Consumer but also result in a more manageable number of active players in the market.

Finally the number of strategies available to the players in the market should also be kept at a minimum.

#### A. Nash Equilibrium Point

From the payoff matrix, it can clearly be seen that the strict Nash Equilibrium Point exists at Outcome 1 (2,2,2). This outcome represents the ideal situation, the ultimate objective for MSAs.

#### B. Optimal Path to Equilibrium Point

Most poorly-regulated markets operate within Outcome 8 (0,2,0). Going back to the statement of the objective, the question therefore is to find the optimal strategic plan for the MSA to condition and move the market from Outcome 8 to Outcome 1 following the most optimal path. The path followed requires gradual changes to limit market disruptions, at the same time ensuring that the Consumer is protected from substandard and unsafe products.

Absence of monitoring by the MSA introduces instability in the market with respect to product quality since the EOs and Consumers lack the incentive and awareness to sustain trade in quality products. The optimal path therefore should avoid Outcomes 7, 6 and 5.

With the MSA focusing on substandard products, the optimal path will be from (8) to (4) to (3), and with the focus finally shifting to maintenance of quality, to (1). This

corresponds to a change in payoffs from (0,2,0) to (1,2,0) to (1,1,1) to (2,2,2) which is the ultimate objective. Outcome 2 is avoided because it implies a relapse to quality aversion on the part of the Consumer, which is not a desired outcome. (8) to (4) implies enhanced quality monitoring and evaluation; (4) to (3) implies enhanced Consumer awareness; (3) to (1) implies both enhanced Consumer awareness and effective sanctions on EOs not complying with regulations.

## VII. OPTIMAL STRATEGIC PLAN

The identified strategic objectives are therefore as follows:

- 1) *Implementing effective Consumer Awareness Initiatives highlighting the gains in using quality products*
- 2) *Implementing effective sanctions on all EOs who trade in substandard products*
- 3) *Supporting enactment of regulations facilitating conglomeration of all MSAs regulating similar products in the market, or a reduction in their number to the most essential*
- 4) *Supporting enactment and enforcement of regulations requiring conglomeration of EOs trading in similar products*
- 5) *Supporting formation of active Consumer Protection organisations, clubs etc. including introduction of product standards and safety training in the school curriculum*
- 6) *Implementing effective MS Strategies to ensure sustained compliance with regulations*

## VIII. CONCLUSION

It has been shown that it is possible to identify market surveillance strategies using basic but well-established principles of Game Theory. This finding cements the applicability of Game Theory as a decision-making tool in real-life situations, and extends Nash's ideas on equilibrium points in games into the growing field of Market Surveillance. An exponential relationship governing the number of players, the number of strategies available to each player and the number of possible outcomes therefrom has also been presented, including a descriptive example of its implication in strategic planning.

## ACKNOWLEDGMENT

The author would like to thank Michael Shell for the IEEE L<sup>A</sup>T<sub>E</sub>X template, and both Jiri Marek and Daniel Kuster for their L<sup>A</sup>T<sub>E</sub>X editing applications. This article was typed in its entirety on a mobile device using the afore-mentioned tools.

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