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## Rivalry and its mysteries: When Physics leverages Strategy

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Abstract: This research considers Michael Porter's "Five Forces" diagram for what forces firstly mean, a strength or an energy as an attribute of physical action or movement. Here, our objective is to build a competitive rivalry assessment tool to assist decision-making processes. Since the literature review has proven that such improbable couples make sense, we have invited Physics to collaborate with Management Sciences. After screening both Structured and Expert diagrams, we came up with a quantitative solution, which might be a new asset to diagnose the intensity of a market's rivalry through the calculation of every force's real weight. A theoretical application to art and salt sectors anchors the roots of further research.

Keywords: market intensity; 5 Forces diagram; industry; competition; Physical Sciences.

Résumé : Dans cette recherche, les 5 forces du diagramme de Porter sont prises dans leur acception première, celle d'une énergie liée à une action physique. Notre objectif est ici de construire un outil diagnostic de l'intensité concurrentielle permettant d'accompagner les processus décisionnaires. Pour cela, nous avons invité les Sciences Physiques à collaborer avec les Sciences de Gestion, un couple improbable comme la littérature en révèle pourtant beaucoup. Après étude des diagrammes Expert et Structuré, nous avons bâti une solution quantitative qui pourrait être un nouvel atout dans le diagnostic d'une intensité concurrentielle par le calcul du poids réel de chaque force. Une application théorique aux secteurs de l'art et du sel pose ici les bases de futures recherches.

Mots-clés : intensité concurrentielle ; modèle des 5 Forces ; industrie ; concurrence ; Sciences Physiques.

Resumen: En este estudio, las 5 fuerzas del diagrama de Michael Porter son consideradas por su primera explicación, aquella que la energía es vinculada a una acción física. Nuestro objetivo es construir una herramienta diagnóstica de la intensidad competitiva para acompañar los procesos decisivos. Para eso, invitamos a las Ciencias Físicas a colaborar con las Ciencias de Gestión, al final como una pareja improbable desde que la literatura lo revela mucho. Después de estudiar los diagramas Experto y Estructurado, hemos construido una solución cuantitativa que podría ser una nueva ventaja en el diagnóstico de la intensidad competitiva por el cálculo del peso real de cada fuerza. Una aplicación teórica en los sectores del arte y de la sal establece aquí las bases de futuros estudios.

Palabras claves: intensidad competitiva; 5 fuerzas; industria; competencia; Ciencias Físicas.

## **After all, Science remains Science**

Management sciences have experienced significant development during the last sixty years (Bain, 1956), with an intensification of business activities, alongside the theorization of entrepreneurial practices on a global academic and professional scale (Camerer, 1991; Brandenberger & Nalebuff, 1995; Whittington, 1996; Stam et al., 2014). By including formal sciences in their construction, management sciences proved not to be just a set of independent disciplines (Dorn, 1994; Suddaby et al., 2010). Although Isaac Newton was mentioned only once in all of Adam Smith's works, Newton had a considerable influence on the father of the modern economy (Montes, 2008), who, in return, also had a great affinity with natural philosophy and a strong willingness to link both the social and the physical worlds. Like in Adam Smith's perception, this mind independence and freedom of thinking, combining formal and soft analysis anchors our paradigm. Here, after a broad review of different strategic tools emphasizing the fact that companies are constantly looking for tangible tools to analyse their current situations and predict the future (Hatchuel et al., 2010; Pech, 2014; Hyytinen et al., 2015), we present techniques to assess industries since environment affect companies' profitability. Then, we explain why Porter's Five Forces diagram remains one of the most suitable tools to assess markets' rival intensity. Finally, we use formal, scientific and rigorous methods to quantify these forces.

## **Diving from Macro to Micro Relevance**

### **Michael Porter, a foregone conclusion**

It has been decades since academics nourish the already abundant strategic analysis tools for business leaders trying to link theory building and testing (Colquitt & Zapata-Phelan, 2007). Indeed, this confirms that strategy's boundaries expand, merely through the assessment of its performativity components (Cabantous et al., 2018).

Consequently, from macro to micro analysis, strategic analytical tools should be considered as the foundation stone of all strategic decisions, either from local, international, corporate, or entrepreneurial business perspective (Degeorge et al., 2018). This is how our thought took us to consider Porter's most famous diagram as a serious candidate to welcome our theory (see figure 1).

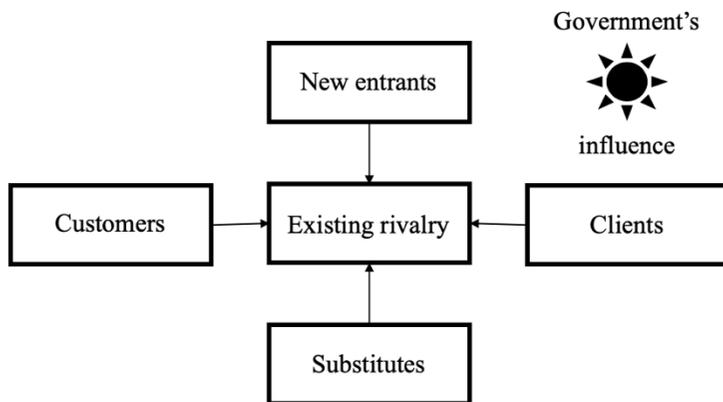
Table 1 highlights our thinking's evolution from our original statement. Just like managers do, organisations also develop natural strategic decisional tendencies, among which the approach through competitive environments investigation clearly roots our motivation to sharpen Porter's Five Forces diagram's relevance. Indeed, we here predicate that organisations that make strategic decisions upon diagnosing their external and internal surroundings naturally seek related levers able to tactically make decision making more flexible as well as more relevant. The latter results in methodologically consider past academic contributions in order to enrich them with further perspectives. In table 1, this intellectual process is made clear.

<i>Corporate Strategic Personalities</i>	Game Theory	Uncertainty	<b>Environment</b>	Resource
<i>Corporate Strategic Behaviours</i>	Organisations' interactions are serial because they are anchored in fixed variables  (Camerer, 1991; Brandenberger & Nalebuff, 1995)	Organisations are either risk-averse or pioneers  (Wernerfelt & Karnani, 1984)	<b>Organisations consider external elements such as market atomicity, environmental rigidity, and consumer behaviour the foundation of all relevant strategic decisions</b>  (Porter, 1981)	Organisations resort to both tangible and intangible resources according to the latter's availability  (Wernerfelt, 1984)
<i>Corporate Tactical Behaviours</i>	Mathematical & econometric approach  (Dorn, 1994)	Historical & cultural approach  (Prasad, 2011)	<b>Structure Conduct Performance (SCP): profitability comes from organisations' diagnosing agility and resilience capabilities</b>  (Mason, 1939; Bain, 1956)	Financial approach  (Gallo, 2016)
<i>Academic contributions</i>	Abduction & stochastic paradigms  (Peirce, 1974)	Resilience  (Werner, 1982)	<b>Porter and the Expert Diagram: offsetting personal interpretation issues by involving experts, and introducing a mathematical intensity weighting system</b>	Economic & business intelligence  (Harbulot, 2012)

			$F_j = \sum_{i=1}^n \frac{E_i/l}{E_{\max}} \times w_i$ <p>where the total forces' intensity is</p> $F = \sum_{j=1}^5 F_j$ <p>and the industry's attractiveness is</p> $A_{\text{ind}} = 5 - F$ <p>(Porter, 1980, 1981, 1991; Rosenthal, 1966; Shkurko, 2014)</p>	
<i>Our contribution</i>	N/A	N/A	<b>Newtonian method associated with Induction method here leads to a mathematical weighting system of Michael Porter's Five Forces Diagram</b>	N/A

**Table 1.** *The foregone 5 Forces compromise.*

From this synthesis, among all approaches developed to study firms' interactions, we knowingly consider the organization as part of a more complex ecosystem since fixed conditions and variables become less relevant in changing environments when technological changes, modified buyer needs, and industry structural mutations (Porter, 1991; Kibler et al., 2017) occur. Michael Porter's original study field was the Industrial Organisation. Indeed, he then quickly focused his research on investigating changing business environments. At the beginning of the 80's, Porter then came up with a Five Forces diagram with the intent to timelessly summarise this complexity through the action of five distinct actors. It is from this perspective that we have considered Michael Porter's Five Forces Diagram as the most relevant tool to welcome our tentative to make transdisciplinary theories meet (see Figure 1).



**Figure 1.** Michael Porter's Five Forces Diagram (source: Mouillot, 2007)

In this diagram, Porter explains that every organisation should raise five specific questions before breaking into a market or developing a competitive position:

- (1) Is the organisation a pioneer or is competition already a reality?
- (2) Is there any organisation aiming at breaking into the same market?

Following the two previous questions, is the organisation able to cope with existing key success factors - *i.e.* elements that are common to all competitors, here to be distinguished from competitive and comparative advantages - or able to create sufficiently demanding key success factors if it comes to be a pioneer?

- (3) What is the level of bargaining power of clients?
- (4) What is the level of bargaining power of suppliers?
- And (5) is the market elastic to price so that there is a competitive threat from substitutes?

Those questions shall, of course, be raised considering the business localisation's governmental rules, regulations and influence.

Notwithstanding the latter, they are essential to determine the degree of rigidity of a market. Consequently, we here outlined a series of mechanisms leading to a new quantified Porter's Five Forces diagram to better implement its related strategies (Akan, 2006) keeping in mind that if quantification cannot fully replace critical analysis, it can still bring extra information leading to consider competitive environments under new angles.

### **Towards a new diagram?**

Here, the importance to offer a fully customizable tool is at stake. Therefore, unlike others quantitative diagrams aiming at managing complex decision making (Quintus & George, 2005), ours is data-based and relies on limited qualitative expertise with the possibility to freely set industry boundaries, products/services and their substitutes in the forces' intensity calculation.

### **Methodological Premises**

To make a first draft of our diagram, we chose the induction method which refers to the process of inferring a general law or a principle from the observation of artefacts (Rothchild, 2006).

Since Newtonian mechanical science is the study of force-governed bodies' physical movement, we see Porter's Five Forces diagram as a system where the industry is the studied object that five distinctive forces influence the direction and the structure. In classical mechanics, the force always equals the dimension of a length and of a mass divided by time squared. In view of the different natures of Porter's forces, it seems difficult to fully transpose the notion of forces' homogeneity. Consequently, to respect this notion, the quantified expression of each one of Porter's forces is neither assigned to a dimension nor to a measurement unit.

### **Non-structural forces**

We followed Porter's definition of industry as a group of similar companies competing against each other (Porter, 1980 & 1981). Some non-structural forces have been introduced since then (Kibler et al., 2017) but not taken into consideration here because their very action is specific to specific industries.

## Forces' variables

Each Porter's force is commonly associated with variables represented in table 2.

Suppliers' bargaining power	Threat of new entrants	Buyers' bargaining power	Threat of substitutes	Industry rivalry
Concentration level	Economic entry barriers	Concentration level	Products/services advantages	Industry growth level
Resources differentiation	Expertise entry barriers	Switching costs	Buyers' switching costs for substitutes	Differentiation level
Switching costs		Price sensitivity		Exit barriers
Activities integration risk		Products/services differentiation		Competitors' concentration level
		Sophistication level		

**Table 2.** Common Porter's Five Forces components.

We noticed that for each force, several non-quantifiable variables could be compiled through a function that equals key variables. Since profitability is a function of price and cost, we sought to relate forces to the latter. Another task was to distinguish tangible and intangible variables. Consequently, to determine each force's formula, we applied four conditions on key variables:

- 1) Tangibility: Key variables are numerically tangible and accessible.
- 2) Importance: Like a physics formula, their role is significant in both the direction and the intensity of the considered force.
- 3) Relevance: They receive strong influence from the force's non-quantifiable variables.
- 4) Practical Use: The formula of the force deriving from them has to be functional.

## Quantitative interpretation

*Industry rivalry.* Four variables respecting the three conditions, were considered.

"Growth index c", divided into four stages - emergence, growth, maturity and decline - and referring to the industry life cycle, is a whole number from one to four.

We also considered the average differentiation cost either spent to improve and maintain the existing key success factors or to produce a unique selling proposal. If this cost is important, competitors shall attempt to adopt a cost domination strategy instead; hence it is in the numerator of the formula.

On the other hand, market size counters the effect of high exit cost. The bigger this size, the more firms shall preferably focus on their market / segment position through differentiation. Consequently, the formula is:

$$\text{Rivalry Weight} = \frac{c \times (\overline{\text{exit cost}} + \overline{\text{differentiation cost}})}{\text{market size}}$$

*Threat of new entrants.* New entrants' strength mainly depends on their capability to acquire the industry's key success factors, and maintain this know-how at a competitive level through research and development. These barriers are divided into two types of cost: the average entry cost, and the sum of all average costs associated with  $i$  different attributes of the products/services, which make the key success factors of the latter. The strength of new entrants will also depend on the size of the market. The larger this size, the higher and diversified the demand, thus increasing the possibility for new entrants to break into new markets. The new entrants' strength formula, symmetrical to Rivalry weight, is translated as:

$$\text{New entrants' strength} = \frac{\text{market size}}{\overline{\text{entry cost}} + \sum_i^n \overline{\text{attribute } i \text{ cost}}}$$

*Bargaining power of buyers.* A buyers' strength formula implying "buyers' switching cost" and "price sensitivity" could hardly be practical due to a very in-depth industry study to access data. Consequently, it does not respect the Practical Use condition. Therefore, we found an alternative: we first defined a high average price  $\overline{p}_{high}$  applied by the biggest competitors in the industry, which shapes the latter.

Knowing that the products and services of the biggest competitors have a better performance and a greater level differentiation than those who hope to dominate the market solely through low average price ( $\overline{p}_{low}$ ), the relationship from the companies' perspective is implied as:

$$\text{Buyers' strength} = \frac{\overline{p}_{low}}{p_{high}}$$

In table 3, we vary the highest and the lowest prices to test correlations between mathematical and analytical results.

Average High Price Variation	Average Low Price Variation	Ratio (or Buyers' strength)	Analytical Results
$\overline{p}_{high} \uparrow$	$\overline{p}_{low} \downarrow$	Strength $\downarrow$	The industry is profitable at every level. Cost dominators lower their overall costs and biggest players leverage performance or differentiation (or both). Ex: The car industry.
$\overline{p}_{high} \uparrow$	$\overline{p}_{low} \uparrow$	Strength $\downarrow$	Cost dominators and the biggest players include features in their products and services. Ex: The growth of Huawei in the smartphones industry.
$\overline{p}_{high} \downarrow$	$\overline{p}_{low} \downarrow$	Strength $\uparrow$	Either all players are involved in a price war or they all found a way to cut the costs, typically in global learning curve, economies of scope and scale. Ex: The current PC industry situation.
$\overline{p}_{high} \downarrow$	$\overline{p}_{low} \uparrow$	Strength $\uparrow$	The biggest players are involved in a price war meanwhile cost dominators are including features in their products and services. Ex: The Japanese quartz watches introduction and quality upgrading during the 1970s.

Table 3. Testing "low & high price" as key variables in buyers' strength formula.

*Bargaining power of suppliers.* To determine our first formula, "suppliers' strength", we focused on the "suppliers' cost" variable. Hypothetically, "suppliers' cost" is translated into a function of three variables: their concentration level, the differentiation level of the assets they sell (Gallo, 2016) and the risk of integrating the activities of their clients: Suppliers cost= f (concentration level, differentiation level, integration risk).

When suppliers cost is high, either suppliers' resources are differentiated (e.g. unique employees skills, rare resources) or their bargaining power became important due to their strong concentration level (Wernerfelt, 1984). Suppliers cost can also be high when suppliers make economies of scale, the integration risk still being valid.

When suppliers cost is low, either suppliers' resources are undifferentiated, or concentration level is low; consequently, their bargaining power is limited. Thus, suppliers' strength moves in the same direction than suppliers' cost, and respects Tangibility, Importance, and Relevance conditions. The suppliers' strength has a general formula which is the average industry profit and the average suppliers' costs ratio so that the user has a comparative basis between different industries.

$$\text{Suppliers' strength} = \frac{\text{external suppliers cost} + \text{internal suppliers cost}}{\text{industry net income}}$$

*Threat of substitutes.* Substitutes' strength comes from two factors: The practical and qualitative benefits of using low-cost alternative products/services and the low buyers' switching cost associated with substitutes. The substitute's strength formula is related to Buyers' strength and can be expressed by the ratio of the average price of products/services of the industry and the average price of substitutes, such as:

$$\text{Substitutes' strength} = \frac{\text{price the industry charges}}{\text{substitutes' price}}$$

### Formulas

To assess the level of an industry's profitability, the Five Forces formulas developed above are multiplied:

$$\begin{aligned} \text{Total strength} = & \frac{\text{suppliers cost}}{\text{industry net income}} \times \frac{P_{\text{low}}}{P_{\text{high}}} \\ & \times c \times \frac{(\text{exit cost} + \text{differentiation cost})}{\text{entry cost} + \sum_i^n \text{attribute } i \text{ cost}} \\ & \times \frac{\text{price the industry charges}}{\text{substitutes' price}} \end{aligned}$$

Even if this formula is functioning for companies, we simplified it as much as possible, under reasonable approximations, for those who meet obstacles in obtaining confidential data. Firstly, we expressed the net profit margin:

$$\begin{aligned} \text{Net profit margin} &= \frac{\text{net income}}{\text{sales revenue}} \\ &= \frac{\text{sales revenue} - \text{suppliers cost}}{\text{sales revenue}} \end{aligned}$$

By deduction and averaging on industry level:

$$\begin{aligned} \frac{\text{sales revenue} - \text{industry net profit margin} \times \text{sales revenue}}{\text{sales revenue}} &= \frac{\text{net income} - \text{suppliers costs}}{\text{net income}} \end{aligned}$$

Therefore, Suppliers' strength is also equal to:

$$\text{Suppliers' strength} = \frac{1}{\text{industry net profit margin}} - 1$$

The real difficulty lies in the factor:

$$\text{Rivalry weight} \times \text{New entrants' strength}$$

At the embryonic stage, investments are low due to uncertainty; entry and exit costs are similar, and essentially depend on the demand. Costs are not associated with key success factors or unique selling proposals. These suppositions implied that the factor between rivalry weight and new entrants' strength could be equal to "growth index c" at this stage.

At the growth stage, companies begin to position themselves and standardize their products/services around a dominant design and technology. Even if entry and exit costs incrementally increase, they remain low, key success factors are still not well defined, and unique selling proposals are not identified. Thus, their costs are both low and on the same order of magnitude. At this stage, the factor is also equal to "growth index c".

For a mature industry, entry and exit costs are high but due to important investments made to obtain key success factors and unique selling proposals, exit costs could be superior to entry costs. Key success factors' costs increase quicker than costs that are linked to unique selling proposals, which are more episodic.

Therefore, we can issue the hypothesis that the factor could be equal to “growth index c” at this moment. We then assume that this factor is equal to “growth index c” regardless of the industry stage. Thus, the simplified formula is:

$$\begin{aligned} & \text{Simplified total strength} \\ &= \left( \frac{1}{\text{industry net profit margin}} - 1 \right) \times \frac{\overline{p_{\text{low}}}}{\overline{p_{\text{high}}}} \times c \\ & \times \frac{\text{price the industry charges}}{\text{substitutes' price}} \end{aligned}$$

As “growth index c” is the only variable which appeals to a qualitative expertise, we use a logarithmic scale, firstly to minimize misjudgement and, secondly, to obtain ranges of industry profitability averaging values:

$$\begin{aligned} \text{Scaled simplified total strength} = \\ \log_{10}(\text{Simplified total strength}) \end{aligned}$$

## Application

We have applied the simplified formula on two industries, the salt and art industries, to demonstrate our arguments and we compared qualitative interpretation and numerical results, as shown in table 4.

We have chosen those sectors for two precise reasons: Firstly, to define limits, indeed a maximum total force and a minimum total force possibly reachable by all industries, and secondly, to show the underlying logic behind the formula.

	Salt		Art	
	Numerical value	Comments	Numerical value	Comments
Net margin	-		-	Same as for
<b>Suppliers' strength</b>	-	Regardless the data on buyers, suppliers, rivalries and new entrants, their investigation is not necessary regarding the substitutes' situation	-	the salt industry, investigation is not
Max price (US\$)	-		-	necessary
Min price (US\$)	-		-	regarding the substitutes' situation.
<b>Buyers' strength</b>	-		-	Here, if the price of the substitutes is zero, it is merely
<b>Growth index</b>	-		-	because art industry's clients buy something with high emotional value.
Price (US\$)	-		-	A ratio of positive certain value and zero is then positively infinite
Substitutes price (US\$)	$+\infty$	A substitute that doesn't exist cannot be purchased; consequently, the price is infinite.	0	
<b>Substitutes' strength</b>	0	A ratio of a positive certain value and positively infinite value is zero	$+\infty$	
<b>Total force</b>	0		$+\infty$	
<b>Logarithmic force</b>	$-\infty$		$+\infty$	

**Table 4.** Numerical applications on salt and art industries of our simplified total formula.

Salt industry's total force is zero because salt is a non-substitutable basic food, which makes it infinitely profitable.

As far as the art industry is concerned, logarithmic force tends towards plus infinite. In this case, buyers are so powerful that trade-offs are non-existent: they buy or they do not buy regardless of the masterpiece's price. Buyers establish price lists and artists are completely subjected to the market's requirements.

Consequently, since those two sectors constitute the lowest and the highest reachable total force, we here draw a parallel between numerical and analytical results: On the one hand, industries manufacturing necessity goods are infinitely profitable because they both do not have a typical product life cycle and are needed regardless of the economic cycle. On the other hand, industries manufacturing ultra-luxury goods are subjected to powerful buyers. Hence, the forces that are at stake are particularly important here. Consequently, analytical and numerical results converge towards the same conclusion.

## **Conclusion**

Through Adam Smith's inspiration from Isaac Newton's mechanical science, we saw that Management Sciences are arguably at the crossroads of all sciences, becoming the privileged bridge that links these to business affairs. Moreover, in a context where decisions concerning business administration must be based on physical data and concrete tools, the development of a quantified diagram from Porter's Five Forces proved to be a solution achieving two goals at once. On the one hand, we showed that this series of tools and theories could be an adequate way to contribute to management sciences, and, on the other hand, we built a strategic analysis tool to make it fully functional to assist managerial decisions more effectively.

Through a series of assumptions and methodical reasoning, we determined a total strength formula to help assessing industry's level of competitive intensity. Obtaining cost data is a difficult task but we circumvented the problem by determining a simplified formula. However, future research shall deeper explain our theoretical contribution, as well as explore new sectors, ideally with the benefit of stochastic data.

Active cooperation between formal and management sciences, that we are trying to resuscitate here, gives some perspectives that should be considered in the future.

Paradoxically, although Smith's division of labour has led to an increasing specialization of skills, thus putting barriers between sciences, we believe that this choice to vertically improve a science can be accompanied by horizontal enrichment from other fields of study.

The considerable development of management sciences supported by the adoption of a distinctive language and representative methods shows that we are still at the dawn of the ambition to raise further epistemological questions.

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