

# BSc in Economics and Finance <br> <br> Department of Business Administration 

 <br> <br> Department of Business Administration}

## The Cost of Thinking:

A Theoretical Analysis of a Homo Economicus Decision Maker Given Dual Process Theory and Information Processing Costs

Declaration of Academic Integrity
This project has not been submitted for approval for a degree, neither domestically nor abroad. The project is the result of a research done by the undersigned individual, except where otherwise stated and accurately referred to according to the APA 7. standard with standard references and bibliography. By signing, I confirm and agree that I have read the University of Reykjavik's code of ethics and rules regarding project work and understand the consequences that violations of the rules entail with regards to this project.



#### Abstract

The standard economic model of human behavior (SEMHB) has been under review ever since its inception. Its predictions have been compared to real world outcomes and the model has often predicted outcomes which do not correspond with the outcomes which are later realized. It is commonly believed that the models' tendency for error is largely caused by its assumptions. Most notable are the assumptions that each economic actor possesses unbounded rationality, unbounded willpower, and unbounded selfishness. The essence of this thesis is the development of a model that unites elements, such as information gathering, information processing costs, and dual process theory to the SEMHB. It does so by assuming that each decision is based on two steps, where in the first step, the individual determines which system will be used for the ultimate decision, and in the second step, utilizes the chosen system.

A theoretical analysis of the model shows that it allows for outcomes that seem irrational to an examiner but are not based on irrational behavior, as opposed to the SEMHB, which allows for neither. Additionally, the model predicts that majority of markets can be deemed somewhat inefficient, as consumer behavior is likely characterized either by low consumer interest and/or limited access to unbiased information. Lastly, the model implies that the current market for consumer information, largely supplied by Alphabet, Inc. and Meta Platforms, Inc., suffers from a principal-agent problem - where consumer information suppliers are incentivized to sell market power and consumer welfare to the highest bidder.


## Preface

This thesis is a final project for a B.Sc. degree in Economics and Finance at Reykjavik University. The project accounts for 12 ECTS and the work was conducted during the spring semester of 2022. I would like to thank my instructor, Ewa Lazarczyk Carlson, PhD , as without her experience and valuable insight, the thesis would have been highly indecipherable.

Furthermore, I want to thank my family, and friends ${ }^{1}$ for their continual support, and my fiancée, Thelma, for her boundless care and unconditional devotion.

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## 1. Introduction

"I have more memories than if I were a thousand years old." Charles Baudelaire.

Imagine a consumer faced with product choice of $n$ products of the same type. The consumer has pricing information of each product and has the ability to attain all the information needed to deduce precise marginal utility attained from the purchase and consumption of each product. What product is ultimately chosen? The traditional view of economics is that, given that the consumer has access to all relevant information, is hedonistic and homo economicus, the consumer will choose the product combination that maximizes his or her consumption utility. However, a rising branch of economics - behavioral economics - focuses its study on the failures of the traditional economic models, where, in practice, humans seem to be full of biases, tendencies and heuristics, which indicates that the decision-making mechanism of the human mind differs from the standard economic model of human behavior.

Behavioral economics is a relatively young branch of economics. One can argue that the branch originated from the writings of Herbert Simon who in the 1950's coined the term "Bounded rationality." Since then, a whole new branch of economics has appeared and gained relative traction, attracting many great minds in the process. The field places an emphasis on dissecting and analyzing three traits of the standard economic model of human behavior. The standard model, among else, assumes that each economic actor possesses

1. Unbounded rationality.
2. Unbounded willpower.
3. Unbounded selfishness.

The subfield states that given the cognitive limitations of the human brain, the utilization of heuristics is indeed rational, as heuristics allows cognitively limited individuals to save psychic costs and time. Furthermore, the field has put forth many interesting theories regarding the boundedness of both human willpower, and selfishness. Most of these theories have been combined into a theory called the prospect theory, which was developed by Kahneman and Tversky in the year 1979 (Mullainathan \& Thaler, 2000). This thesis, and the model it contains, relies heavily on both the standard economic model of human behavior, and Daniel Kahneman's interpretation of the dual process theory (2003, 2011). The decision-making model which will be developed can be described accordingly: The mathematical model is based on a decision maker that is faced with a choice of $n$ products. The decision maker has access to all relevant information, is hedonistic and has most of the characteristics of a homo
economicus decision maker. The only difference, however, is that the decision maker experiences information gathering and information processing costs ${ }^{2}$. That is, the individual has access to any information relevant to the decision and has full capability to process the information without bias - but doing so takes time and energy. Both time and energy are resources which the decision maker finitely rations to given choices, depending on the individuals' interest level on the topic of which the decision is relevant to ${ }^{3}$. The consumer also has fallback strategies - a method of random product choice. The differences between the preexisting models of human behavior and the model which is developed in this thesis is therefore based on differences in used assumptions regarding rationality and willpower, and the thesis highlights the mathematical modeling of a decision maker under the emergence of two underlying theories, one of which originates from economics, while the other originates from psychology. The differences between the common models and the new model can best be explained with the use of graphics.

Graph 1: The differences between the three models of human behavior.


As graph 1 implies, the standard economic model of human behavior describes humans as biological machines with theoretically unlimited cognitive capabilities. While prospect theory, in contrast, describes the human cognition as inherently flawed. Prospect theory bases its

[^1]arguments and models on measurements and results from a myriad of examinations on the human behavior in both controlled test environments and in the real-world. The data simply implies that humans seem to be limited, biased, and inconsistent when it comes to logic and reasoning. The last model depicted in the graph is the model developed in this thesis. It is based on the standard model framework but includes a new element, the perfect knowledge of limited time. The element is inserted in the model to encapsulate the need for prioritization of topics. The prioritization of topics is then used as a determining criteria for which of the two systems in the dual process theory the individual will use for each, given topic.

To better grasp different aspects of the model developed in this paper, mainly, its assumptions, and implications, one can imagine a sophisticated machine. A machine with the capability of generating unlimited, unbiased, and precise logic and therefore has the theoretical capacity to solve any conceivable problem. It is common knowledge that all machines require power of some kind, whether it is in the form of electricity or any other power source. To simplify, let us assume that this particular machine requires electricity. Let us further imagine that the machine's operator suddenly decides to limit the electricity available to the machine considerably. How would the machine respond? That is, how would the machine solve the problem of the newly introduced resource constraint?

One might hypothesize that the machine, due to its level of immense sophistication, would begin to prioritize processes as a method to reduce electricity usage, rather than simply to power off. Furthermore, such a machine might utilize different methods to solve different problems, based on their priority and relative importance. That is, the machine might use energy intensive methods to derive precise results for the more important tasks but might utilize approximations and other simplifying methods to save energy for less important decisions. The machine might do so to maximize its lifetime productive potential.

Sophisticated machines with great processing power already exist, and they were designed and created by a biological machine, the homo sapiens. From the perspective of an outsider, humans are a biological machine capable of displaying great cognitive capabilities. It is believed that the human brain can hold, on average, 2.5 petabytes of data (Reber, 2010; Wang et al., 2003), which amounts to roughly $2,621,440$ gigabytes according to the binary approximation of the power-of-two rule. To put that size into perspective, a single human brain can theoretically hold an amount of data equaling 40,960 standard smartphones of 64 gigabytes (Gordon \& Ridgeway, 2013). Even the entire works of humankind written in all languages since the beginning of history is believed to be able to fit into just twenty human brains (Pence, 2014).

Furthermore, the human brain has the capability to store, transfer, and process the data while only utilizing between 13 to 23 watts of energy (Balasubramanian, 2021; Jabr, 2012) which is less than one tenth of the energy consumption of an average desktop computer (Power Management Statistics, 2018). Which leads to the conclusion that the human brain is immensely powerful and extremely energy efficient.

Early in their life cycle, humans seem to develop the ability to recognize the exogenous constraints imposed upon them by nature. A review of available data gathered from numerous examinations and experiments determines that, on average, children gain understanding of death at the age of seven (Speece \& Brent, 1984). At age seven, humans begin to process the fact that there exists a constraint on an important resource, time. Furthermore, the constraint is, on an individual level, largely exogenous. The perfect knowledge of limited time module introduced in graph 1 encapsulates exactly that. That is, the fact that great mental capabilities allow humans at early age to fully grasp the notion of death, the permanence of it, and it, among else, requires enough sentient awareness to generalize from others’ experience to oneself. Therefore, the use of the word "perfect," since the knowledge of limited time exists in other species, but humans seem to be one of the few, if not the only species that can generalize in that way. That is, for all seven sub-components of the scientific concept of death, humans fulfill the criterion (Monsó, 2019; Panagiotaki et al., 2018; Slaughter, 2005).

Furthermore, human cognition seems to be not only time constrained, but severely energy constrained. As the average human, at rest, is estimated to produce around 100 watts of energy, with the upper limit of 300-400 wattage production sustained for few minutes (LaBonta, 2014). If true, the human body, with all its functions and processes, has less available power production to utilize than an average desktop computer. Moreover, it seems as before humans gain the ability to recognize their own resource constraints, human cognition is immensely more active. It has been shown that children's brains are twice as active as an adult's and it has been found that even toddlers do think in a highly logical manner (McBroom, 1999).

Therefore, the data implies that there might exist some correlation between the development of cognitive capabilities and an increased tendency for the human brain to reserve energy. Which implies that, from an economists' standpoint, the development of human cognition might be viewed not so differently from how an elaborate operating system recognizes resource constraints and utilizes "energy saving mode." It is hypothesized, that even the act of forgetting things temporarily is an energy-saving mechanism of the brain, because maintaining unnecessary association pathways requires energy (Rasmussen et al., 2015). The human brain
seems to be so efficient at saving energy that leading research in neural networks attempts to imitate and understand the human brain's method of transient memories as an attempt to further modern computational capabilities (Li \& van Rossum, 2020). Though it seems that despite having immense cognitive capabilities in theory, humans often tend to fall into relatively simple cognitive traps. When tested, educated humans even tend to fail when it comes to performing simple logical tasks such as inferring transitive relations (Frank et al., 2005). Furthermore, humans also seem to be inconsistent when it comes to valuation, estimation, and extrapolation of data (Hansz \& Diaz III, 2001). The amount of research data highlighting, what seems to be human errors, is of monumental quantity. Proponents of behavioral economics have, since its origin, applied the results from experiments and research to form the modern model of human behavior and decision making with the aim of evolving the Homo Economicus into Homo Sapiens (Thaler, 2000).

Consequently, it seems as if it is inherently implied that both models of human behavior cannot coexist in the same individual. The standard economic model of human behavior, and the model proposed by behavioral economists. Such a conclusion is, of course, tempting given that the two models often come to differing predictions, and when measured, one model consistently performs better than the other. The model introduced in this thesis attempts to bridge the differences between the two former models and states that because humans are so cognitively advanced, they have taken up heuristics and other simplifying algorithms to better utilize the limited resources available to them - and those heuristics, unfair assumptions, and simplifications of subjects, lead to the biases which are frequently being measured. Therefore, the differences between the model explained in this paper and prospect theory lie in the causality of human errors and biases. Furthermore, the model in this paper further implies that, if the boundaries of the constraints imposed by nature are expanded, humans should tend to utilize simplifying measures less and human cognition, as measured, improves.

Over millennia, humans have proven themselves to be able to expand the boundaries of the constraints imposed upon them by nature, even though the constraints are mostly exogenous on the individual level. Humans do that by pooling the resources of multiple humans. Doing so requires fulfilling multiple requirements, such as inventing languages to be able to pool the cognitive abilities of multiple humans, creating societies to be able to better pool resources, and developing the scientific method to be able to, over time, constructively expand the time and energy constraints imposed upon them by nature.

The list of human achievements in that regard continues ad infinitum. The model expressed in this thesis therefore states that humans are perfectly rational biological machines with theoretically immense processing power, but due to constraints imposed upon them by nature, and due to the exceptional capability of the human cognition, humans tend to utilize heuristics and other algorithms, and those simplifying algorithms might lead to biases or irrational-choice-tendencies when certain tasks are performed, which are frequently being measured.

The thesis highlights the utilization of both the standard economic model of human behavior and dual-process theory to develop a decision-making model with the intention of emulating the human thought pattern, and from there derive conclusions, predictions, and analyze the implications.

## 2. Theory

"It is the interest of every man to live as much at his ease as he can; and if his emoluments are to be precisely the same, whether he does, or does not perform some very laborious duty, it is certainly his interest...either to neglect it altogether, or...to perform it in [a] careless and slovenly a manner..."

### 2.1. Background

### 2.1.1. Overview and Literature

As stated in the introduction, the model developed in this thesis attempts to emulate the thought-pattern of a typical consumer by merging two schools of thought from two respective fields of social science, the standard economic model of human behavior (SEMHB), and the dual process theory. The model achieves that by assuming that as the need for a decision related to a given topic comes up, the individual will first use the SEMHB to determine which of the two system will be used. That is, as the individual is needed to decide on a given topic, the individual will first decide whether he or she will make the decision based on system one, or system two. Where the characteristics of the systems are:

System one is often called the "automatic system." Bargh and Ferguson (2000) describe the system as a system based on four components: awareness, intentionality, efficiency, and controllability. They state that agents who utilize system one must be unaware of it, be utilizing it unintentionally, the system must be highly efficient at saving energy, and it must be uncontrollable.

System two is often called the "rational system," "the controlled system," or "the analytic system." It engages in reasoning according to logical standards (Tsujii \& Watanabe, 2009).

The economic interpretation of such models are often grouped under the multiple-self theory. The multiple-self theory has gained significant traction within behavioral economics and neuroeconomics. It states that within each individual reside multiple different, distinctive subpersonalities (Alós-Ferrer \& Strack, 2014; Lester, 2012). Kahneman interprets the dual-process theory differently, where he states that system one is based on intuition and system two is based on reasoning, which implies that the individual has some control of which system is used (Kahneman, 2003). The mathematical model in this thesis adopts a variant of Kahneman's interpretation, where system one is assumed to be a single method, and system two is assumed
to be the complete, and costly, use of the SEMHB. Therefore, the representation used implies the following mapping of an individuals' decision tree (graph 2).

Graph 2: A simplified decision tree.


The decision tree highlights the focus of the model. The model assumes that for the individual to determine which system is ultimately used, the individual weighs the respective benefits and costs, and makes an ultimate choice of which system to utilize according to the SEMHB. The logical support for this methodology is based on the energy-saving nature of such a layout, where compared to the classic SEMHB models, the system allows for considerable energy savings through the use of system one for tasks deemed as "unimportant." Such behavior is not different from how a sophisticated, exogenously constrained machine might first determine which tasks to prioritize.

The mathematical models' approach is heavily influenced by Weitzman's (1979) model for optimal search for the best alternative. Where Weitzman envisioned the mythological entity Pandora facing a dilemma whether to keep searching for boxes to open, or to stop altogether, he created a decision-making model based on expected payoffs. His modeling technique is applicable to many different circumstances, and unsurprisingly, is highly relevant in the case of an individual consumer deciding whether to utilize system 1 or 2 based on expected payoffs. The mathematical model developed in chapter 2.2. is based on the foundation which he developed and shares the same steps until equation (3) in subchapter 2.2 , where the paths diverge, mainly due to differences in the variables of interest (See Appendix A).

### 2.1.2. Priority Ranking

Since the model is based on the assumption that the human is, in its core, a perfectly rational biological machine, which lives in a resource-constricted reality, the natural implication is that
humans must then prioritize. Since, without prioritization, the human being would not be maximizing its lifetime production towards the goal which it strives. The question then remains, how do humans prioritize? There is a word which describes adequately human prioritization, interest. Humans prioritize topics by interest level.

The mathematical model in this thesis denotes interest level by $\phi$, which is also referred to as psychic information processing cost. Where a low value of $\phi$ implies that the psychic information processing cost is small, and the individual is therefore more willing to process information related to a certain topic. Therefore, a lower $\phi$ indicates a higher interest level. Furthermore, the factors which determine each individuals' interest level are exogenous to the model: the factors will not be further defined in this thesis, but each individual's interest level on a certain topic is assumed to be determined by concepts which already exist within the field of economics and psychology. The model implies that each individual, when faced with a decision of any kind, decides between two approaches. Either to utilize system 1, to reduce the resource costs which follow the use of mental power, or to perform information gathering and processing to arrive at the optimal, but mentally costly conclusion - system 2.

The entirety of the psychic cost which falls on the decision maker, if system 2 is chosen, equals the value $\phi f$, where $\phi$ denotes the psychic cost which falls on the decision maker following the processing the information, and the value $f$ which denotes the quantity of information which is needed to be processed to utilize system 2 successfully. The value of $\phi$ can be viewed similarly as the mental "price" of processing one unit of information, where a unit is not defined further, and $f$ as the information quantity, in units, which must be processed. Furthermore, the value of $\phi$ is endogenous to the decision maker, while the value of $f$ is exogenous. That is, the value of $\phi$ is derived from the decision makers' own preferences, views, and interests, as opposed to $f$, which derives its value from other factors, such as the overall complexity of the given topic. $f$ will be omitted in this subchapter as the subchapters' focus is merely on the value of $\phi$. Therefore, the value of $f$ is assumed to equal 1 for all topics in the examples below.

To fully grasp the mathematical model, the reader must have an adequate understanding of utility theory, transitive relations, probability theory, differentiation \& integration, and understand how decisions regarding future payoffs are determined by expectations. The subchapter can therefore be concluded by stating the mechanism of $\phi$ via lingua mathematica:

There are two topics, $A$ and $B$, and individual $j$ needs to address a decision related to both topics, either by utilizing system 1 , and experiencing information processing cost of zero, or
by gathering and processing the information needed to come to the optimal conclusion. Individual $j$ 's information processing cost regarding topic $A$ is $\phi_{A}$, and information processing cost regarding topic $B$ is $\phi_{B}$. To simplify ${ }^{4}$, assume that the expected payoff of the decision to process the information is $P_{A}$ for topic $A$, and $P_{B}$ for topic $B$. The expected payoff of applying system 1 is $p_{A}$ for topic $A$, and $p_{B}$ for topic $B$. Furthermore, assume that the individual is hedonistic. Topic $A$ therefore has the following decision rule: choose to apply system 1 , unless
$P_{A}-\phi_{A} \geq p_{A}$, therefore $\phi_{A} \leq P_{A}-p_{A}$ is the requirement for individual $j$ to prefer processing the information.

Topic $B$ has the following decision rule: choose to apply system 1 , unless

$$
P_{B}-\phi_{B} \geq p_{B}, \text { therefore } \phi_{B} \leq P_{B}-p_{B} \text { for the same. }
$$

Let's assume that $\phi_{A} \leq P_{A}-p_{A}$ and $\phi_{B} \leq P_{B}-p_{B}$ are true ${ }^{5}$ such that $P_{A}-p_{A}=P_{B}-p_{B}$. Therefore, a simplifying assumption is made that the net payoff of utilization of system 2 is equal for both topics ${ }^{6}$. Let's also assume that $\phi_{A}<\phi_{B}$. If assumed that the individual does not have the resources to apply system 2 for both topics, the following decision rule remains: choose to apply system 2 for topic $B$ unless

$$
P_{A}-p_{A}-\phi_{A} \geq P_{B}-p_{B}-\phi_{B} .
$$

It is easily possible to show that the individual, given hedonism and perfect rationality, will never choose to apply information gathering and processing (system 2 ) for topic $B$, since the rule above can be simplified to $\phi_{A} \leq \phi_{B}$ and since assumed that $\phi_{A}<\phi_{B}$, and $\phi_{A} \leq P_{A}-p_{A}$. Therefore, it is possible to conclude that the individual will prefer to apply system 2 on topic $A$ over topic $B$, even though their payoffs are equal. The individual does so because $\phi_{A}<\phi_{B}$ and therefore topic $A$ is priority-ranked above topic $B$. Consequently, it is possible to show that if $\phi_{A}=\phi_{B}$, the individual would be indifferent between the two topics, and that if $\phi_{A}>\phi_{B}$, the individual would prefer to apply system 2 on topic $B$ over topic $A$. The same argument can be applied to $n$ number of topics given that transitivity holds. A simple three-topic example might be:

[^2]For the topics $A, B$, and $C$, all of equal residual payoff, if $\phi_{A} R \phi_{B}$, and $\phi_{B} R \phi_{C}$, then $\phi_{A} R \phi_{C}$. Where $R$ denotes a relation of any type. The result, derived from the use of transitive relations, allows for a priority-ranking of any comparable and competing decisions. If $R:=\{>\}$, then $\phi_{A}>\phi_{B}, \phi_{B}>\phi_{C}$, and $\phi_{A}>\phi_{C}$. The following preference ranking can thus be made

1. Gather and process information regarding topic C .
2. Gather and process information regarding topic B.
3. Gather and process information regarding topic A.

The importance of the ranking is that it states that if individual $j$ only has enough resources to apply system 2 for fewer types of topics than the number of relevant types of topics ${ }^{7}$, the individual will apply system 1 to all topics that do not meet the minimum criteria. E.g., if assumed that the individual has enough resources to successfully gather and process information regarding two topics, the cutoff point will be right above topic A , and system 1 will be applied to any topic below that of topic $B$.

1. Gather and process information regarding topic C .
2. Gather and process information regarding topic B.
3. Gather and process information regarding topic $\Lambda$.

It is possible to see that the list can theoretically be unending. The relationship described can be mapped according to graph 3 , given that

$$
\begin{aligned}
& P_{C}-p_{C}=P_{B}-p_{B}=P_{A}-p_{A}=P-p, \\
& \text { and } \phi_{C}<\phi_{B}<\phi_{A} .
\end{aligned}
$$

The result displayed in graph 3 is obtained by assuming equal net payoffs of each of the

Graph 3: Relationship between marginal benefit of system
2 , information processing costs, and choice of system.
 three, but by assuming different psychic information processing costs for each topic. The criteria which determines whether system 1 or system 2 is used is therefore based on the number of available topics, the psychic information processing $\operatorname{cost}(\phi)$ for each topic, and the restraint introduced by natural constraints of energy and time. The indifference line denotes the exact values of the payoffs and costs which lead to the individual being indifferent between systems. Furthermore, the model states that the coordinates of the topics need not be fixed: where changes in the individuals' constraints can lead to an increase or decrease in the value of $\phi$ for

[^3]any or all given topics. Changes in factors exogeneous to this model, such as energy, or time, should therefore lead to movements along the horizontal axis of the graph. E.g., if the individual experiences sudden severe constraints on energy and/or time, one might expect each point to shift to the right. Shift, which if large enough, would cause topic B to also enter the system 1 zone.

The graph therefore highlights the relationship between individual's interest level, prioritization, and limits introduced by nature, where a relaxation of the constraints introduced by nature should lead the individual to utilize system 2 - the SEMHB - for more topics, where the individual would then resemble the traditional Homo Economicus decision maker. Conversely, tightening of the constraints should lead the individual to utilize system 1 for more topics, which would lead the individual further away from the Homo Economicus decision maker. Furthermore, this mechanism implies that an unconstrained individual would utilize system 2 for all topics, and therefore behave exactly like predicted by the SEMHB, whereas a heavily constrained individual would utilize system 1 for most topics and would therefore be deemed as highly irrational - or uninterested in the topics. As stated before, the constraints are imposed by an exogeneous force, nature, and they appear in an individual's decision making mainly through restriction of time and energy. Therefore, it is possible to see that a constrained, perfectly rational individual should apply system 1 to a plethora of topics.

Research on particular subjects has found that consumer behavior tends to deviate substantially from the behavior proposed by the SEMHB, and these deviations are often implied to relate to consumer's lack of interest in that particular subject. Trotta (2021) analyzed residential energy demand in Finland. The analysis focused on consumer behavior, interest level and awareness. A survey was sent to 244 individuals, of whom 184 completed the survey. The survey's major findings were that less than half of individuals are even remotely aware of how much they pay for electricity. That is, majority of the sample had not attained information regarding the pricing of electricity, despite having full access to the information and the means of changing between energy providers. The findings, when analyzed in the scope of this text, imply that residential electricity consumers simply do not prioritize analyzing the supply of - and their use of electricity, which implies that a large share of the sample utilized system 1 for the topic. The same seems to be true for residential energy markets in Lianoning, China (Dianshu et al., 2010), and Serbia (Podbregar et al., 2021). Similar behavior can be found when pension finance literacy is analyzed in Kenya (Gitau Njuguna \& Kennedy Otsola, 2011).

Since interest level and priority ranking has been defined, and since the model is structured in that way so that if a topic is prioritized, and if the person has enough resources, the person will decide according to the standard economic model of human behavior, assumed to be system 2, the last prerequisite before the model can be created is defining what exactly is meant by the utilization of system 1 - heuristics.

### 2.1.3. Heuristics

The Merriam-Webster dictionary defines a heuristic technique as
> "Involving or serving as an aid to learning, discovery, or problem-solving by experimental and especially trial-and-error methods."

While Daniel Kahneman, in his book, Thinking, Fast and Slow (2011), defines the heuristic technique as a rule-of-thumb, or a guide toward what behavior is appropriate for a certain situation. In psychology, heuristics is a term used to describe a "mental shortcut" (Lim, 2018). From those definitions, one can conclude with considerable certainty that the utilization of heuristics must require little-to-no mental power. In this thesis, a simplifying assumption is made that the psychic cost of the utilization of heuristic technique is zero. The question remaining, then, is in what manner are heuristics applied? From the perspective of the consumer there are numerous types of heuristic techniques available. The following system 1 rules-ofthumb are analyzed, of which, one was chosen for the base model included in this thesis.

- Choose the brand based on price. Either by choosing the cheapest, the average, or the most expensive "luxurious" brand.
- Choose a brand at random. In essence, choosing a product that is closest.
- Choose the same brand as was chosen the last time.

The last item of the list is not logically sound. Since by choosing the brand that was chosen the last time implies that the first time the brand was chosen, another method was required for the making of the decision. Therefore, the last answer type can safely be excluded from the list of possible tactics. The tactic of choosing based on price can be excluded since is that it is likely that choosing the brand based on price is severely dependent on the price range of the supply relative to one's income. That is, a consumer might easily change his or her tactic dependent on the price level. E.g., if a consumer applies the tactic to always choose the priciest brand, as a rule-of-thumb, that might change if, for example, a new overly expensive brand appears in the consumers' supply pool. In addition, a concept introduced in behavioral economics, extremeness aversion bias, implies that decision makers tend to avoid options deemed by them
as extreme (Neumann et al., 2016). In the scope of the thesis, an extreme good might be a good that is the cheapest, priciest, or has certain characteristics deemed as extreme, such as flashiness. It is possible to develop the model to account for a bias of this type but doing so is not the essence of this thesis. Therefore, the model will assume that individuals who will utilize mental shortcuts will choose products at random with equal probabilities.

Since prioritization, interest level, and heuristics have been defined, the next step is to create a mathematical model aimed to encapsulate those factors and demonstrate their effects on consumer decision making and market outcomes.

### 2.2. The Consumer - A Mathematical Model

This subchapter represents an attempt to create a consumer decision-making model based on consumer characteristics introduced in earlier chapters. The consumer decision-making model is loosely based on a result developed in Weitzman's model (1979). The variables and concepts introduced in the subchapter are the following.

Table 1: Variables of interest.

| $u_{i}^{\prime}$ | The marginal utility of consumption of product $i$. | $P_{i}$ | The marginal price of product $i$. |
| :---: | :---: | :---: | :---: |
| $\phi$ | Information processing costs (higher cost represents lower relative interest). | $I$ | The product set. A set of all products of a given type (comparable products). |
| $\phi^{*}$ | The value of information processing cost where the individual is indifferent. This value essentially denotes the priorityranking cutoff point where individuals will prefer to utilize system 1. | $f$ | Information gathering function (higher level denotes more information gathering needed to be able to make an informed decision). |
| $R_{i}^{\prime}$ | Expected residual marginal utility gained from choosing product $i \in I . R_{i}^{\prime}=u_{i}^{\prime}-$ $P_{i}$. | $L$ | The set of the "leading" product. A singleton set where the element exhibits $\left\{L \subset I \mid R_{j_{L}}=\max R_{j}^{\prime}\right\}$ for individual $j$. |
| $y$ | Expected residual marginal utility from choosing a product at random. | F | The set of "follower" brands. The complement of set $L$. |

There are $n$ types of products that are distinguishable by a common characteristic. Purchase of product $i, 1 \leq i \leq n$ derives the expected marginal utility $u_{i}^{\prime}$ and carries the price $P_{i}$. The marginal utility of consumption is determined by traditional economic factors external to the
model. Let the product assortment of similar characteristics be further defined into the product set $I=\{1,2, \ldots, n\}$, where each product in the set has a discrete price which is known beforehand and derives marginal utility which is originally not known by the decision maker. Let $R_{j}^{\prime}$ be defined as the marginal residual utility for individual $j$, where $R_{j i}^{\prime}:=u_{j i}^{\prime}-P_{i}$ denotes individual $j$ 's marginal residual utility gained from the purchase of product $i$. The decision maker ${ }^{8}, j$, only has information regarding the price of each product in the set but is able to attain all relevant information regarding the marginal utility gained by experiencing the psychic cost determined by $\phi_{j} f$, where $\phi_{j}$ denotes the information processing cost and $f$ denotes - for now - an undefined information gathering function grasping the quantity of information needed to be able to distinguish the optimal product. That is, $f: \mathbb{R}^{k} \rightarrow \mathbb{R}_{+}$where $k \in \mathbb{N}$. The variables $\phi$ and $f$ should be multiplied as the value of $\phi$ denotes the cost of processing the information while the value $f$ denotes the quantity of information needed to utilize system 2 successfully. Finally, let $y_{j}=\frac{1}{|I|} \sum_{i=1}^{|I|} R_{j i}^{\prime}$ be defined as the expected residual utility of a secondary tactic, system 1 , where individual $j$ chooses and purchases a good at random - which is the assumed result from the utilization of system 1 . Thus, individual $j$ receives the expected residual utility $y_{j}$ and no psychic costs as a result of information gathering and processing. Finally let $X_{j}$ denote $j$ 's expected marginal residual utility gained from following an optimal decision strategy. Thus, the optimal strategy payoff must always satisfy the following relationship at every possible margin
(1) $X_{j}=\max \left\{y_{j}, \max \left(R_{j}^{\prime}(I)-\phi_{j} f\right)\right\}$.

Where
(2) $y_{j}=\frac{1}{|I|} \sum_{i=1}^{|I|} R_{j i}^{\prime}$.

This result is similar to the result attained by Weitzman's model of optimal search for the best alternative. At any given time, individual $j$ can determine whether to attain relevant information and choose the optimal product, therefore utilizing system 2 and experiencing cost determined by $\phi_{j} f$ - or to choose products at random and receive $y_{j}$ as residual utility, thus the right-hand side of (1) leads to the optimal policy which maximizes individual $j$ 's residual utility. This leads to a decision rule. The value of $X_{j}$ can be determined at every possible margin as

[^4]\[

X_{j}=\left\{$$
\begin{array}{c}
\max \left\{R_{j}^{\prime}(I)-\phi_{j} f\right\} \text { if } \max \left\{R_{j}^{\prime}(I)-\phi_{j} f\right\} \geq y_{j}  \tag{3}\\
\frac{1}{|I|} \sum_{i=1}^{|I|} R_{j i}^{\prime} \text { else }
\end{array}
$$\right.
\]

Thus, individual $j$ will base his or her decision on a specific, optimal product choice where information is gathered, processed, and optimal product is chosen when $\max \left\{R^{\prime}{ }_{j}(I)-\phi_{j} f\right\} \geq$ $y_{j}$. Else, the individual will rely on system 1 , assumed to be random choice of equal probabilities, which returns marginal utility of $y_{j}$. Define $\phi_{j}^{*}$ as the highest possible value of $\phi_{j}$ such that $j$ is indifferent between choices, therefore, $\phi_{j}^{*}$ is a value of $\phi_{j}$ which leads to a coordinate on the indifference line in graph 3 in subchapter 2.1.2. - the exact cutoff point in the individual's priority ranking, the following equality is attainable
(4) $\phi_{j}^{*}=\frac{\max \left\{R^{\prime}(I)\right\}-y_{j}}{f}$.

Therefore, if $\phi_{j} \leq \phi_{j}^{*}$, individual $j$ will base his or her product decision on information gathering and rational choice leading to the optimal product (system 2), else, the individual will choose product at random (system 1). Furthermore, it is possible to partition the product assortment $I$ into a set of a single, leading product $\left\{L \subset I \mid R_{j}^{\prime}(L)=\max R_{j}^{\prime}\right\}$, which is defined as the product in the set that maximizes ${ }^{9} R_{j}^{\prime}(I)$, and the complement set $F:=\left\{F \subset I \mid R_{j}^{\prime}(F)<\max R_{j}^{\prime}(I)\right\}$, which has the cardinality $|F|=n-1$ and denotes all other products in the product class that offer lesser residual utility for individual $j$. By utilizing this method of partition and assuming the law of large numbers, the likelihood that product $L$ is chosen, $\frac{q_{L}}{Q}$, can be evaluated as
(5) $\frac{q_{L}}{Q}=\int_{\text {inf } \phi}^{\phi^{*}} \operatorname{Pr}(\phi) d \phi+\frac{1}{|I|} \int_{\phi^{*}}^{\sup \phi} \operatorname{Pr}(\phi) d \phi$. Where
$\operatorname{Pr}(\phi):=$ probability density function. Which leads to
$\phi^{*}=\frac{R^{\prime}(L)-y}{f}=\frac{u^{\prime}{ }_{L}-P_{L}-y}{f}$.
From there, an estimation of the leading products' market share is possible - as long as the law of large numbers holds. For simplification, the shorthand script $\mathbb{F}$ will be used to denote the cumulative distribution function, therefore $\mathbb{F}\left(\phi^{*}\right)=\int_{\text {inf } \phi}^{\phi^{*}} \operatorname{Pr}(\phi) d \phi$. Furthermore, the use of this function format implies continuous differentiability of the distribution $\operatorname{Pr}(\phi)$. The quantity purchased of the leading good by the market must be
(6) $\quad q_{L}=Q\left[\mathbb{F}\left(\phi^{*}\right)+\frac{1}{|I|}\left(1-\mathbb{F}\left(\phi^{*}\right)\right)\right]$.

[^5]Where $Q$ denotes the total market quantity. Note that $Q$ is determined by traditional economic factors, such as income, and prices. These factors are external to this model. Let $\bar{\phi}$ denote the highest level of $\phi$ within a given population $(\max \phi)$ and let $\phi$ denote the lowest level of $\phi$ within the same population ${ }^{10}(\min \phi)$. The market share of the leading product $\left(\frac{\%}{100}\right)$ can be evaluated as
(7. a) $\frac{q_{L}}{Q}=\mathbb{F}\left(\phi^{*}\right)\left(1-\frac{1}{|I|}\right)+\frac{1}{|I|}$.

Thus, a relative demand function for the leading good has been determined. The market demand function for the leading good (in total quantity) equals $q_{L}$. Furthermore, given a market with two market suppliers, it is possible to derive that the follower good attains the following market share

$$
\text { (7.b) } \frac{q_{F}}{Q}=1-\frac{q_{L}}{Q}=1-\frac{1}{|| |}-\mathbb{F}\left(\phi^{*}\right)\left(1-\frac{1}{|| |}\right) \text {. }
$$

The demand curve and its responses to changes in the price of the products can also be evaluated. To successfully do so, $f$ and $\phi$ need to be further defined. $\phi$ is defined as a variable that represents information processing costs - primarily psychic costs due to loss of energy and loss due to time spent processing information. The function $f$ represents the information gathering function. A simple representation of such a function might be
(8) $f=\frac{|F|}{\max R^{\prime}(I)-\min R^{\prime}(I)}$.

Where $|F|$ denotes the cardinality of the set of follower goods. This function format allows for an increase in information gathering quantity needed as the number of product options increases, also, the information gathering difficulty increases as the residual utility from each product becomes more similar. Thus, an individual that has an abundance of product options that are similar in expected residual utility can be expected to experience a larger amount of information gathering needed to deduce the optimal product than an individual that faces considerably few product options that are very dissimilar in expected residual utility attained from consumption. Note that this format is by no means the only format or even the adequate format - it is merely a simple representation of how the function might work and will be used for the specific cases in coming subchapters. Utilizing result (7) allows for the estimation of the demand function in the specific case where (8) holds as

[^6]$\frac{q_{L}}{Q}=\mathbb{F}\left(\phi^{*}\right)\left(1-\frac{1}{|I|}\right)+\frac{1}{|I|}$ where $\phi^{*}=\frac{\left(\max R^{\prime}(I)-y\right) \times\left(\max R^{\prime}(I)-\min R^{\prime}(I)\right)}{n} \operatorname{and} \max R^{\prime}(I)=u_{L}^{\prime}-P_{L}$. This model offers a different view than the traditional SEMHB on consumer choice. Its usability and value is better shown by analyzing a specific example.

### 2.2.1 An Introductory Example

To better demonstrate the inner workings of the mathematical model introduced in chapter 2.2. it is possible to continue the example from the introduction chapter. Let's again view humans as machines which operate solely on electricity to calculate and make carefully thought-out decisions. Assume that a standard human brain draws 20 watts of power constantly. Over a given year, a human brain would then utilize 175.2 kilowatt-hours ( $k W h$ ) of energy ${ }^{11}$. With that in mind, it is possible to calculate the average price per kilowatt-hour of consumer brainpower

$$
P_{k W h}=\frac{M}{E_{k W h}} .
$$

Where $M$ denotes the average after-tax income. In that respect, from the perspective of an average individual, the benefit of brain utilization must be equal to - or greater than - the price per kilowatt-hour, $P_{k W h}$ times the amount of kilowatt-hours needed $k W h_{N}$ to make a carefully thought-out decision. Otherwise, a rational individual should avoid utilizing brain power for determination. That is, the marginal benefit ( $M B$ ) from a carefully thought-out decision (system 2) must be greater than the marginal cost (MC) of a carefully thought-out decision for it to be feasible for an individual to spend his or her energy. From the viewpoint of a consumer, the increase in expected marginal utility of a consumer choice must be greater than the expected marginal cost of energy from making a carefully thought-out decision. Imagine the choice between two products, a leading product, which the consumption of gives $u_{L}^{\prime}$ and carries the price $p_{L}$, and a follower product, with $u_{F}^{\prime}$ and price $p_{F}$, where $u_{L}^{\prime}-p_{L}>u_{F}^{\prime}-p_{F}$. Furthermore, assume that an unplanned decision leads to an equal chance of both products being chosen for consumption. That leads to

$$
M B=R_{L}^{\prime}-y=u_{L}^{\prime}-p_{L}-\frac{1}{2}\left(u_{L}^{\prime}-p_{L}+u_{F}^{\prime}-p_{F}\right) .
$$

Therefore, the marginal benefit of utilization of system 2 is that the system leads to the optimal good being chosen, a good that derives the residual marginal utility of $u_{L}^{\prime}-p_{L}$, instead of

[^7]system 1 , which depends on choosing a good from the product set, $I$, at random with equal probabilities. That leads to the $M B$ displayed above. The marginal cost, on the other hand, can be shown to be
$$
M C=P_{k W h} \times k W h_{N} .
$$

That is, the marginal cost following the utilization of system 2 is the cost of energy for information processing, $P_{k W h}$, and the quantity of energy needed for the information processing, $k W h_{N}$, multiplied. The SEMHB implies that an individual would always avoid making an educated, carefully thought-out decision unless $M B \geq M C$. The price-per-kilowatthour which leads to an individual being indifferent between choices, $P_{k W h}^{*}$, is then
(2.2.1. a) $\quad P_{k W h}^{*}=\frac{u_{L}^{\prime}-p_{L}-\frac{1}{2}\left(u_{L}^{\prime}-p_{L}+u_{F}^{\prime}-p_{F}\right)}{k W h_{N}}$.

Note the similarity between the result derived (2.2.1. a) and result (4) derived in chapter 2.2.

$$
\begin{equation*}
\phi^{*}=\frac{\max \left\{R^{\prime}(I)\right\}-y}{f}=\frac{u_{L}^{\prime}-p_{L}-\frac{1}{2}\left(u_{L}^{\prime}-p_{L}+u_{F}^{\prime}-p_{F}\right)}{f} . \tag{4}
\end{equation*}
$$

One can therefore, in this context, imagine $\phi$ as the price per kilowatt-hour, $P_{k W h}$, and $f$ as kilowatt-hours needed, $k W h_{N}$, to make an educated, carefully thought-out decision (system 2). Moreover, given that price-per-kilowatt-hour is assumed to be related to one's income, an avid reader might notice that the model leads to the implication that one can expect great differences in the decision-making mechanism of individuals - based on their income - but this assumption is merely made for this specific case and therefore does not hold for any other application of the model in this thesis. It is easy to show that, on average, the probability that the leading product is chosen equals the probability that system 2 is utilized plus the probability that system 1 is utilized, multiplied with the probability that system 1 leads to purchase of the leading product, or

$$
\rho_{L}=\operatorname{Pr}\left(P_{k W h} \leq P_{k W h}^{*}\right)+\frac{1}{2} \operatorname{Pr}\left(P_{k W h}>P_{k W h}^{*}\right),
$$

Where $\rho_{L}$ denotes the probability that product $L$ is purchased by a consumer. Furthermore, it is possible to show that if a total of $k$ products are purchased, where $k$ denotes a value large enough so that the law of large numbers holds, of them

$$
q_{L}=k\left[\operatorname{Pr}\left(P_{k W h} \leq P_{k W h}^{*}\right)+\frac{1}{2} \operatorname{Pr}\left(P_{k W h}>P_{k W h}^{*}\right)\right], \text { will be the leading product. }
$$

Lastly, one can assume symmetry to derive exactly the same results that are used in the paper. So, to conclude, the model is theoretically based on the standard model of economic behavior and dual-process theory, it assumes the exogenous constraints of energy and/or time, requires that the law of large numbers holds, assumes continuous probability density, and, for convenience, assumes that the energy-saving mechanism that individuals use is random-choice of equal probability.

### 2.2.2. A Specific Example - Constant Probability Density

Perhaps the simplest way to demonstrate the model itself is by analyzing consumer behavior in a market with two products and the case where the distribution of the populations' information processing cost is constant. Assume that the consumers' information processing cost distribution is the constant $\operatorname{Pr}(\phi)=\frac{1}{5}$. Therefore, $\mathbb{F}=\frac{\phi}{5}$ where $\underline{\phi}=0$ and $\bar{\phi}=5$. Assume that information gathering quantity needed is determined by

$$
f:=\frac{1}{u_{L}^{\prime}-P_{L}-\left(u_{F}^{\prime}-P_{F}\right)} .
$$

Furthermore, assume that $u_{1}^{\prime}=3, u_{2}^{\prime}=2, P_{1}=P_{2}=1$. Product 1 is, therefore, the leading product $\left(R_{1}^{\prime}>R_{2}^{\prime}\right)$, hence, given that $R_{1}^{\prime}>R_{2}^{\prime}$ holds, $u_{1}^{\prime}=u_{L}^{\prime}, P_{1}=P_{L}, u_{2}^{\prime}=u_{F}^{\prime}$ and $P_{2}=P_{F}$. With that information, result (2) from chapter 2.2 leads to $y=\frac{3}{2}$. Moreover, given the assumed values and the nature of the function which determines the information gathering quantity needed, it is possible to derive $f=\frac{1}{3-1-(2-1)}=\frac{1}{3-2}=1$. Result (4) from chapter 2.2 leads to

$$
\phi^{*}=\frac{u_{L}^{\prime}-P_{L}-y}{f}=\frac{3-1-\frac{3}{2}}{1}=\frac{1}{2} .
$$

That implies that all consumers with a value of $\phi$ equal to or less than $\frac{1}{2}$ will collect information and utilize system 2, which leads to the purchase of the product which maximizes $R^{\prime}$. All consumers with $\phi>\frac{1}{2}$ will utilize system 1 and choose products at random with equal probabilities. Given the assumed distribution, only $10 \%$ of consumers will inform themselves and choose products based on the standard model of economic behavior (system 2), assuming that the law of large numbers holds, the rest will choose products at random (system 1) which leads to an expected market share of the leading product of $55 \%$. If the expected marginal utility of product 1 would increase to, for example, $u_{1}^{\prime}=4.8$, the same results as used above allow us to compute $\phi^{*}$ again. In this case, $y=\frac{1}{2}(4.8-1+2-1)=2.4, f=\frac{1}{2.8}$ and $\phi^{*}=$
$\frac{4.8-1-2.4}{1 / 2.8}=3.92$. From there it is possible to derive from the cumulative distribution that $\frac{3.92}{5}$ share of consumers will then inform themselves, or around $78.4 \%$ of consumers, and the leading product (product 1 ) will attain a market share of $78.4 \%+\frac{1}{2}(1-78.4 \%)=89.2 \%$. Note that $u_{i}^{\prime}$ equals the expected marginal utility gained from the purchase of product $i$ not the realized marginal utility gained. The model is able to predict and plot the market share of the product 1 , given any price, $P_{1}$, by using the following correspondence
(2.2.2.a) $\frac{q_{1}\left(P_{1} ; P_{2}, u_{1}^{\prime}, u_{2}^{\prime}\right)}{Q}=\left\{\begin{array}{l}\frac{q_{1}}{Q}=\frac{q_{L}}{Q} \text { if }\left\{P_{1} \in \mathbb{R}: R_{1}^{\prime}>R_{2}^{\prime}\right\} \\ \frac{q_{1}}{Q}=\frac{1}{2} \text { if }\left\{P_{1} \in \mathbb{R}: R_{1}^{\prime}=R_{2}^{\prime}\right\} . \\ \frac{q_{1}}{Q}=\frac{q_{F}}{Q} \text { if }\left\{P_{1} \in \mathbb{R}: R_{1}^{\prime}<R_{2}^{\prime}\right\}\end{array}\right.$.

The correspondence (2.2.2.a) states that the market share of the product abides by rules (7), developed in chapter 2.2. The rules are stated below
(7. a) $\frac{q_{L}}{Q}=\mathbb{F}\left(\phi^{*}\right)\left(1-\frac{1}{|I|}\right)+\frac{1}{|I|}$.

This rule holds as long as the product remains the leading product, that is, as long as the product remains the product that a Homo Economicus consumer should choose (as long as $R_{1}^{\prime}>R_{2}^{\prime}$ ). Secondly, as the price of the product 1 increases, or its utility decreases, both products should at one point become equivalently benefitting options in the eyes of the consumer. That occurs when the residual marginal benefits of both options are equal, $\left(R_{1}^{\prime}=R_{2}^{\prime}\right)$. In that case, the consumer should be unable to distinguish between them and should choose randomly. Lastly, the correspondence states that if the price of product 1 becomes too high, or its utility becomes too low, it becomes a follower good, and its market share follows rule (7.b).
(7.b) $\frac{q_{F}}{Q}=1-\frac{1}{|I|}-\mathbb{F}\left(\phi^{*}\right)\left(1-\frac{1}{|I|}\right)$.

The correspondence allows for the graphing of the market share of good 1 , given any values of $P_{1}$, or $u_{1}^{\prime}$. The two cases will be analyzed, where $u_{1}^{\prime}=3, u_{2}^{\prime}=2, P_{2}=1$, and $f$ is assumed to be a fixed value of 1 . Afterwards, the case where $u_{1}^{\prime}=5, u_{2}^{\prime}=2, P_{2}=1$ and $f$ is assumed to be determined by the following rule

$$
f:=\frac{1}{u_{L}^{\prime}-P_{L}-\left(u_{F}^{\prime}-P_{F}\right)} \text {, will be analyzed. }
$$

The two different cases will assume the same, constant information processing cost distribution of $\operatorname{Pr} \phi=\frac{1}{5}$, where $\underline{\phi}=0$, and $\bar{\phi}=5$. Given the values in the former case, it is possible to
calculate the value of the information processing cost which makes an individual indifferent between system 1 and system 2 , which can be seen in result (4) from chapter 2.2.

$$
\phi^{*}=\frac{u_{L}^{\prime}-P_{L}-y}{f}=1-\frac{P_{L}}{2} .
$$

Graph 4: Market share of product 1, given constant distribution of $\boldsymbol{\phi}$ and a fixed value of $\boldsymbol{f}$.


Furthermore, given the values, it is possible to see that $R_{1}^{\prime}>R_{2}^{\prime}$ as long as $P_{1}<2$. Therefore, it is possible to see that as long as $P_{1} \geq 2$, the good is not a leading good, in that case, the market demand follows rules $\frac{q_{1}}{Q} \in \frac{1}{2}$ and (7.b) from the correspondence.

The linear relationship between market share and price is linear (see graph 4) is caused by both the distribution of $\phi$ being constant and the value of $f$ being fixed. If the latter case is plotted, (see graph 5 ), and compared to graph 4 , it is possible to see the effect varying values of $f$ has on the nature of the market share w.r.t. price of product 1 . If $f$ is assumed to follow the rule displayed above, it is possible to calculate the value of the information processing cost which makes an individual indifferent between systems

$$
\phi^{*}=\frac{u_{L}^{\prime}-P_{L}-y}{f}=\left(u_{L}^{\prime}-P_{L}-y\right)\left(u_{L}^{\prime}-P_{L}-\left(u_{F}^{\prime}-P_{F}\right)\right)=\frac{\left(P_{L}-4\right)^{2}}{2} .
$$

Where $P_{L}$ denotes the price of the leading product, which can be either product 1 or 2 , depending on their values of $R^{\prime}$. Note that an increase in value of $P_{1}$, which equals $P_{L}$ until a price of 4 is reached (since $R_{1}^{\prime}>R_{2}^{\prime}$ ) leads to a decrease in $\phi^{*}$ until $P_{1}$ reaches a value of 4 where both products become indistinguishable in the eyes of the consumer. As $P_{1}$ reaches the value of $4, \phi^{*}$ will equal 0 . A value of $\phi^{*}=0$ simply states that if a consumer experiences any psychic cost or energy loss when processing information, the consumer should prefer system 1. Furthermore, if the price of $P_{1}>4$, the value of $\phi^{*}$ begins to climb again, which states that consumers will have an easier time distinguishing between the goods. Given varying values of $f$, the market share, again, needs to be calculated by use of the rules highlighted by correspondence (2.2.2. a).

Graph 5: Market share of product 1, given constant distribution of $\phi$ and a varying value of $\boldsymbol{f}$.


Graph 5 displays the predicted market share of product 1 , given that the distribution of the populations' information processing cost, $\phi$, is constant, and if the value of $f$ increases as product options' residual marginal utility becomes similar and decreases as their expected residual marginal utility becomes more dissimilar, that is if the value of $f$ abides by the following rule $\frac{\Delta f}{\Delta d\left(R_{L}^{\prime}, R_{F}^{\prime}\right)}<0$, where $d: \mathbb{R} \rightarrow \mathbb{R}$ is a function which maps the distance between the two values. Allowing for varying levels of $f$ introduces curvature into the plot and leads to varying price sensitivity of consumers given different prices of product 1 . That is, given that the value of $f$ varies, consumers become relatively insensitive to changes in price of product 1 if the goods are similar in how much residual marginal utility they derive. Furthermore, it is possible to show that even with varying slope of the marginal demand function, the price elasticity of demand for product 1 increases as its price increases. To show the different price elasticities of demand, given different pricing, choose three different starting values of $P_{1}$ and estimate the values of $\eta$ given an increment in $P_{1}$ by 1 unit from the starting point denoted in the subscript

$$
\begin{aligned}
& \eta_{P_{1}=1} \approx \frac{\frac{0.7 Q-0.95 Q}{0.95 Q}}{\frac{2-1}{1}} \approx-0.26, \\
& \eta_{P_{1}=3} \approx \frac{\frac{0.5 Q}{1} 0.55 Q}{\frac{0.5 Q}{3}} \approx-0.273, \text { and } \\
& \eta_{P_{1}=5} \approx \frac{\frac{0.3 Q}{3}}{\frac{0.45 Q}{6-5}} \frac{\frac{0-5}{5}}{} \approx-1.67 .
\end{aligned}
$$

Therefore, given the specific cases above the model predicts that the price elasticity of demand for product 1 rises ${ }^{12}$ with regards to increases in the price of product 1 . Later in this thesis, it will be shown that the factors that affect the curvature and price sensitivity of the market share of product 1 with regards to changes in price are the nature of the distribution of the consumers' information processing cost, $\phi$, and the average value of $\phi$ relative to the markets' price level, and the variation of the value $f$, dependent on $P_{1}, P_{2}, u^{\prime}{ }_{1}$, and $u^{\prime}{ }_{2}$.

[^8]
### 2.2.3. A Specific Example - Gaussian Normal Distribution

Perhaps a more realistic population distribution might be the Gaussian normal distribution. It is possible to show that the model can equally be utilized for analysis in the case of Gaussian normal distribution. To simplify, features of the distribution such as skew, variance and kurtosis will be omitted. For simplicity, evaluate the expected marginal consumption utility as the linear function

$$
U_{c}^{\prime} \approx u_{1}^{\prime} \Delta x_{1}+u_{2}^{\prime} \Delta x_{2} .
$$

Since the model aims to evaluate decision making at the margin $\Delta x_{1}+\Delta x_{2}=1$ where

$$
\mathrm{x}_{1}:=\text { quantity consumed of product } 1, \mathrm{x}_{2}:=\text { quantity consumed of product } 2 .
$$

Consumers attempt to maximize $R_{i}^{\prime}=u_{i}^{\prime}-P_{i}$, for $i \in\{1,2\}$ where

$$
P_{1}:=\text { price of product } 1, \text { and } P_{2}:=\text { price of product } 2 .
$$

Consumers can choose between system 1 and system 2 . The model assumes that the evaluation of options imposes costs that increase with increased similarity of product choices. That leads to the following decision rule. The consumer always chooses products at random (system 1) unless

$$
\text { (1.c.) } \max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}-\phi f \geq \frac{1}{2} \sum_{i=1}^{2} R_{i}^{\prime} \text { where } R_{i}^{\prime}=u_{i}^{\prime}-P_{i} \text {. }
$$

Again, it is possible to state a specific case of the function $f$ as

$$
f:=\frac{1}{\max \left(R_{1}^{\prime}, R_{2}^{\prime}\right\}-\min \left\{R_{1}^{\prime}, R_{2}^{\prime}\right)_{2}^{\prime}}
$$

If $\phi^{*}$ is defined as the maximum amount of $\phi$ so that the consumer is indifferent between choices. $\phi^{*}$ is, therefore, the exact value of $\phi$ such that the right-hand side and the left-hand side of equation (1.c) become equal, which leads to the following outcome

$$
\max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}-\frac{\phi^{*}}{\max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}-\min \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}}=\frac{1}{2} \sum_{i=1}^{2} R_{i}^{\prime} .
$$

It is possible to solve for $\phi^{*}$

$$
\phi^{*}=\left(\max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}-\min \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}\right)\left(\max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}-\frac{1}{2} \sum_{i=1}^{2} R_{i}^{\prime}\right) .
$$

It is apparent that the complexity and the length of the analysis tends to become tedious as the cardinality of the product class $I$ of comparable products increases. However, since $L$ is defined as the leading product and $F$ as the follower product, the $\phi^{*}$ can be simplified considerably
$\phi^{*}=\left(\max \left\{R_{L}^{\prime}, R_{F}^{\prime}\right\}-\min \left\{R_{L}^{\prime}, R_{F}^{\prime}\right\}\right)\left(\max \left\{R_{L}^{\prime}, R_{F}^{\prime}\right\}-\frac{1}{2} \sum_{i=1}^{2} R_{i}^{\prime}\right)=\left(R_{L}^{\prime}-R_{F}^{\prime}\right)\left(R_{L}^{\prime}-\frac{1}{2}\left(R_{L}^{\prime}+R_{F}^{\prime}\right)\right)$.
This simplification is possible given that the analysis is only based on a market with two products. Given $R_{L}^{\prime}:=\max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}$ and $R_{F}^{\prime} \neq \max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}$ is possible to take the following simplifying steps.

$$
\begin{aligned}
& \phi^{*}=\left(R_{L}^{\prime}-R_{F}^{\prime}\right)\left(R_{L}^{\prime}-\frac{1}{2}\left(R_{L}^{\prime}+R_{F}^{\prime}\right)\right), \text { which is possible to further simplify into } \\
& \phi^{*}=\left(R_{L}^{\prime}-R_{F}^{\prime}\right)\left(\frac{1}{2} R_{L}^{\prime}-\frac{1}{2} R_{F}^{\prime}\right)=\frac{1}{2}\left(R_{L}^{\prime}-R_{F}^{\prime}\right)^{2} .
\end{aligned}
$$

Interestingly, the following equality must also hold in the case of a leading product

$$
R_{L}^{\prime}=\sqrt{2 \phi^{*}}+R_{F}^{\prime} .
$$

The relative demand for the leading product can be determined by
(2.2.3. a) $\quad q_{L}=Q\left(\int_{-\infty}^{\frac{1}{2}\left(R_{L}^{\prime}-R_{F}^{\prime}\right)^{2}} \operatorname{Pr}(\phi) d \phi+\frac{1}{2} \int_{\frac{1}{2}\left(R_{L}^{\prime}-R_{F}^{\prime}\right)^{2}}^{\infty} \operatorname{Pr}(\phi) d \phi\right)$.

Given that $R_{i}^{\prime}=u_{i}^{\prime}-P_{i}$. For example, if assumed that $u_{1}^{\prime}=3, u_{2}^{\prime}=2, P_{1}=P_{2}=1$. If further assumed the Gaussian normal distribution $\operatorname{Pr}(\phi)=\frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}}$. The probability that the leading product is purchased $q_{L} / Q$ equals $\approx 84.6 \%$. That is due to the fact that the probability density function (PDF) implies that there is $\approx 69.1 \%$ chance that the interest level, $\phi$, is lower than (or equal to) $\phi^{*}$. In all such cases, the consumer chooses the leading, consumption utility maximizing product. However, the PDF also states that there is around $30.9 \%$ chance that the consumer will utilize system 1 and choose at random with equal probability (see appendix B for a step-by-step derivation). Thus, the expected leading products' share of the market should approximately equal $84.6 \%$, in this case, the leading good is product 1 since $R_{1}^{\prime}>R_{2}^{\prime}$.

This further allows for the evaluation of the sensitivity to changes in the price of the leading good. Note that the definition of a leading good demands that the price of product 1 is strictly less than 2 in this example so $P_{1}<2$. If $P_{1} \geq 2$, the good becomes a follower brand, for which case, the consumer should then prefer product 2 and product 1's demand should be transposed. The function (see graph 6) can be drafted by plotting the values of the function $\frac{q_{1}}{Q}$, derived in (2.2.3. a) subject to different values of $P_{1}$, holding other factors constant. Therefore, the plot demonstrates $\frac{q_{1}\left(P_{1} ; P_{2}, u_{1}^{\prime}, u_{2}^{\prime}\right)}{Q}$, where $\operatorname{Pr}(\phi)=\frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}}$.

The same applies as before: For all values of $P_{1}>2, R_{1}^{\prime} \neq \max \left\{R_{1}^{\prime}, R_{2}^{\prime}\right\}$, hence, for all values

Graph 6: Leading products' share of market demand, if average $\phi=0$, as a function of price.


Graph 7: Leading products' share of market demand, if average $\phi=2$, as a function of price.
 $P_{1}>2$, the brand is a follower brand. The same rule applies in this case as in former cases since the value of $f$ is assumed to vary given different values of $R_{1}^{\prime}$ and $R_{2}^{\prime}$. That leads to the conclusion that correspondence (2.2.2.a) and result (2.2.3.a) divided by $Q$ allow for the plotting of both functions displayed in graphs 6 and 7. Similarly to the example in subchapter 2.2.2., at $P_{L}=2$, the two products are equal and the information gathering converges to $\infty$. Thus, the person is expected to choose at random. However, a Gaussian (normal) distribution with an average $\phi$ of zero leads to around $50 \%$ chance that a consumer experiences the information processing costs $\phi<0$, which would indicate that the individual would derive pleasure from processing the infinite amount of information needed for successful use of system 2, hence, the model implies that, in the case of an indistinguishable choice, such a person would live in a state of unending euphoria.

If the same example is analyzed, but where $\operatorname{Pr}(\phi)=\frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}}$ and $u_{1}^{\prime}=5$, which leads to a shift in the normal distribution from the standard distribution by 2 units ${ }^{13}$ (see graph 7), the discrepancy between the results becomes even more striking, since now the leading product derives even higher marginal utility than before. At lower prices, nearly everyone is willing to take on the costs associated with the collection and processing of information needed and choose the optimal product (system 2 ). However, as the distance between $R_{1}^{\prime}$ and $R_{2}^{\prime}$ decreases, following an increase in $P_{1}$, the individuals quickly begin to prefer system 1 , which is assumed

[^9]to be random choice of equal probabilities. In this case, around $2.3 \%$ of individuals exhibit $\phi<0$ which can be considered far more likely than in the case of the former example, therefore, the specific example where $\operatorname{Pr}(\phi)=\frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}}$ and $u_{1}^{\prime}=5$ will be used for further demonstrations of the model.

### 2.3. Utility

The model presents a result that tends to deviate from the one proposed by the traditional SEMHB. It is possible to apply information gathering and processing costs into the SEMHB by many means. However, the separation of utility into two types, consumer utility and total utility might be preferred, since both information gathering and processing costs are factors which do not directly affect consumption utility, rather encapsulate the total costs of the process. That is, total utility of the decision, purchase, and ultimately the consumption of the good does not equal the utility of solely consuming the good. Furthermore, doing so allows us to analyze better the differences in the predicted results, and their causes. As before, the expected marginal consumption utility function was determined as the linear function

$$
\begin{aligned}
& U_{C}^{\prime} \approx u_{1}^{\prime} \Delta x_{1}+u_{2}^{\prime} \Delta x_{2}, \text { where } \\
& x_{1}:=\text { quantity of product } 1, x_{2}:=\text { quantity of product } 2 .
\end{aligned}
$$

The optimal marginal total utility function must fulfill the following condition

$$
\text { (2.3. a) } \quad U_{T}^{\prime}=\max \left\{\max \left\{u_{1}^{\prime}, u_{2}^{\prime}\right\}-\phi f, \frac{1}{2}\left(u_{1}^{\prime}+u_{2}^{\prime}\right)\right\} .
$$

If the previous example for individual $j$ is continued where

$$
u_{j_{1}}^{\prime}=u_{j_{L}}^{\prime}=5, \phi_{j}=\text { average } \phi=2, u_{j_{2}}^{\prime}=u_{j_{F}}^{\prime}=2, P_{L}=P_{F}=1, f=\frac{1}{3} .
$$

Therefore, $R_{1}^{\prime}>R_{2}^{\prime}$ and product 2 is therefore a "lesser" follower good. If assumption is made that individual $j$ has the dedication to purchase a single unit, the expected change in his or her consumption utility can be determined as

$$
U_{j}{ }^{\prime}{ }_{C} \approx \Delta x_{2} u_{j_{2}}^{\prime}+\left(1-\Delta x_{2}\right) u_{j_{1}}^{\prime}, \text { where } \Delta x_{2} \in[0,1] .
$$

That allows the graphing of the expected marginal consumption utility function with regards to the likelihood of choice of a lesser good. The expected marginal consumption utility of individual $j$ with regards to the likelihood of choice of a lesser good is a linear, strictly decreasing function due to the linear nature of the specific example chosen. This function demonstrates the expected marginal consumer utility attained given the two choices.


Graph 8: Marginal utility as a function of the likelihood of the choice of a lesser good, in percentage.

As graph 8 demonstrates, the maximization of consumer utility is attained at $\Delta x_{F}=0$. However, in the case of marginal total utility, the following result can be demonstrated for individual $j$ in the case where $\phi_{j}=2$. Given the assumed example values, result (2.3.a) derives the value $U_{j_{T}}^{\prime}=\max \left\{\frac{13}{3}, \frac{7}{2}\right\}$. Therefore, the recursive relationship from result (1) in chapter 2.2. leads to the two set of coordinates in $\mathbb{R}^{2},\left(0, \frac{13}{3}\right)$ and $\left(\frac{1}{2}, \frac{7}{2}\right)$, where the former denotes the system 2 solution, and the latter denotes the system 1 solution ${ }^{14}$. The marginal total utility function always shares a coordinate with the marginal consumption utility function in the case of system 1 since assumed that the individual suffers no information gathering and processing costs when system 1 is utilized. In the case where $\phi_{j}=0$, both marginal utility functions should be congruent, and the individual would never be perceived to deviate from the behavior expected by the SEMHB. In the analyzed case where $\phi_{j}=2$, the individual is not expected to deviate from the SEMHB utility maximizing behavior, however, if the individuals' information processing cost would equal $\phi=6$, the individuals' decision deviates from the traditional SEMHB as the marginal utility functions become

$$
\begin{aligned}
U_{j_{C}}^{\prime} & \cong \Delta x_{2} u_{j_{2}}^{\prime}+\left(1-\Delta x_{2}\right) u_{j_{1}}^{\prime}, \text { and } \\
U_{j_{T}}^{\prime} & =\max \left\{3, \frac{7}{2}\right\}, \text { which maps the coordinates }(0,3) \text { and }\left(\frac{1}{2}, \frac{7}{2}\right) .
\end{aligned}
$$

Therefore, such an individual could be perceived to behave irrationally in cases where the random choice leads to the purchase of a lesser good, while the individual is, in fact, maximizing a different function. In the case where $\phi_{j}=6$, individual $j$ 's marginal choice of products would lead to a consumption utility loss from the optimal value of $\frac{3}{2}$ utils while, in fact, individual $j$ would experience a total utility loss of $\frac{1}{2}$ utils by maximizing his or her consumption utility. That is, the mental cost of $6 \times \frac{1}{3}=2$ leads to a net utility loss from the use of system 2 compared to the use of system 1 . The expected net loss of system 2 leads the individual to choose products at random (system 1). As individual $j$ utilizes his or her strategy

[^10]of choosing products at random, every instance where the lesser (follower) good is chosen would seem irrational to an examiner, even when the individual is in fact being perfectly rational and is simply maximizing a different function.

Graph 9: Marginal utility as a function of the likelihood of the choice of a lesser good, compared.


Continuing the example above, it is possible to show the effect the value of $\phi_{j}$ has on individual $j$ 's utility gained from the entirety of the process relating to the choice and ultimate consumption of the good as compared to the utility gained from just the consumption of the product. Graph 9 shows the predicted utility gained from the traditional SEMHB, as shown by the solid gray line. The dashed lines represent the effect different values of $\phi_{j}$ have on
individual $j$ 's utility gained from the utilization of system 2 and the consumption of the good, given that the utilization of system 2 requires that $f=\frac{1}{3}$ of units of information be processed. Both the SEMHB and the new model assume that the individual is hedonistic and therefore wishes to maximize his or her utility. The graph shows that at value $\phi_{j}=0$, the model cannot be distinguished from the traditional SEMHB. Furthermore, if the value of $\phi_{j}$ is negative, individual $j$ will gain surplus utility from the process, where he or she derives utility from the information gathering and processing. That is, if the individual experiences enjoyment from the collection and processing of information, his or her utility derived from the entire process will become greater than his or her utility derived from solely the consumption of the good. Conversely, if individual $j$ 's information processing cost equals $\phi_{j}=2$, the individual suffers disutility from the collection and processing of information, but not so much as to deincentivize him or her from utilizing system 2 , since the value $\frac{13}{3}$ remains greater than $\frac{7}{2}$. Lastly, if individual $j$ 's information processing cost equals $\phi_{j}=6$, the disutility suffered from the utilization of system 2 is great enough to de-incentivize him or her from utilizing system 2 . The individual would therefore prefer to utilize system 1 which leads to random choice of equal probabilities as depicted by the dot located in the coordinate $\left(\frac{1}{2}, \frac{7}{2}\right)$.

### 2.4. Model Generalized to Problem Solving \& Different Tactics

The decision-making model also has use in determining any agents' optimal decision when faced with a problem that can be solved using a specific solution or heuristics. It is possible to determine marginal residual utility, or benefit, from each solution as

$$
\begin{aligned}
& \text { marginal residual utility (specific) } R_{S}^{\prime}:=u_{S}^{\prime}-c_{S} \text {, and } \\
& \text { marginal residual utility (heuristic) } R_{H}^{\prime}:=u_{H}^{\prime}-c_{H} .
\end{aligned}
$$

That leads to the following optimal function $X$

$$
X=\max \left\{R_{H}^{\prime}, \max \left(R_{S}^{\prime}, R_{H}^{\prime}\right)-\phi f\right\} .
$$

Therefore, the following decision rule holds; the agent chooses to utilize heuristics unless

$$
\max \left(R_{S}^{\prime}, R_{H}^{\prime}\right)-\phi f \geq R_{H}^{\prime} .
$$

It is important to note a key difference between this approach and the previous. In this case, the individual is determining whether to search and find a specific solution to a given problem or to solve the problem with the aid of a simplified measure, heuristics, while the previous approach focused on the case where an individual decides between the utilization of system 2, which is assumed to be the SEMHB, or uses a fallback strategy, (system 1), assumed to be a single decision method based on random choice of equal probabilities. It is possible to once again define $\phi^{*}$ as the highest possible value of $\phi$ such that the agent is indifferent between choices

$$
\phi^{*}=\frac{\max \left(R_{S}^{\prime}, R_{H}^{\prime}\right)-R_{H}^{\prime}}{f} .
$$

It is, again, possible to determine that an individual will decide to solve the problem with the use of heuristics if $\phi>\phi^{*}$. Thus, high psychic information processing costs can be thought as one reason for why an individual might tend to live a "heuristic" lifestyle.

### 2.5. Firms and Markets

To be able to evaluate the models' market outcome predictions, supply-side analysis is also needed. This subchapter focuses on answering questions regarding firms' behavior, given that consumers tend to utilize system 1 or system 2. It is possible to use the specific, Gaussian (normal) distribution, cases of the model to analyze possible market outcomes if the supply behavior is further defined. If the market is characterized by two firms that operate under the
objective of profit maximization, and, for simplification, are assumed to exhibit no fixed costs and equal constant marginal costs of production, both profit functions can be defined as

$$
\Pi_{1}=P_{1} q_{1}\left(P_{1} ; P_{2}\right)-c q_{1}\left(P_{1} ; P_{2}\right), \text { and } \Pi_{2}=P_{2} q_{2}\left(P_{2} ; P_{1}\right)-c q_{2}\left(P_{2} ; P_{1}\right)
$$

If further assumed that the firms employ a price management strategy, firms' 1 profit is maximized when the first-order conditions of profit maximization are satisfied

$$
\frac{\delta \Pi_{1}}{\delta P_{1}}=0 \Rightarrow \frac{\delta q_{1}}{\delta P_{1}}\left(P_{1}-c\right)+q_{1}=0 . \text { Define } P_{1}^{*} \text { as the optimal price level which }
$$ maximizes firm 1 's profit. The outcome leads to $P_{1}^{*}=c-\frac{q_{1}}{q_{1}^{\prime}}$, where $q_{1}^{\prime}:=\frac{\delta q_{1}}{\delta P_{1}}$, such that the condition that $q_{1}^{\prime}<0$ must hold, therefore $P_{1}^{*}>c$. It is possible to estimate the firm 1's optimal $\operatorname{markup}\left(\frac{\%}{100}\right)$ as $\mu_{1}:=\frac{P_{1}^{*}-c}{c}=-\frac{1}{c} \frac{q_{1}}{q_{1}^{\prime}}$. Two cases are analyzed: the specific cases where $\operatorname{Pr}(\phi)=\frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}}, u_{1}^{\prime}=5, u_{2}^{\prime}=2, P_{2}=c=1$, and then $\operatorname{Pr}(\phi)=\frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}}$, where the average $\phi=0$. Firm 1's profit function w.r.t. $P_{1}$ can be mapped. The graphs on the left column represent firm 1's profit and market share (below) in a market where average $\phi=2$ and the right column represents the same in a market where the average $\phi=0$.

Graph 10: Firm 1's market share as a function of price if average $\phi=0$.


Graph 12: Firm 1's (relative) profit as a function of price if average $\phi=0$.


Graph 11: Firm 1's market share as a function of price if average $\phi=2$.


Graph 13: Firm 1's (relative) profit as a function of price if average $\phi=2$.


These results require that firms maximize profits by utilizing a price management strategy and that consumers make decisions according to the model derived in chapter 2.2. The differences
in the behavior of the expected profit functions (graphs 12 and 13), given different consumer interest levels, is caused by differences in the share of the consumer base that utilizes system 2. If the markets are enthusiastic ${ }^{15}$, a large share of the consumer base utilizes system 2 which leads to those consumers quickly moving away from a product that derives lesser (residual) benefit (see graph 10). Graphically, that indicates a large drop in market share if the price of the product 1 rises to the point that it becomes a purchase that derives lower residual marginal utility than good 2 . Conversely, in uninterested markets, a smaller share of consumers rejects the lesser good (see graph 11) and the drop at price level $P_{1}=4$ becomes significantly smaller. Therefore, the model implies that firms in a market where average $\phi=0$ might have an incentive "to take the lead" by developing the product so that consumers' marginal utility is maximized by the purchase of the firms' product and then capitalize on the lead by price adjustments. The opposite seems to be true for firms in uninterested markets ${ }^{16}$. The firm with the originally leading product has an incentive to raise prices to benefit from the originally high residual marginal utility and the bias introduced by consumer tendency to utilize system 1 . This allows for the speculation that markets with lower average $\phi$ should tend to have a strong leader firm and suppliers in such markets can be expected to compete by increasing marginal residual utility $R^{\prime}$, which can be done by raising either $u^{\prime}$ or lowering $P$, hence, spending more in product development than in uninterested markets. From now on, markets with low average $\phi$ shall be named "enthusiast markets" and markets with higher average $\phi$ shall be named uninterested markets for convenience.

Graph 14: Firm 1's market share as a function of $f$.


A graphical representation of the predicted market share of firm 1 given different values of $\boldsymbol{f}$ (see table in appendix C). Ceteris paribus, higher values of $f$ lowers firm 1's market share, but reduces firm 1's market share more in the case of uninterested markets than interested markets.

Furthermore, to fully analyze market outcomes and agent incentives, an analysis of $f$ is needed. The function $f$ is defined as a function that represents consumer information gathering needed to decipher the optimal basket, hence, the function can be viewed simply as a relative complexity measurement, as an increase in market - or product - complexity requires additional information gathering needed to deduce the optimal product. The function should be heavily influenced by product characteristics

[^11]and the number of brands available. Graph 14 displays the predicted effects of an increase in the value of $f$ on market share for a leading brand, where $P_{1}=P_{2}=c=1$ (see appendix C for a step-by-step derivation). This result indicates that follower firms on markets that are characterized by highly uninterested consumers might have a greater incentive to increase the overall complexity and difficulty of attaining information ( $f$ ) than markets that are characterized by enthusiastic consumers, where the follower firm gains considerable market share just by complicating the environment for the consumer. The opposite is true for leader firms, who might experience an increase in market share, and profits, solely by simplifying the topic. This marginal effect of simplification and amplification increases as average interest level decreases ( $\phi$ increases), as shown by graph 14, uninterested consumers are more easily swayed to utilize system 1 as perceived complexity increases than interested consumers, where utilization of system 1 tends to benefit following firms and utilization of system 2 tends to benefit the leading firm. The functions plotted in graph 14 are the following (also shown in detail in appendix C).
\[

$$
\begin{aligned}
& e(f)=\int_{-\infty}^{\frac{3}{2} f^{-1}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi+\frac{1}{2} \int_{\frac{3}{2}}^{\infty} f^{-1} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi, \text { and } \\
& u(f)=\int_{-\infty}^{\frac{3}{2} f^{-1}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}} d \phi+\frac{1}{2} \int_{\frac{3}{2}}^{\infty} f^{-1} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}} d \phi .
\end{aligned}
$$
\]

Where $e(f)$ denotes the "enthusiastic market" outcome, where the average $\phi=0$, and $u(f)$ denotes the "uninterested market" outcome, where the average $\phi=2$. From the differences in the nature of the plots, given the two different values of $\phi$, it is possible to hypothesize the nature of the changes in the leading firms' market share given any value of average $\phi$.

### 2.5.1. Model Predictions

The inclusion of psychic information processing costs $(\phi)$, information gathering $(f)$, and dual process theory into a single model based on the SEMHB implies the presence of and predicts the following

1. Consumers maximize total utility, not just consumption utility. Therefore, their decisions regarding product choices might, in some cases, seem irrational to the examiner due to the tendency to utilize system 1 .
2. Some markets experience a market failure caused by consumers' tendency to utilize system 1. The tendency is introduced by the aim to avoid information gathering and processing costs as a method to save resources, such as energy or time.

- $\quad$ The market failure should be least apparent in simple (low $f$ ) enthusiast markets (low average $\phi$ ).

3. Enthusiast markets (markets with low average $\phi$ ) are likely to be characterized by a strong leader and the opposite is true for uninterested markets that might be characterized by many suppliers and lower overall competitive levels. However, an increase in relative complexity diminishes the effect.
4. Suppliers in enthusiastic markets have an incentive to "take the lead" and compete by maximizing consumers' marginal residual utility, hence, the market is likely to be characterized by higher product development expenditures, lower margins, and overall competitiveness.
5. Suppliers in uninterested markets have an incentive to capitalize on the consumer tendency to utilize system 1 and overcharge consumers (optimal pricing might be larger than average $u^{\prime}$ ).
6. Follower firms in markets have an incentive to amplify perceived consumer complexity of the given topic while leader firms have an incentive to simplify. The incentives become stronger as average consumer interest level decreases (average $\phi$ increases).
7. The value of $f$ is crucial for the determination of the relevance of the SEMHB. Ceteris paribus, as $f$ increases, consumers will be more likely to apply system 1. Concurrently, as $f$ decreases, a larger share of consumers will apply the system $2-$ the SEMHB.
$\square$ The implication is that $f$ can greatly affect societal welfare, consumer behavior, and market outcomes.
$\square \quad$ The value of $f$ is largely determined by information accessibility and relative complexity of a given subject. Therefore, the model implies that information providers, such as Google, have an immense control of the market outcomes of various markets, and can greatly affect overall societal welfare in modern societies, for better or for worse.

## 3. Implications

"The brains of humans contain a mechanism that is designed to give priority to bad news." - Daniel Kahneman. The introduction of information processing costs $(\phi)$, information gathering ( $f$ ), and dual process theory into a single model has led to differing predictions on market outcomes based on the overall interest level of consumers. The model predicts that highly interested consumers lead to overall better market outcomes; higher competitive levels, and incentives for firms to implement product development and/or lower margins, given that the value of $f$ is relatively low. Conversely, the model predicts that uninterested consumers lead to worse market outcomes; lower competitive levels, and ultimately leads to dishonest tactics, such as overcharging consumers, being feasible for firms to apply.

On a similar note, the level of information gathering needed to make an optimal decision based on expectations $(f)$, leads to predictions regarding overall welfare of consumers and market outcomes where low access to information leads to $f$ being a high value which, ceteris paribus, leads to lower competitive levels and an outcome similar to the uninterested market outcome. On the contrary, easy access to information leads to $f$ being a low value which, ceteris paribus, leads to higher competitive levels. The relationship between relative values of $\phi, f$ and the predicted market outcomes can be mapped (table 4).

Table 2: Values of $\phi, f$, relative to $u^{\prime}$, and the predicted market outcomes.

| Relative value of $\phi$ | Relative value of $f$ | Predicted market outcome |
| :---: | :---: | :---: |
| High | High | Inefficient market |
| Low | High | Inefficient market |
| High | Low | Inefficient market |
| Low | Low | Efficient market |

As the table indicates, only one of four possible market outcomes can be deemed as efficient. Where, in this case, an efficient market outcome would be a market characterized by strong competition, high product development and/or lower margins and high overall consumer welfare. Furthermore, the table highlights the result that $f$ is also a necessary condition for markets to be efficient. That is, interested consumers with little to no access to information make similar choices as uninterested consumers, and uninterested consumers with access to abundance of information will nevertheless make suboptimal choices.

One of the main differences between $\phi$ and $f$ lies in the nature of the variables, where the value of $\phi$ resides within the consumer and, therefore, belongs to his or her preferences, persona, and constraints. Whereas $f$ is a value which represents the burden which falls on the consumer if
he or she determines to collect the information needed to make an optimal decision. The value of $f$ should ultimately be determined by both the quantity of information needed and the information accessibility. The quantity of information needed is determined by numerous factors, such as the characteristics of said product and its market environment while information accessibility is determined by the informational environment surrounding the particular consumer.

## 3.1. $T h e f$

The value of $f$ is one which can safely be assumed to have changed considerably in recent decades. Relatively recent developments in technology has given a large share of consumers access to information which was not readily available just few decades ago. Faced with the need to attain information, consumers can now use multiple platforms available to them and within few moments receive access to the information which they require to make an optimal decision - given that the information they receive is unbiased.

### 3.1.1. The Role of Consumer Information Providers

The demand for consumer information providers seems to be shifting away from entities, such as libraries and smaller independent information distributors ${ }^{17}$ to online platforms, such as Google, YouTube, Facebook, or Instagram, in tandem with technology advances. The platforms listed are all owned by two parent companies, Alphabet Inc., and Meta Platforms Inc. Each of these platforms has from hundreds of millions of users to billions of users. As of April 2021 Google is the world's largest platform with an estimated 4.3 billion users worldwide, making it the website with the highest traffic in the U.S., after YouTube, and Facebook (Walsh, 2021). Therefore, a large share of the world's consumer information supply is controlled by two publicly traded corporations.

The corporations can be assumed to operate with the intention of maximizing profits. The two corporations practice the same modus operandi - to give consumers information free of charge and receive all their income from other agents willing to pay for consumer information and/or consumer salience. As shown in appendix D, the model is able to predict that the current market structure incentivizes these information providers to not act in the best interest of their

[^12]consumers, rather the interest of other, paying agents, which might lead to a considerable consumer welfare loss.

When the actions of these corporations are reviewed in this context, their incentives become relatively clear. Since Q2, 2017 Alphabet Inc. has been accused and/or pinched for

- Illegal tracking of online traffic (BBC News, 2020).
- Abusing its market dominance by manipulating search engine results to favor its own shopping services (Boffey, 2017).
- Breaking data protection rules (Fox, 2019).
- Failing to adhere to licensing deals with publishers and news agencies (Browne, 2021).
- Violating children's privacy on YouTube (Singer \& Conger, 2019).
- Invading the privacy of millions of Google Chrome users (Stempel, 2020), and more.

A similar story can be found when Meta Platforms Inc. is analyzed. Recent history seems to imply that there might exist a principal-agent problem, where the corporations do not share their users' interests. If so, the corporations might actively be selling market power, and consumer welfare, to the highest bidder.

## 4. Closing Statements

The standard economic model of human behavior has been tested ever since its inception. Its predictions have been compared to real world outcomes and the model has often predicted outcomes which do not correspond to the outcomes which are then realized. Behavioral economists believe that the models' tendency for error is largely caused by its assumptions. Among those are the assumptions that each actor possesses unbounded rationality, unbounded willpower, and unbounded selfishness.

The model developed in this thesis attempts to unite elements, such as information gathering, information processing costs, and dual process theory to the traditional standard economic model. It does so by assuming that each decision is based on two steps, where in the first step, the individual utilizes SEMHB to determine which system will be used for the ultimate decision, and in the second step, utilizes the chosen system. The addition of these elements to the standard model leads to considerably different predictions and allows for outcomes which might seem irrational by an examiner. Acts, such as choosing a product, in a set of products, which is strictly dominated by another, or failure at inferring transitive relations, can all be explained by the individual utilizing system 1 . Therefore, the model allows for irrational outcomes without allowing for irrational behavior. The model states that an actor does not behave irrationally when he or she chooses system 1. It is merely an act of saving constrained resources, such as energy and/or time, as their costs tend to become larger than the marginal benefit of utilizing the perfectly rational system 2 .

The model predicts contrasting market outcomes based on the values of both information gathering, and information processing costs. Out of the four possible market outcomes, only one is deemed efficient ${ }^{18}$. The model predicts, therefore, that many markets experience failures as considerable share of individuals might utilize system 1 . The tendency to utilize system 1 is caused by either too high information processing costs, or lack of access to information.

Furthermore, the model highlights the importance of both information gathering and information processing costs for consumer welfare, where information processing costs are related to individual preferences, persona, and their constraints, while information gathering is

[^13]related to information accessibility. Both of these variables are related to constraints experienced on the individual level due to nature or environment, such as of energy and time. Currently, most individuals can access almost any information needed to be able to derive the optimal good within few moments. These services are offered free to the consumer by two corporations, Alphabet Inc., and Meta Platforms Inc. where the corporations' modus operandi is to service a large share of the populace, collect their personal information to be sold to other economic agents, and to sell other economic agents the ability to increase their brands' salience. The model predicts that the structure of the market allows for principal-agent problems to arise, where the corporations which offer the services to the populace do not share their users' interests, rather the interests of economic agents who wish to gain market power. If so, the corporations might ultimately be selling market power, and consumer welfare, to the highest bidder.

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## Appendix A - Weitzman's model (1979)

A certain result developed in Martin L. Weitzman's thesis on the model of optimal search for the best alternative, commonly known as the Pandora's problem, inspired the creation of the mathematical model developed in this thesis. Weitzman based his thesis on the creation of a decision-making model where an agent decides between accepting the rewards already gained, $y$, or to keep searching for a higher reward. The search, which he describes visually as opening boxes, leads to the cost $c$ for each box that is opened and a reward which is determined by a probability distribution which the agent knows beforehand. As Weitzman guides the reader through the steps necessary to develop the model, he developed the following expected present discounted value of following an optimal policy, $\Psi$, where its value is determined as follows,

$$
\Psi(\bar{S}, y)=\max \left\{y, \max _{i \in S}\left\{-c_{i}+\beta_{i}\left[\Psi(\bar{S}-\{i\}, y) \int_{-\infty}^{y} d F_{i}\left(x_{i}\right)+\int_{y}^{\infty} \Psi\left(\bar{S}-\{i\}, x_{i}\right) d F_{i}\left(x_{i}\right)\right]\right\}\right\} .
$$

Where, as before, $y$ denotes the highest already sampled reward, $c_{i}$ denotes the cost of opening box $i$, and $\beta_{i}$ denotes the discount factor of the expected value gained from opening a new box. The expected value gained from opening a new box is determined by the following,

$$
\Psi(\bar{S}-\{i\}, y) \int_{-\infty}^{y} d F_{i}\left(x_{i}\right)+\int_{y}^{\infty} \Psi\left(\bar{S}-\{i\}, x_{i}\right) d F_{i}\left(x_{i}\right) .
$$

Where $\Psi(\bar{S}-\{i\}, y)$ denotes the expected reward "gained" from opening a box, from the set of boxes which are unopened, which has a lower value than $y$, in which case, Pandora is expected to rather choose a reward from a former box, which has value of $y$. Conversely, $\Psi\left(\bar{S}-\{i\}, x_{i}\right)$ represents the expected net benefit of all boxes which contain a higher reward, and, as before, $F_{i}$ denotes the probability distribution of the rewards within the set of boxes.

This result became the basis for the model developed in this thesis, where result (1) in subchapter 2.2., which is restated below,

$$
X_{j}=\max \left\{y_{j}, \max R_{j}^{\prime}(I)-\phi_{j} f\right\},
$$

Is based on the same expected value of following an optimal policy, where an individual, at every margin, determines between system 1 , which leads to expected utility of $y_{j}$, or system 2 , which leads to expected utility of $\max R_{j}^{\prime}(I)-\phi_{j} f$. This particular result is critical for the development of the rest of the model.

## Appendix B - Step-by-Step Derivation of Example 2.2.3.

A market is characterized by two products in the supply pool, a leading product, which is the product which maximizes consumers' residual marginal utility, and a follower product, which is the product that does not maximize consumers' residual marginal utility ${ }^{19}$. Assume that the marginal utility gained from the purchase of the leading product is $u_{1}^{\prime}=3$, and that the leading product is sold at a price of $P_{1}=1$. Assume that the marginal utility gained from the purchase of the follower product is $u_{2}^{\prime}=2$, and that it is sold at a price of $P_{2}=1$. That leads to

$$
R_{1}^{\prime}=2, R_{2}^{\prime}=1
$$

Which implies that a perfectly rational individual ${ }^{20}$ should always prefer product 1 over product 2. Assume symmetry. The model states that the market share of the leading product should therefore be $\frac{q_{L}}{Q}$. Utilizing results (5) and (8) in chapter 2.2. leads to

$$
\frac{q_{L}}{Q}=\int_{-\infty}^{\frac{1}{2} \times\left[u_{1}^{\prime}-P_{1}-\left(u_{2}^{\prime}-P_{2}\right)\right]^{2}} \operatorname{Pr}(\phi) d \phi+\frac{1}{2} \int_{\frac{1}{2} \times\left[u_{1}^{\prime}-P_{1}-\left(u_{2}^{\prime}-P_{2}\right)\right]^{2}}^{\infty} \operatorname{Pr}(\phi) d \phi .
$$

Which, given the assumed values, leads to

$$
\frac{q_{L}}{Q}=\int_{-\infty}^{\frac{1}{2}} \operatorname{Pr}(\phi) d \phi+\frac{1}{2} \int_{\frac{1}{2}}^{\infty} \operatorname{Pr}(\phi) d \phi
$$

To calculate the market share in $\left(\frac{\%}{100}\right)$, an assumption of the distribution of $\phi$ is needed. Assume the standardized Gaussian normal distribution $\operatorname{Pr}(\phi)=\frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}}$. The probability that the leading product is purchased $q_{L} / Q$ then equals

$$
\frac{q_{L}}{Q}=\int_{-\infty}^{\frac{1}{2}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi+\frac{1}{2} \int_{\frac{1}{2}}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi \approx 0.846 .
$$

That is, the model implies that the likelihood that system 2 is used, in which case, the leading product (product 1 ) will always be chosen is

$$
\int_{-\infty}^{\frac{1}{2}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi=0.691 .
$$

[^14]The model furthermore assumes that the likelihood that system 1 is used, in which case the products will be chosen at random, with equal probabilities (which, in the case of two products amounts to $50 \%$ probability of either product being chosen), is

$$
\frac{1}{2} \int_{\frac{1}{2}}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi=0.154
$$

The model implies that the likelihood that system 1 is used is $30.9 \%$, in which case, the leading product will be chosen at random, with a probability of $50 \%$ each time. That leads to an estimated market share of $0.691+\frac{1}{2} \times 0.309=0.846$ or $84.6 \%$.

## Appendix C - Step-by-Step Derivation of Market Share as a Function of $f$

It is possible to solve result (5) for $f$ to show the effects of information gathering on the market share of the leading firm. The graph examines the effects of $f$ on both uninterested markets (markets assumed in this case to have an average $\phi=2$ ) and enthusiastic markets (markets assumed to have an average $\phi=0$ ). Assume that $u_{1}^{\prime}=5, u_{2}^{\prime}=2, P_{1}=P_{2}=1$. Furthermore, assume the same Gaussian distribution for both markets, where the uninterested market has a distribution centered around the value $\phi=2$, such that $\frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}}$ in the case of an uninterested market, and the standardized normal distribution of $\frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}}$ in the case of an enthusiastic market. In both cases, the distribution states that $\inf \phi=-\infty$, and $\sup \phi=\infty$. Which leads to the function $e(f)$ in the case of enthusiastic markets

Which can be reduced to

$$
e(f)=\int_{-\infty}^{\frac{3}{2} f^{-1}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi+\frac{1}{2} \int_{\frac{3}{2} f f^{-1}}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi, \text { given the specific values. }
$$

The same leads to the following function $u(f)$ in the case of uninterested markets

$$
u(f)=\int_{-\infty}^{\frac{3}{2} f^{-1}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}} d \phi+\frac{1}{2} \int_{\frac{3}{2}}^{\infty} f^{-1} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-2)^{2}}{2}} d \phi
$$

From there, it is possible to create a table displaying predicted market shares, given specific values of $f$.

Table 3: The predicted market share of both markets, given specific values of $f$.

| $\boldsymbol{f}$ | $\boldsymbol{e}(\boldsymbol{f})$ | $\boldsymbol{u}(\boldsymbol{f})$ |
| :---: | :---: | :---: |
| 0.01 | 1 | 1 |
| $1 / 2$ | .999 | .921 |
| $3 / 4$ | .989 | .75 |
| 1 | .967 | .654 |
| 2 | .887 | .553 |
| 4 | .823 | .526 |
| 5 | .809 | .522 |

The table highlights the differences between markets. As information gathering increases, uninterested markets quickly turn to system 1 as primary tactic, and the leading firms' market share converges to $50 \%$, while enthusiastic markets still utilize system 2 as a primary tactic. Given the distributions, the enthusiastic market should converge to a market share of $75 \%$ as information gathering increases. $50 \%$ of enthusiasts experience no or negative information processing costs - in all such cases, they will prefer the leading product, the rest will choose at random, which leads to a convergence point of $.5+\frac{1}{2} \times .5=.75$.

## Appendix D - Information Providers: A Principal-Agent Problem

 ExampleInformation providers can lead to biased market outcomes by two means; either by releasing information to consumers which affects $u^{\prime}$ where $u^{\prime}$ denotes the expected marginal utility of consuming the brands, or by actively affecting the visibility of certain brands. Let's continue with an example similar to example 2.3.3 and analyze the predicted effects of doing so in the case of two different markets, an enthusiastic market $e$, and an uninterested market, $u$, where average $\phi_{u}=3$, and average $\phi_{e}=0$. Assume that there are two firms competing in both markets, firm $L$, and firm $F$, where

$$
u_{L}^{\prime}=5, u_{F}^{\prime}=2, P_{L}=P_{F}=1 . \text { Therefore, } R_{L}^{\prime}=4, \text { and } R_{F}^{\prime}=1 .
$$

The difference between the residual marginal utilities of product $L$ and product $F$ highlight the immense benefit for consumers to purchase product $L$ over $F$. Let's further assume that information is relatively accessible, thanks to a search engine, which operates under profit maximization with a modus operandi of providing free information and receiving ad revenue
from the competing firms. Under normal circumstances, the market share $\left(\frac{\%}{100}\right)$ of firm $L$ in the enthusiastic market should be

$$
\frac{q_{L_{e}}}{Q_{e}}=\int_{-\infty}^{\frac{3}{2} f^{-1}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi+\frac{1}{2} \int_{\frac{3}{2} f f^{-1}}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi .
$$

While the market share of firm $L$ in the uninterested market should be

$$
\frac{q_{L_{u}}}{Q_{u}}=\int_{-\infty}^{\frac{3}{2} f^{-1}} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-3)^{2}}{2}} d \phi+\frac{1}{2} \int_{\frac{3}{2} f-1}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-3)^{2}}{2}} d \phi .
$$

Let's assume that thanks to the search engine, information is easily accessible, and $f=\frac{1}{3}$. The predicted market share, if consumers in both markets receive unbiased results, is

$$
\frac{q_{L_{e}}}{Q_{e}}=\int_{-\infty}^{9 / 2} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi+\frac{1}{2} \int_{9 / 2}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi \approx 1
$$

which means that practically every consumer in the enthusiastic market will purchase product $L$ over product $F$. In the uninterested market a similar result can be derived

$$
\frac{q_{L_{u}}}{Q_{u}}=\int_{-\infty}^{9 / 2} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-3)^{2}}{2}} d \phi+\frac{1}{2} \int_{9 / 2}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-3)^{2}}{2}} d \phi \approx 0.967 .
$$

Which leads to a predicted market share of firm $F$ of

$$
\frac{q_{F_{e}}}{Q_{e}}=1-\frac{q_{L_{e}}}{Q_{e}} \approx 0 \% \text {, and } \frac{q_{F u}}{Q_{u}}=1-\frac{q_{L_{u}}}{Q_{u}} \approx 3.33 \% \text {. }
$$

Let's now assume that firm $F$ has the ability to pay the search engine for the service of increasing consumers' expected utility of purchasing product $F$, not realized utility, such that $u_{F}^{\prime}=4$. By doing so, the market share of the leading firm in both markets drops down to just

$$
\begin{aligned}
& \frac{q_{L_{e}}}{Q_{e}}=\int_{-\infty}^{3 / 2} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi+\frac{1}{2} \int_{3 / 2}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{\phi^{2}}{2}} d \phi \approx 0.967, \text { and } \\
& \frac{q_{L_{u}}}{Q_{u}}=\int_{-\infty}^{3 / 2} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-3)^{2}}{2}} d \phi+\frac{1}{2} \int_{3 / 2}^{\infty} \frac{1}{\sqrt{2 \pi}} e^{-\frac{(\phi-3)^{2}}{2}} d \phi \approx 0.533 .
\end{aligned}
$$

Which leads to a predicted market share of firm $F$ in following markets

$$
\frac{q_{F_{e}}}{Q_{e}}=1-\frac{q_{L_{e}}}{Q_{e}} \approx 3.33 \% \text {, and } \frac{q_{F_{u}}}{Q_{u}}=1-\frac{q_{L_{u}}}{Q_{u}} \approx 46.7 \% .
$$

That is, the search engines' value is derived from its ability to bias market outcomes, and its power to do so is largely dependent on the interest levels of consumers. Furthermore, the welfare effect of the bias is the following in both the case of the enthusiastic market and the
uninterested market. Let's denote $q_{L_{e: t}}$ as the quantity of product $L$ purchased at time $t$, which denotes the period before firm $F$ paid the search engine for its service, and $q_{L_{e: t+1}}$ denotes the period where the search engine actively increases consumers expected utility. The same notation is used for product $F$.

$$
\begin{aligned}
& \Delta C S_{e}=q_{F_{e: t+1}} R_{F}^{\prime}+q_{L_{e: t+1}} R_{L}^{\prime}-q_{F_{e: t}} R_{F}^{\prime}-q_{L_{e: t}} R_{L}^{\prime} . \\
& \Delta C S_{e}=R_{L}^{\prime} \Delta q_{L_{e}}+R_{F}^{\prime} \Delta q_{F_{e}} .
\end{aligned}
$$

Note that the search engine is able to raise the expected marginal utility of consuming the product, but not the realized marginal utility, which leads to consumers receiving less than expected. The realized residual marginal utilities of $R_{L}^{\prime}>R_{F}^{\prime}$, which leads to $\Delta C S_{e}<0$. In the specific example above, it is possible to calculate the change in consumer marginal surplus, $\Delta C S_{e}=-0.1 Q_{e}$, by utilizing simple algebra:

The following applies $\frac{q_{L_{e}}}{Q_{e}}, \frac{q_{L_{u}}}{Q_{u}}, \frac{q_{F_{e}}}{Q_{e}}, \frac{q_{F_{u}}}{Q_{u}} \in[0,1]$, it is possible to perform the following operation

$$
\frac{\Delta C S_{e}}{Q_{e}}=R_{L}^{\prime} \frac{\Delta q_{L_{e}}}{Q_{e}}+R_{F}^{\prime} \frac{\Delta q_{F_{e}}}{Q_{e}} .
$$

The two firms together share $100 \%$ of the market hence the following must hold $\frac{q_{L_{e}}}{Q_{e}}+\frac{q_{F e}}{Q_{e}}=1$, and $\frac{q_{L_{u}}}{Q_{u}}+\frac{q_{F_{u}}}{Q_{u}}=1$. It is possible to perform the following transformation $\frac{q_{L_{e: t+1}}}{Q_{e}}-\frac{q_{L_{e: t}}}{Q_{e}}+$ $\frac{q_{F_{e: t+1}}}{Q_{e}}-\frac{q_{F_{e: t}}}{Q_{e}}=0$, which leads to $\frac{\Delta q_{L_{e}}}{Q_{e}}=-\frac{\Delta q_{F_{e}}}{Q_{e}}$, where $\Delta q_{L_{e}}=q_{L_{e: t+1}}-q_{L_{e: t}}$. The process ends with the result

$$
\Delta C S_{e}=\Delta q_{F_{e}}\left(R_{F}^{\prime}-R_{L}^{\prime}\right) Q_{e} .
$$

The same calculation can be performed for the case of an uninterested market. The calculation leads to $\Delta C S_{u}=-1.4 Q_{u}$, which is a negative welfare effect that is 14 times larger than in the case of the enthusiastic market, relative to the quantity purchased.


[^0]:    ${ }^{1}$ In particular, Arnór, Erika, and Ingibjörg.

[^1]:    ${ }^{2}$ There is a distinction between this assumption and the traditional assumption of bounded rationality. In this case, the agent can fully evaluate options without bias or any cognitive limitations. The agent experiences costs that can be assumed to be psychic and costs experienced due to foregone time.
    ${ }^{3}$ Hence, the relevance of the dual process theory.

[^2]:    ${ }^{4}$ This approach leads to exactly the same conclusion as the utility maximizing approach - since the minimization of costs w.r.t. certain action is necessary to achieve the maximization of utility w.r.t. certain action. The payoffs, in this case, are determined by the same economic factors as in a standard payoff function.
    ${ }^{5}$ This assumption leads to the individual experiencing a net benefit of applying system 2 and therefore should want to apply system 2 to both topics, if able to do so.
    ${ }^{6}$ This assumption is not in any way necessary for the inner workings of the model. This assumption is made to simplify the introductory case.

[^3]:    ${ }^{7}$ In this case, fewer than three.

[^4]:    ${ }^{8}$ It is assumed that decision makers are hedonistic and fully rational.

[^5]:    ${ }^{9}$ Thus, the partition $L$ has the cardinality $|L|=1,|F|=n-1, L \cap F=\emptyset$, and $L \cup F=I$.

[^6]:    ${ }^{10} \operatorname{Or}(\sup \phi)$ and $(\inf \phi)$ if the populations' values of $\phi$, for some reason, belong in an open interval.

[^7]:    ${ }^{11}$ The formula is $E_{k w h}=\frac{W \times t_{h r}}{1000}$, where $W$ denotes wattage and $t_{h r}$ denotes time in hours.

[^8]:    ${ }^{12}$ The calculations above assume that the total quantity of the product type demanded is a constant value of $Q$.

[^9]:    ${ }^{13}$ A shift of 2 units was an arbitrary value chosen. It was deemed to be of relevant size, where the same result could have been shown for any shift, as long as it is not too great (or too small) in relation to the marginal utility of consumption from the goods supplied.

[^10]:    ${ }^{14}$ Which is assumed to be random choice. Therefore leading to $50 \%$ chance of lesser good being chosen.

[^11]:    ${ }^{15}$ Assumed to have a low average $\phi$.
    ${ }^{16}$ Assumed to have a high average $\phi$.

[^12]:    ${ }^{17}$ E.g., a friend giving a recommendation to purchase a certain brand and describing its characteristics would be deemed a independent information distributor.

[^13]:    ${ }^{18}$ Therefore, low values of $\phi$ and $f$ are a necessary condition for an efficient market to form. The definition of an efficient market is a market characterized by high competitive levels, high consumer welfare, and lower tendency of firms to act against the interests of consumers.

[^14]:    ${ }^{19}$ in the case of only two products in the supply pool, the follower product must be the one which minimizes the consumer surplus.
    ${ }^{20}$ An individual which utilizes SEMHB.

