Effects of marketing, bank loan and credit debt on consumer's spending: Mathematical models based on an engineering concept

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Introduction to the study

The main objective of this study is to utilize an engineering concept in order to propose a mathematical model to correlate consumer spending, utility and income. The difference between the proposed model and the Keynesian consumption theory is explained by the fact that the Keynesian consumption theory takes into account the consumption of costumers with no income. The effects of marketing, bank loans and credit debt on consumer spending are also analyzed using the general equation of transport phenomena and mathematical models are presented for the first time. Based on a case study, marketing has increased the utility (driving force) by 61%. Taking into account the theory of consumption smoothing, bank loans also provide the consumer with additional spending power by decreasing the resistance for consumption. In case of excessive debt, customers might spend the money only to buy the "utility" in order to be able to repay the debt. In this situation, the effects of debt are described in the proposed engineering model as a decrease in income (extra resistance to spend money).

1. Dynamic Systems & their Universal Law

Everything in the universe is continuously in motion and the object can be as small as an atomic particle or as large as a planet. Gravitational and electromagnetic forces are responsible for large objects to be in motion while weak and strong nuclear forces are the driving factors for the quantum world to be in continuous motion. From an engineering perspective, flows take place in dynamic systems due to a driving force within the system and are controlled by a resistance located between two poles of the system. According to the second law of thermodynamics, this driving force is the difference in concentrations of energy between the two poles. For example, heat transfer in a piece of metal is transported from a higher temperature to a lower temperature and the speed of the flow of heat transfer is controlled by the resistance of the metal to heat transfer. The rain falls from the sky (higher altitude) to the land (lower altitude). Without the resistance of air to the gravitational force, rain drops will destroy all the trees and vegetation. This universal phenomena could therefore be described using the following generalized relationship for transport phenomena:

$$Flow \propto \frac{Driving\ Force}{Resistance} \tag{1}$$

In the field of electricity, the current I (flow of electrons) is motivated by a driving force (difference in potential = ΔU) and controlled by the electrical resistance (R) of the circuit. Ohm's law is then obtained:

$$I = \frac{\Delta U}{R} \tag{2}$$

In the study of Chemical Engineering, momentum, mass and heat transport also share a very similar framework. For example, Fourier's law of heat conduction (Thermal Ohm's law) is defined as:

$$Q = \frac{\Delta T}{\Delta x / kA} \tag{3}$$

Where: Q = heat flow; ΔT= Difference in Temperature (driving force), Δx= distance of heat conduction, A= Surface area of the metal, k= Heat conductivity of the metal; ($\Delta x/kA$) is therefore the resistance to heat flow by conduction.

Based on the same concept of transport phenomena, described in equation (1), people could be described as dynamic systems motivated to take roads and highways to go to schools for studying, to workplaces to make money and to markets to buy what is needed for their daily life. People have therefore a natural motivation (driving force) to spend their money on buying food, homes, furniture, electronic devices, etc. On the other hand, the amount of money spent by consumers is limited by their income (conductance). The main objective of this investigation is an attempt to find a mathematical model, based on an engineering concept, in order to: (1) propose a new mathematical model for consumer spending, (2) mathematically correlate the effects of marketing (increasing the driving force), bank loan (decreasing the resistance) and credit debt (increasing resistance) on consumer spending (flow of money).

2. Gross domestic product and consumer-based economy

The gross domestic product (GDP) is the indicator of national income and all outputs for a given country's economy. The GDP represents therefore the total expenditures for all final goods and services produced within the country in a stipulated period of time. As shown in Figure 1, the Gross Domestic Product (GDP) of the United States was worth 19390.60 billion US dollars in 2017[1]

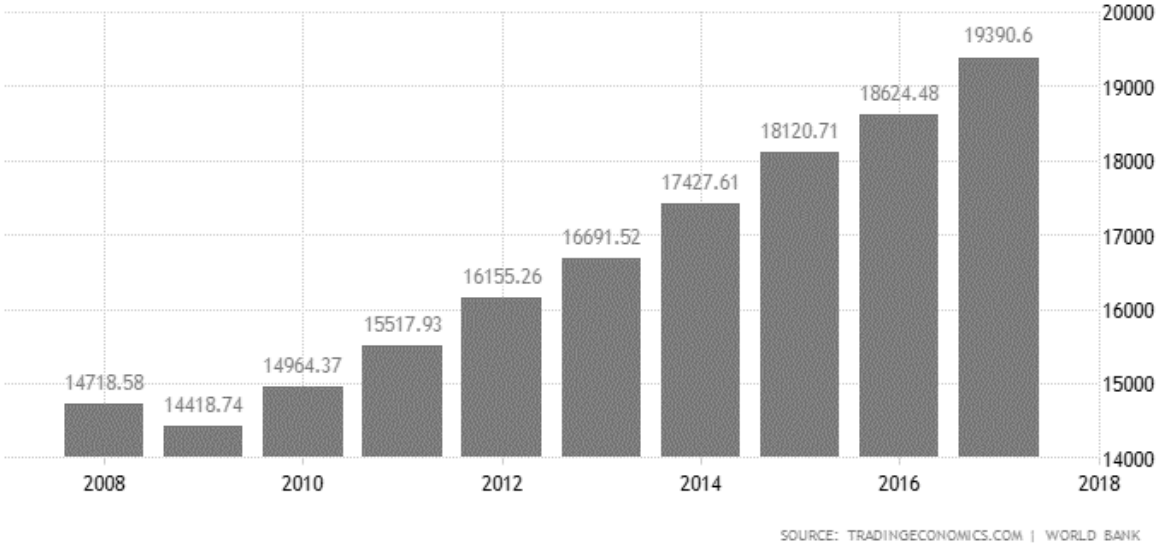

Figure 1: Gross Domestic Product for the USA from 2008 to 2017[1].

The expenditures approach and the income approach are the two known methods to calculate the gross domestic product (GDP). Both of these approaches attempt to best approximate the monetary value of all final goods and services produced in an economy over a set period of time (normally one year). The major distinction between each approach is its starting point. The expenditure approach

begins with the money spent on goods and services. Conversely, the income approach starts with the income earned (wages, rents, interest, profits) from the production of goods and services[2]. For the income approach, the GDP is calculated by adding the following elements[3]:

$$GDP = TNI + ST + D + NFFI \quad (4)$$

Where TNI= Total National Income; ST= Sales Taxes; D= Depreciation and NFFI= Net Foreign Factor Income. TNI is equal to the sum of all wages plus rents plus interest and profits. Some economists challenge the notion of including sales taxes in the GDP formula on the basis that taxation is counterproductive. They think it should subtract from total output rather than add to it. However, most use the income approach that includes sales taxes.

For the expenditure approach, the formula utilized to calculate the GDP is[4]:

$$GDP = C + I + G + (X-M) \quad (5)$$

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1. "C" (consumption) is normally the largest GDP component in the economy, consisting of private expenditures (household final consumption expenditure) in the economy.
2. "I" (investment) includes, for instance, business investment in equipment and spending by households (not government) on new houses is also included in Investment.
3. "G" (government spending) is the sum of government expenditures on final goods and services
4. "X" (exports) represents gross exports. GDP captures the amount a country produces, including goods and services produced for other nations' consumption.
5. "M" (imports) represents gross imports. Imports are subtracted since imported goods will be included in the terms "G", "I", or "C", and must be deducted to avoid counting foreign supply as domestic.

A consumer economy is defined as an economy driven by consumer spending as a percentage of its GDP (Gross Domestic Product). Keynesian economic theory proposes that governments should stimulate spending to end a recession. Supply-side economists recommend the opposite. They believe that governments should cut business taxes to create jobs. However companies won't increase production if the demand is not there[5]. Consumers are, therefore, very important to businesses. The more money consumers spend with a given company, the better that company tends to perform. For this reason, it is unsurprising that most investors and businesses pay a great amount of attention to consumer spending figures and patterns[6].

3. Proposed engineering model for consumer spending

Contemporary measures of consumer spending include all private purchases of durable goods, nondurables and services. Consumer spending (CS) is the demand side of "supply and demand"; production is the supply. Without consumer spending, there is therefore no motivation to produce goods. Goods are generally divided into two categories: durable goods, like autos, furniture or any

item that has a useful life of three years or more. The second is non-durable goods, such as fuel, food, and clothing. In 2017, the consumer spending in the USA made up to 70% of GDP ($12.6 trillion) [3, 4]. Consumer spending is therefore the main driving force of the economic system in the USA. Nearly two-thirds of consumer spending is on services, like real estate and healthcare. The remaining one-third of personal consumption expenditure is on goods. These include so-called durable goods, such as washing machines, automobiles, and furniture. More frequently, people buy non-durable goods, such as gasoline, groceries, and clothing. The consumption of these goods is the result of economic activity. This is because individuals ultimately use these goods to satisfy their own needs and wants; economists refer to this satisfaction as "utility[4].

The consumption function, or Keynesian consumption function, is an economic formula that represents the functional relationship between total consumption and gross national income. It was introduced by British economist John Maynard Keynes, who argued the function could be used to track and predict total aggregate consumption expenditures[7]. The relationship between consumption and income is based on the fundamental psychological law of consumption which states that when income increases consumption expenditure also increases but by a smaller amount[8].

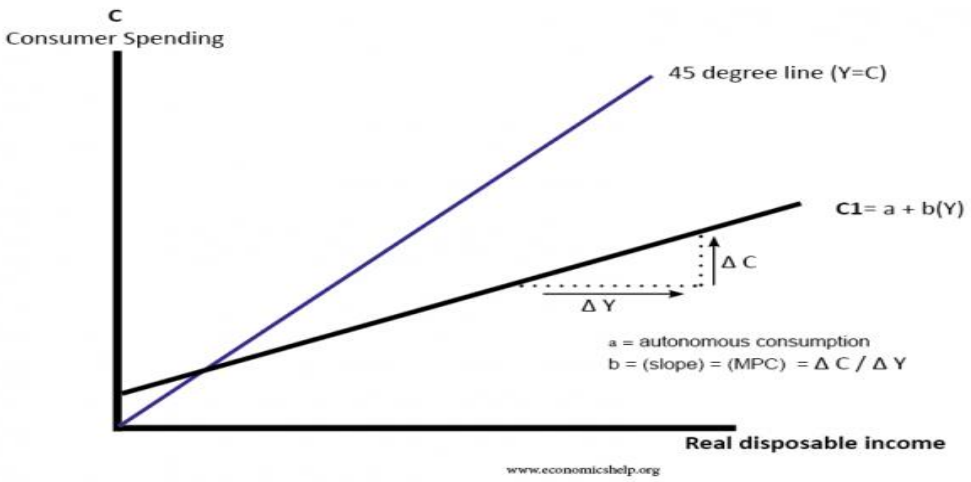

Figure 2: Consumption Function[8]

Based on Figure2, the Keynesian consumption function is linear[8]:

$$C = a + b.Y \qquad a > 0 \qquad 0 < b < 1 \qquad (6)$$

Where **a** is the intercept (a constant which measures consumption at a zero level of disposal income), **b** is the marginal propensity to consume (MPC) and **Y** is the disposable income. The MPC is the proportion of an aggregate raise in pay that a consumer spends on the consumption of goods and services, as opposed to saving it. Y is total personal income minus personal current taxes. The above formula describing consumption as a function of current disposable income whether linear or non-linear is called the absolute income hypothesis. This consumption function has the following properties[8]:

1. As income increases, average propensity to consume (APC = C / Y) falls.

2. The marginal propensity to consume MPC is positive but less than unity (0 < b < 1) so that higher income leads to higher consumption.

3. The consumption expenditure increases or decreases with increase or decrease in income but non-proportionally. This non-proportional consumption function implies that in the short run average and marginal propensities do not coincide (APC > MPC).

4. This consumption function is stable both in the short run and the long run.

In this investigation, consumer's spending (CS) taken as the money people spend to buy the goods during one month will be defined. Considering an analogy with equation (1), people have a motivation (driving force) to spend their money to buy goods, defined as utility[4]. On the other hand, the amount of money spent depends on personal income. The income effect relates to how a consumer spends money based on an increase or decrease in income. An increase in income results in demanding more services and goods, thus spending more money. A decrease in income results in the exact opposite. In general, when income is lower, less spending occurs[9]. In the proposed model, the income is considered as the conductance for spending money and the inverse (1/income) is therefore its resistance. Following the general equation (1) of transport phenomena, consumer's spending (CS) is defined in this investigation as:

$$CS \propto \frac{Utility}{(\frac{1}{income})} \tag{7}$$

Equation (7) could be reorganized as:

$$CS \propto Utility\,.Income \tag{8}$$

The proposed equation (8) indicates that consumer spending increases proportionally with the utility, as the driving force, and the personal income of the buyer as the conductance (1/resistance) for buying. In this concept of dynamic systems, it is assumed that people buy only what they need. As a consequence, without this driving force, the consumer spending is equal to zero. This concept is also based on the fact that people with no income are not able to spend money to buy what they need. In comparison with the Keynesian consumption function, the proposed equation (8) could be rewritten as:

$$CS = c.Y \tag{9}$$

Where the slope **c** represents the utility, similar to the factor **b** (marginal propensity to consume) in equation (6) and Y is the disposable income. The difference between equations (6) and (9) is due to the fact that the Keynesian consumption theory takes into account the autonomous consumption **a** (consumption of costumers with no income). In the proposed model, the value of **a** is equal to zero. The most recent data release from the United States Bureau of Economic Analysis shows that the real personal spending was up by 0.4% in November 2017 after being virtually unchanged in October. Moreover, the analysis indicates that personal income climbed 0.3% in November, largely

driven by gains in wages and salaries[10]. For this specific case study, the slope **c** of equation (9) is equal to:

$$c = \frac{\Delta(CS)}{\Delta(Y)} = \frac{0.4\%}{0.3\%} = 1.33 \quad (10)$$

This result is in contradiction with the property of the Keynesian consumption function. The fact that the value of the slope **c** is higher than unity while the slope **b** of the Keysian consumption function is lower than unity, could be explained by the fact that the constant **a** (autonomous consumption) of the Keysian Consumption theory takes into account the consumption of people with no disposable income.

4. Effects of marketing on consumer spending

During the industrial revolution, mass production generated many industries in order to serve the growing needs of consumers. It also created a need for producers to find better ways to develop new products needed by customers and a more sophisticated strategy to inform them. Starting in the 1960s, the markets in many industries became saturated with competition and, in order to get and keep customers, companies needed to hire specialists in the area of marketing. Businesses started to adopt marketing applications to both understand customers, and have personalized communication with them.

According to Kotler and Armstrong[11], marketing mix is the set of tactical marketing tools - product, price, place, and promotion - that the company blends to produce the response it wants in the target market. Following this concept, advertising utilized many forms of media to reach customers. Print, television, radio, cinema, outdoor, mobile and digital have all been targeted by advertisers. Global advertising spending has been constantly increasing since 2010, and is forecast to reach nearly 548 billion U.S. dollars in 2017. Digital advertising spending worldwide – which includes both desktop and laptop computers as well as mobile devices – stood at an estimated 194.6 billion U.S. dollars in 2016. This figure is forecast to constantly increase in the coming years, reaching a total of 335 billion U.S. dollars by 2020[12].

For specialists in marketing, there have been many attempts to understand the behavior of consumers because their choices are the most important indicator of purchasing decisions. For example, impulse buying is omnipresent and unique aspect of consumer behavior. According to Piron[13], impulse buying is a purchase that is unplanned (non-utility), the result of an exposure to a stimulus, and decided on-the-spot. According to some data, 84% of Americans admit they have made an impulse buy[14]. In order to utilize the proposed engineering concept, it is assumed that marketing adds an additional driving force to the 'utility". As a consequence, the resulting driving force to consumer spending is higher. As a case study, the effects of marketing on consumer spending are analyzed in the data comparing planned and impulse clothing purchases grouped by age and household income of shoppers[14]

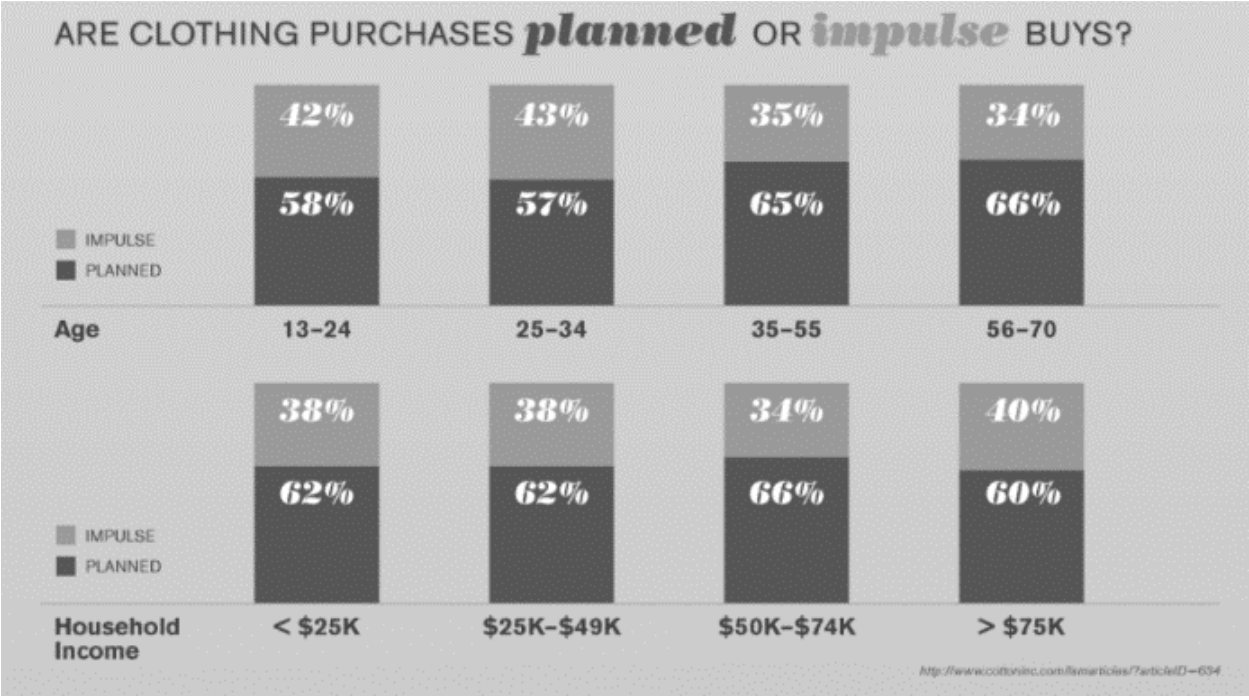

Figure 3: Planned and impulse clothing purchases[14]

Figure 3 shows that marketing have stimulated impulse buying and costumers have spent more money. To reflect the effects of marketing on consumer spending, equations (7) and (9) could respectively be formulated as:

$$CS \propto \frac{(Utility+Marketing)}{(\frac{1}{income})} \tag{11}$$

$$CS = \frac{e.c}{(\frac{1}{Y})} \tag{12}$$

Where the effects of marketing **e** is multiplied by the utility **c** with values of **e** higher than one. Analyzing the data of impulse buying for a household income $25K-$49K (Figure 3), the marketing's parameter **e** is equal to 61% of the utility. Marketing has therefore increased the utility (driving force) by 61%. The effects of marketing on consumer spending is given in the equation:

$$CS = \frac{1.61c}{(\frac{1}{Y})} \tag{13}$$

Including the autonomous function $\mathbf{a_1}$ of the Keynesian consumption function, equation (12) is modified and defined as the Dadach Consumer's Spending Equation #1 (DCSE1):

$$DCSE1 = a_1 + \frac{e.c}{(\frac{1}{Y})} \tag{14}$$

Sales volume is typically measured in either total dollars or number of units sold. Higher sales volume usually means that the company is getting a higher profit margin or increasing demand and the number of units sold. In concordance with the positive effects of advertisement on the demand side (consumer spending), Figure 4 also indicates that spending in media has increased the supply side (volume of sales).

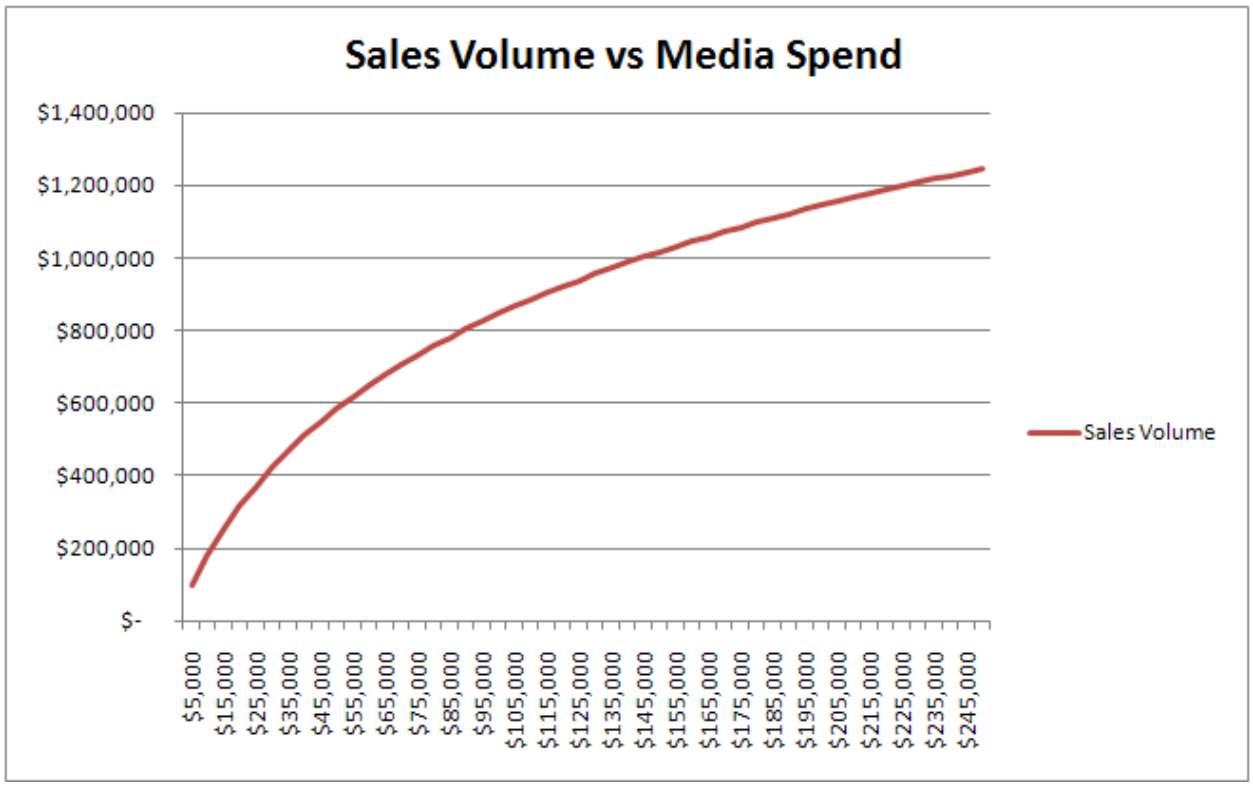

Figure 4: Sales Volume vs. Media spend[12]

5. Effects of bank loans on consumer spending

The life-cycle hypothesis indicates that consumers attempt to maintain their lifestyle and consumption baskets over their lifetime even though their income and wealth may fluctuate over time[15]. For example, old consumers can take money from their past savings and consume at levels beyond their current incomes. On the other hand, young consumers can borrow from their expected "future income" to support their present lifestyle. This behavior is known as consumption smoothing[16]. Bank loans facilitate this practice because it provides the consumer with additional spending power in the present in exchange for repayment (of the loan and interest) in the future. Based on this information, the effects of bank loans could be introduced in the proposed formula for consumers spending as:

$$CS \propto \frac{Utility}{\left(\frac{1}{income + Bank\ loan}\right)} \tag{15}$$

Similar to the effects of marketing on the driving force (utility) for consumer spending, bank loans have decreased the resistance for spending. Similar to the effects of marketing, the effects of bank loans on consumer spending could also be represented with a percentage of the income. Based on these assumptions, the effects of bank loans on consumer spending could be represented by the following equation:

$$CS = \frac{c}{(\frac{1}{f.Y})} \qquad f>1 \tag{16}$$

Including the autonomous function $\mathbf{a_2}$ of the Keynesian consumption function, equation (16) is modified and defined as the Dadach Consumer's Spending Equation #2 (DCSE2):

$$DCSE2 = a_2 + \frac{c}{(\frac{1}{f.Y})} \qquad f>1 \tag{17}$$

For the determination of the value of the bank loan parameter **f**, representing the effects of bank loans on consumer spending, a study has shown that if consumers have access to large amounts of credit, their willingness to use credit (and their spending) will also be high. Conversely, for consumers who are granted lower amounts of credit, their spending will also be lower[17].

3.3 Effects of marketing and bank loans on consumer's spending

Combining both marketing and credit, the following equations could be utilized to analyze their effects on consumer spending:

$$CS \propto \frac{(Utility+Marketing)}{(\frac{1}{income+Bank\ loan})} \tag{18}$$

$$CS = \frac{e.c}{(\frac{1}{f.Y})} \tag{19}$$

Including the autonomous function $\mathbf{a_3}$ of the Keynesian consumption function, equation (19) is modified and defined as the Dadach Consumer's Spending Equation #3 (DCSE3):

$$DCSE3 = a_3 + \frac{e.c}{(\frac{1}{f.Y})} \tag{20}$$

Consumer spending is now enhanced by parameters **c** and **f**. Consumers could borrow up to the credit limit. However, if they exceed that amount, they have to pay extra penalties in addition to their regular charge.

6. Effects of marketing and bank loans on consumer's spending

Combining both marketing and credit, the following equations could be utilized to analyze their effects on consumer spending:

$$CS \propto \frac{(Utility+Marketing)}{(\frac{1}{income+Bank\ loan})} \tag{21}$$

$$CS = \frac{e.c}{(\frac{1}{f.Y})} \tag{22}$$

Including the autonomous function $\mathbf{a_3}$ of the Keynesian consumption function, equation (22) is modified and defined as the Dadach Consumer's Spending Equation #3 (DCSE3):

$$DCSE3 = a_3 + \frac{e.c}{(\frac{1}{f.Y})} \tag{23}$$

Consumer spending is now enhanced by parameters **c** and **f**. Consumers could borrow up to the credit limit. However, if they exceed that amount, they have to pay extra penalties in addition to their regular charge.

7. Effects of credit debt on consumer spending

Credit cards are utilized to finance consumption and therefore support the economy. However, excess debt may hinder future consumption and therefore slows down economic growth. For example, the average credit card debt per U.S. household was $8,431 in September 2018. That's $1.041 trillion in total credit card debt divided by 123 million U.S. households[18]. Moreover, according to the 2004 Survey of Consumer Finances, approximately 75 percent of all households own at least one credit card, and 58 percent of those holding a credit card carry a balance[19]. A recent study has also found a negative relationship between debt and consumption growth. The results indicate that a one-thousand dollar increase in credit card debt results in a decrease in quarterly consumption growth of almost two percent[18]. Based on these findings, excessive credit debt effects could be represented in the proposed engineering model, as a decrease in income, or therefore an increase of the resistance for consumer spending. Assuming that marketing does not play an important factor for customers who have credit debt, equations (14) and (15) are adjusted as:

$$CS \propto \frac{Utility}{\left(\frac{1}{income-debt}\right)} \tag{24}$$

$$CS = \frac{c}{\left(\frac{1}{g.Y}\right)} \qquad g < 1 \tag{25}$$

Including the autonomous function $\mathbf{a_4}$ of the Keynesian consumption function, equation (25) is modified and defined as the Dadach Consumer's Spending Equation #4 (DCSE4):

$$DCSE4 = a_4 + \frac{c}{\left(\frac{1}{g.Y}\right)} \qquad g < 1 \tag{26}$$

The values of the credit debt parameter **g** smaller than unity indicates the negative effects of credit debt on consumer spending. The value of **g** equal to zero indicates that all the income has been used to pay the credit debt

9. Proposed Mathematical models and Analysis

The four proposed mathematical models are shown in Table 1.

Table 1: Proposed mathematical models for the effects of marketing, bank loan and credit debt on consumer spending

Purpose of the equation	Equations	Parameters
Effects of marketing on consumer spending	$DCSE1 = a_1 + \frac{e.c}{(\frac{1}{Y})}$	e:marketing parameter (e>1) a_1: autonomous function (a_1>0)
Effects of bank loans on consumer spending	$DCSE2 = a_2 + \frac{c}{(\frac{1}{f.Y})}$	f = bank loan parameter (f>1) a_2: autonomous function (a_2>0)
Effects of marketing and bank loans on consumer spending	$DCSE3 = a_3 + \frac{e.c}{(\frac{1}{f.Y})}$	e:marketing parameter (e>1) f = bank loan parameter (f>1) a_3: autonomous function (a_3>0)
Effects of credit debt on consumer spending	$DCSE4 = a_4 + \frac{c}{(\frac{1}{g.Y})}$	g: credit card parameter g<1 a_4: autonomous function (a_4>0)

The objective of this study was an attempt to introduce an engineering concept of transport phenomena based on flow, a driving force and a resistance, in order to propose a new mathematical model for consumer spending. Similar to the flow of electrons in an electrical circuit (Ohm's law), consumer spending is described as a flow of money in the consumer-based economy. This flow is enhanced by a driving force, called "utility", which is the motivation of customers to buy what is needed. Considering that consumer spending increases with the income (conductance), the inverse of income is therefore the resistance for consumer spending. In contradiction with the Keynesian Consumption function, the parameter **c** of the proposed equation (9) was found higher (1.33) than unity for the analysis of a given case study. The difference was explained by the fact that the Keynesian consumption theory takes into account the consumption of customers with no income. On the other hand, the engineering concept considers no consumption if the resistance (1/ income) is equal to infinity, which means that the income is equal to zero.

The proposed engineering concept was also utilized to analyze the effects of marketing on consumer spending. Collected data indicates that marketing encouraged impulse buying and therefore, stimulated consumer spending. In the proposed equation (14), the marketing parameter **e** is multiplied the utility **c** with values of **e** higher than one. Analyzing the data of impulse buying for a household income $25K-$49K (Figure 3), marketing has increased the utility (driving force) by 61 percent. These enhancing effects are also confirmed by the fact that marketing has increased the volume of sales (Figure 4).

According to the life-cycle hypothesis, consumers have a tendency to maintain their level of consumption even though their income and wealth may fluctuate over time. According to the literature, bank loans provide the consumer with additional spending power in the present in exchange for repayment (of the loan and interest) in the future. This enhancement of consumer spending is introduced in the proposed engineering model as an extra salary. As a consequence, the resistance for spending is decreased. This is represented in equation (19) by having a value of the parameter **f** higher than unity. According to the literature, the value of the parameter **f** depends on the credit limit. Equation (20) is also proposed to represent the effects of both marketing and bank loans. Consumer spending is therefore enhanced by two parameters **c** and **f**.

While marketing is limited by the budget of the corresponding company, bank loans are limited for consumers and credit debt will have opposite effects. In case of excessive debt, customers may be more careful to spend money. They might spend the money only to buy the "utility" in order to be able to repay the debt. In this situation, the effect of debt is described in the proposed engineering model (Equation 23) as a decrease in income or an extra resistance to spend money.

10.
Conclusion

To the best of my knowledge, this is the first attempt to introduce an engineering concept in order to correlate consumer spending, utility and income. In the proposed concept, the flow under consideration was the flow of money spent by consumers, the driving force for spending money was the utility (what customers need to buy for their daily life). Finally, considering the income as the conductance for buying, its inverse is considered as the resistance for the flow of money spent by consumers. The effects of marketing, bank loans and credit debt on consumer spending were also analyzed and respective equations are proposed for the first time.

11.
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