Green Investment and Price Decisions under the Blockchain Technology Era

C. H. Hsiao*, J. J. Lai, and C. C. Hsieh

***Abstract*—Due to the advancement in network technology, consumer behavior has changed gradually. In face of continually developing technology and the upsurge of environmental awareness, the negative environmental impacts generated from the production process and logistics are gradually being valued. In this research, a mathematical model has been built in consideration for a manufacturer with green investments, an online sales platform with blockchain technology, and consumers with environmental awareness in correlation to a supply chain. From the manufacturer's perspective, decisions on distribution channels, green investment, and pricing will be explored with illustrations of the influence made on the supply chain.**

***Index Terms*—Blockchain, green investment, online sales platform, supply chain**

I. Introduction

In the past decades, organizations cooperate with online sales platforms to gain ancillary advantages have been expanded in an expeditious manner [1]. Other than simply executing appropriate supply chain management and determining channel alternatives, sustainability in the market positioning seems to be mandatory. Such proposition of sustainability was accentuated in terms of social welfare and environmental protection that ultimately gained considerable attention from consumers [2].

With the connoted motivation of such a market juncture, ecolabels are one of the suggesting mechanisms that can fulfill the environmental impact of products to consumers [3]. Ecolabels could be issued by governments, non-governmental organizations (NGOs), or private companies. Furthermore, some ecolabels allow organizations to self-label. This may consist of a certain level of trust evaluation from consumers where the credibility of the ecolabel varies among adopting organizations. In a competitive market situation, organizations may adopt different ecolabel strategies concerning cost input. Trustworthy organizations may choose to apply self-established ecolabel while less trustworthy organizations may be required to push the level up by selecting a more credible ecolabel that is established by NGOs [4].

Mentioning the fact that the credibility of ecolabel varies, in this research, we consider alternative solutions upon distribution through different channels. From the manufacturer's point of analysis to examine direct channel in comparison to how online sales platform can support ecolabels and invests in blockchain technology to resolve the credible issue of ecolabels. The particular reason that the research tends to illustrate upon the online sales platform is that the managerial focus in the presence of e-commerce is simply not neglectable. According to Yang & Xu [5], it was stated that the "China E-Commerce Report 2017 (2018)", released by the E-commerce Department of the Ministry of Commerce in May 2018, shows that the national online retail sales reached 7.18 trillion CNY in 2017, an increase of 32.2% year-on-year, accounting for 15% of the total retail sales of consumer goods. In the online retail business, the agency business model has become a popular model in many industries. With the example given, blockchain technology sets in as the main role of a communication tool for information management. Not only blockchain technology records the data but also provides transparency in corresponding product origin, supply function, and consumer rights in product evaluation. The matter of transparency allows the manufacturer's effort to be insightfully transferred along with the distribution through blockchain technology. On the other hand, the fact that consumers often face imperfect information could also be resolved to avoid stereotype or perceptions against brands and products, which reduces misleading thoughts on product selection, and create opportunities for bad organizational products [6].

A decent amount of the existing research illustrates the study on a single focus academically either to blockchain technology or green technology without ecolabel specified. By stepping up the correlation significance, this research will examine ecolabels and blockchain technology simultaneously. While manufacturers pay effort to product greenness, online sales platform pays effort towards establishing blockchain technology to make the greenness creditable and transparent to consumers. Under the determined condition, this research will establish the setting where a single manufacturer decides on a distribution mechanism either through a direct channel or an online sales platform. After the channel selection, greenness level and selling price will be collectively considered as another decision content by the manufacturer.

The research will be arranged with illustrations into five sections. The first section expounds the introduction in illustration of research background and motivation, containing purpose and procedure and the research structure. The second section, the literature review, will examine a collection of relevant literature, respectively are ecolabels,

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blockchain technology, and online sales platform. The literature review process will examine the relevant collection to fulfill the necessity of identifying aspects with disparity. The third section constructs a mathematical model to correspond with the quantitative decision phase for the supply chain members under a divergent channel structure. The fourth section explores numerical analysis, where interactions between decision variables and affection of parameter change to different models will be discussed. The final section, the conclusion, will summarize the outcome analysis and inspires managerial insights for future research direction and successive study reference.

II. Literature Review

Several fundamental elements will be examined in this research, consisting of ecolabel, blockchain technology, and online sales platform. Correlating literature will be reviewed respectively for the identified research streams.

A. Ecolabel

With the increase of the awareness of environmental protection, consumers have been involved in the bandwagon effect of green products which also elaborates the green investments by suppliers in a spanned array of product categories [7]. In relation to green investment, the validation of green strategies and how consumers accept the product's correlation to environmental concerns is also challenging. The conceptual model and the actual results obtained from the practical implementation, in reality, may differ tremendously [8].

Ecolabels could be seen as one of the most successful mechanisms that hold the key to the validation of green strategies recognized by the consumer [9]. Many researchers study the impact of ecolabels and how additional value ecolabels could attach to the identifying product categories. For instance, Lin and Huang [2] proposed a set of diverse values that affect consumer choice behavior regarding green products. With the utilization of multiple linear regression analysis, positive impact persuades that significant relationship to consumers' purchasing behavior.

A worldwide example of a recognizable ecolabel is the Forest Stewardship Council (FSC). Through the designed certification scheme, the FSC focuses on promoting responsible forestry. Through scrutinizing an organization's operation through audit performance, executed transactions are simplified and shown as an ecolabel for consumers to recognize the validating message [10]. However, there are variations among the audit level of ecolabels. Along with the wide adoption of ecolabels over a spanned array of product categories, consumers sometimes may hold uncertainties, ambiguity, and stereotypes. Harbaugh et al. [11] illustrated the FSC label in comparison to Sustainable Forestry Initiative (SFI), where one is controlled by an environmental NGO and the other by an industry-backed NGO. The similar-appearing labels both designated for forest products may give consumers uncertainty over the unclear certification and source of a label.

B. Blockchain Technology

In question to the ambiguity from consumer perceptions and how green investments shall be executed with correlated specification and credibility, blockchain technology provides a comprehensive solution. By definition, blockchain technology is an internet-based technology that provides attributes of visible transparency in operation transactions among all members of the supply chain. The transactional data could be combined in a chronological sequence forming a chain and also being able to share among members [12]. Furthermore, Hirata et al. [13] suggest that blockchain technology could provide consumers and businesses to understand production sustainability better and minor the possibility of environmental damage, and illegal or unethical products. With the implementation of blockchain technology into the supply chain, the transparency and traceability attributes allow responsible production and consumption to be driven.

Viewing the blockchain technology and supply chain management from the suppliers' point of perspective, Bag et al. [14] stated that in order to enhance the flexibility of supply chains, many organizations transfer a portion of their business processes to outsourcing. However, under such practice, inter-organizational transactions often lead to loss of control and therefore become a barrier to supply chain management. The introduction of blockchain technology could be the solution, where integrated transport and visible production stages could be delivered from manufacturers to end-users. The US wholesaler Walmart was looking for execution beyond traditional governance tools over its supply chain management. The aim was to increase efficiency, transparency, and traceability of products from the manufacturer to the store. The blockchain-based cloud network engaged in the transactions by allowing the participating member to obtain data from the entire food ecosystem, allowing confidence in food safety, reliable and cost-effective supply chain management. Blockchain technology enables Walmart to coordinate the supply chain information among participating members through decentralized servers and processes only end when the product reaches Walmart's consumers [15].

C. Online Sales Platform

The final focusing research stream is the online sales platform. In the past decade, the development of the Internet and e-commerce has been tremendously advanced. By utilizing the attributes of e-commerce, an online sales platform is capable to be ergonomically designed to understand more in-depth consumer behavior, demand preference, demand forecast, and many other information streams [5]. A comparable well-known example is Amazon and Alibaba, due to their leading position in the global e-commerce industry. From their 2017 annual reports, Amazon had USD 177.9 billion in revenue with a 56% annual growth rate while Alibaba had USD 22 billion in revenue with a 56% annual growth rate [16]. Both illustrated the fact that opportunities lie among the utilization of the online sales platform.

Under the distribution strategy through online sales platforms, commonly adopted business models are the reselling model and agency model [17]. In the reselling model, the manufacturer sets the wholesale price and sells the product to the online sales platform. The online sales platform then sets the targeted retail price for the consumers. With the

agency model, through the online sales platform, the manufacturer set the targeted retail price and pays the online sales platform a percentage of its revenues in return for accessing the consumer through the online sales platform. The stated formats could even be extended into a green supply chain setting. For instance, Guo et al. [18] examined the concept of eco-labeling and the impact of the stated two selling formats on the online sales platform, the correlations to the supply chain's performance, environmental impact, and social welfare. Furthermore, XU et al. [19] found that blockchain technology not only helps products become more environmentally friendly but also brings more profits to the manufacturer and the online sales platform.

D. Summary

In summary, many existing studies explored the interactions between single or competing manufacturers through correlating aspects of an online sales platform, green technology, or blockchain technology. This research aims to fill the gap in the present literature. The research will be performed by analyzing the implementation of blockchain technology on the online sales platform, along with green investment and pricing aspects when manufacturers sell products through their direct channel and online sales platform.

III. Model Framework and Assumptions

A. Conceptual Framework

The conceptual framework consists of a supply chain with a manufacturer and an online sales platform in a market situation where the consumers are sensitive to product greenness and the degree of information transparency. Regarding the manufacturer's distribution channel strategy, two models are developed. In Model 1, the manufacturer sells its product through its direct channel exclusively. In Model 2, the manufacturer sells the product through the online sales platform exclusively.

To avoid complexity obscuring the model construction, assumptions are made in regards to other influences with minor impacts. Firstly, the manufacturer is capable of reaching the consumers through its direct channel, and the distributed product is of the same quality among all applicable channels. Secondly, there will be no order processing lead time in the supply chain. Lastly, with the application of blockchain technology, the entire transaction will be meticulously recorded and irrevocable. Thus, blockchain technology allows consumers to recognize the authenticity of product greenness better and enhance consumer trust in the green supply chain.

B. Green Investment

In reflection of environmental protection, the manufacturer could invest more effort into the product nature in correlation to environmental greenness. In this research, symbol g denotes the level of product greenness that the manufacturer chooses. Whereas, as product greenness advances to a higher level, suggestions of the product being more environmentally friendly stand. By holding substantial green investment, larger marginal cost incurs while the level of product improvement increases. Therefore, a quadratic cost function g^2 in terms of product greenness improvement will be adopted.

The purpose of the online sales platform is not simply to serve as a usual platform but also as a credible issuer. When the manufacturer's product is being distributed, the online sales platform will have to certify the manufacturer's green investment and provide detailed information regarding the manufacturer's product greenness. The online sales platform requires to provide irrevocable and transparent transaction records that fully illustrate the credibility of the greenness in support for consumers to be influenced for beliefs and purchasing behavior. The essential mechanism for the green investment to be utilized in function is the adoption of blockchain technology. When the manufacturer distributes through the online sales platform, it is assumed that the platform has already implemented blockchain technology to ensure the credibility of the ecolabel. If the manufacturer chooses to distribute through the online sales platform, per-unit cost $ce > 0$ will incur symbolizing the engagement of maintaining the green investment cost in relation to blockchain activities utilization along the supply chain.

C. Consumer Utility

Consumers are heterogeneous in product valuation v, which is assumed to be uniformly distributed over $[0,1]$, with the market size being normalized to 1. Consumers are having a level of sensitivity to product greenness, selling price, and greenness transparency. As the manufacturer sells products through its direct channel exclusively, consumers will have the utility U_{M1}.

$$U_{M1} = v + \theta g - p_d \tag{1}$$

Accordingly, p_d is the manufacturer's selling price through its direct channel, and $\theta > 0$ is the consumers' sensitivity towards the level of product greenness. The $v + \theta g$ could be comprehended as the total perceived value from product functionalities and greenness. Referring to the online sales platform, consumers who purchase the products on the platform receive the utility U_{M2}.

$$U_{M2} = \alpha(v + \theta g) - p_s \tag{2}$$

Correspondingly, p_s is the manufacturer's selling price through the platform while $\alpha > 1$ is the factor accounting for the platform's ecolabel provision under blockchain technology. As α becomes larger, it indicates the consumer value the greenness, and information transparency through blockchain technology to be more significant.

D. Model 1: Direct Channel

As in Model 1, the manufacturer exclusively sells the product through its direct channel. Consumers would purchase the product when their utility U_{M1} is non-negative. x^{M1} is the indifference point of v such that $U_{M1} = 0$, and the product demand is $D_M^{M1} = 1 - x^{M1}$.

$$x^{M1} = p_d - \theta g \tag{3}$$

$$D_M^{M1} = 1 - p_d + \theta g \tag{4}$$

Regarding the manufacturer's profit, the manufacturer's production cost is normalized to zero while $k * g^2$ is allocated for the product greenness investment. The manufacturer's profit in Model 1 could be developed as

$$\pi_M^{M1} = (p_d) * D_M^{M1} - k * g^2 \quad (5)$$

In this model, it is essential for the manufacturer to determine the level of investment in greenness for the product and the price in the distributing channel. By maximizing the manufacturer's profit, we obtain that the manufacturer's optimal selling price pd^{M1*}, and optimal level of product greenness g^{M1^*} are

$$p_d{}^{M1^*} = \frac{2k}{4k - \theta} \quad (6)$$

$$g^{M1^*} = \frac{\theta}{4k - \theta^2} \quad (7)$$

The manufacturer's optimal profit is

$$\pi_M^{M1^*} = \frac{k}{4k - \theta^2} \quad (8)$$

The demand $D_M^{M1^*}$ through the direct channel is

$$D_M^{M1^*} = \frac{2k}{4k - \theta^2} \quad (9)$$

E. Model 2: Online Sales Platform

In Model 2, the manufacturer sells exclusively through the online sales platform. Once more, consumers would purchase the product when their utility U_{M2} is non-negative. x^{M2} is the indifference point such that $U_{M2} = 0$, and the product demand is $D_S^{M2} = 1 - x^{M2}$.

$$x^{M2} = \frac{p_s - \theta g \alpha}{\alpha} \quad (10)$$

$$D_S^{M2} = 1 - \frac{p_s - \theta g \alpha}{\alpha} \quad (11)$$

In Model 2, the online sales platform adopts an agency business model where a commission rate ϕ, $(0 < \phi < 1)$, is charged for each product being sold. As concerning to the manufacturer, it is compulsory for the manufacturer to bear the blockchain technology and green investment's unit cost ce, consisting of inputs, certification, and time consumption for sustaining the greenness of the product. The manufacturer's cost for applying a one-time application for green investment is neglected in this model. For instance, the registration fee for a particular ecolabel. Hence, the manufacturer determines the selling price p_s and the incurring cost of $k * g^2$ for the product greenness improvement. Consequently, in Model 2, the manufacturer's profit π_M^{M2}, and the platform's profit π_S^{M2} could be developed as

$$\pi_M^{M2} = \big((1 - \phi) * p_s - ce\big) * D_S^{M2} - k * g^2 \quad (12)$$

$$\pi_S^{M2} = (\phi * p_s) * D_S^{M2} \quad (13)$$

In general, various product categories are being offered on the online sales platform. In respect, the platform's commission rate ϕ could be considered as exogenous. The decision of the commission rate requires to include the factors where the green investment and blockchain technology utilizations are being covered. Such a decision-making process suggests a uniform commission rate for all product categories sold on the online sales platform, unless profit-oriented otherwise.

In consequence, the manufacturer decides the selling price p_s and the product greenness level g that allows maximization upon its own profit π_M^{M2} in (12).

For (14) to (18), the symbols are defined as follows:

$A = \alpha(1 - \phi) - ce.$
$B = \big(4k - \alpha\theta^2(1 - \phi)\big)(1 - \phi).$
$C = 2cek + 2k\alpha(1 - \phi) - ce\alpha\theta^2(1 - \phi).$

In Model 2, the manufacturer's optimal selling price $p_s{}^{M2^*}$ and optimal level of product greenness g^{M2^*} are

$$p_s{}^{M2^*} = \frac{C}{B} \quad (14)$$

$$g^{M2^*} = \frac{\theta A(1 - \phi)}{B} \quad (15)$$

The manufacturer's profit $\pi_M^{M2^*}$ and the platform's profit $\pi_S^{M2^*}$ are

$$\pi_M^{M2^*} = \frac{kA^2}{\alpha B} \quad (16)$$

$$\pi_S^{M2^*} = \frac{2kAC\phi}{\alpha B^2} \quad (17)$$

The demand $D_S^{M2^*}$ through the platform is

$$D_S^{M2^*} = \frac{2kA}{\alpha B} \quad (18)$$

IV. Numerical Analysis

In this section, the constructed models will be conducted with numerical analysis. The effects of model parameters on the manufacturer's choice of distribution channel, price, and green investment will be analyzed.

A parameter set will be given for numerical analysis to simulate the supply chain conditions. These parameter values will be plugged into the constructed models consisting of decision variables, demand function, and profit function. The parameter set for this study are $\alpha = 1.3, k = 1, \theta = 0.3, ce = 0.05,$ and $\phi = 1.5$

By adopting the parameter values into Model 1 and Model 2, the manufacturer's decisions and profit and the online sales platform's profit are shown in Table I and Table II.

TABLE I: DEMANDS AND PROFITS IN MODELS 1 AND 2

Outcome\Model	Model 1	Model 2
Manufacturer profit	0.255754	0.258236
Platform profit		0.051053
Direct channel demand	0.511509	
Platform demand		0.489547
Total Profit	0.255754	0.309289
Total Demand	0.511509	0.489547

TABLE II: DECISIONS IN MODELS 1 AND 2

Outcome\Model	Model 1	Model 2
Product greenness g	0.076763	0.081142
Direct channel price p_d	0.511509	
Platform price p_s		0.695235

From the numerical results, we observe that Model 1 has a higher product demand than Model 2. However, in terms of profit, Model 1 is not as good as Model 2. This suggests that blockchain technology and green investment have a positive influence. When the manufacturer decides to sell the product through the online sales platform, as the credibility and transparency in the supply chain increases, the manufacturer could set a higher selling price and obtain a higher profit. Furthermore, the manufacturer tends to make more on green investment in Model 2 than in Model 1 in comparison.

Sensitivity analysis for ce on price is illustrated in Fig. 1. When setting a parameter variation range for the unit cost ce from 0 to 0.21, since Model 1 contains no ce, it could be seen that it is not affected. In Model 2, the price will be higher than Model 1, and as ce becomes larger, it is capable to set for a higher price.

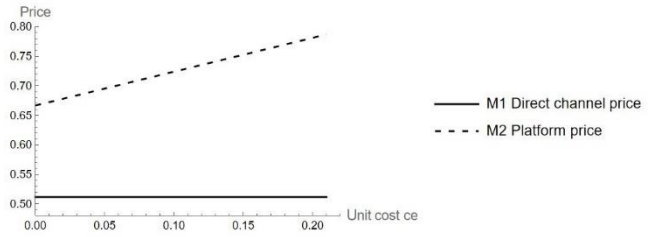

Fig. 1. Influence of ce on price.

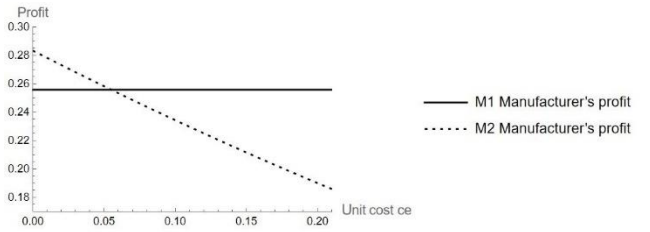

Fig. 2. Influence of ce on profit.

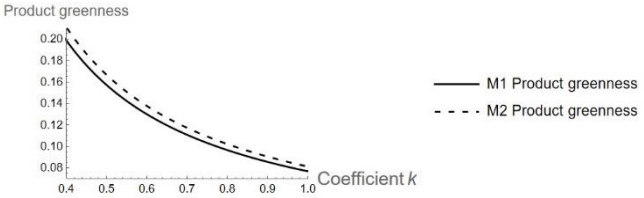

Fig. 3. Influence of k on product greenness.

Fig. 2 illustrates the influence of ce on profits. Once more, ce has no affection for Model 1, but has a negative impact on Model 2. Thus, Model 2 benefits the manufacturer when the unit cost ce is small. The value of ce is one of the key factors that may affect a manufacturer's determination on the choice of distribution channel. However, it could be assumed that along with the advancement in technology development, ce may be high at the beginning of the investment or cooperation with the platform, and then decrease over time.

Lastly, in Fig. 3, the influence of coefficient k on product greenness will be examined. The parameter variation range for the coefficient k is from 0.4 to 1.0. As k becomes larger, it directly reduces the product greenness in both models. On the other hand, Model 2 yields a higher level of product greenness than Model 1. It suggests that when a manufacturer determines to sell its product through the platform, it contributes to a better product environmentally.

V. CONCLUSION AND FUTURE RECOMMENDATION

In this research, we studied a supply chain which consists of a manufacturer producing green products, and an online sales platform utilizing blockchain technology in a market with consumers having environmental awareness. We built Model 1 in which the manufacturer sells the product through the direct channel exclusively, and Model 2 in which the manufacturer sells the product through the online sales platform exclusively. The manufacturer decides its channel choice in terms of profit maximization.

Our analysis revealed that selling through the platform will provide the manufacturer with a better foreseeable future assuming that the environmental greenness may become a significant aspect to consumers. Furthermore, Model 2 allows the manufacturer to set a higher price for the product, which leads to a higher profit for itself.

Viewed from the perspective of product greenness, Model 2 provides a greener product than Model 1. This suggests that when the manufacturer decides to sell through the online sales platform, the supply chain will be elaborated with better transparency and credibility. The combination of blockchain technology and green investment could effectively raise the level of environmental protection.

Two extensions to this study are possible. First, we could allow for different distribution channels and explore how different channel configurations and model parameters affect the manufacturer's channel and price decisions. The other extension is to consider coordination mechanisms that yield a win-win outcome in the considered supply chain.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

Author Contributions

C. H. Hsiao, J. J. Lai and C. C. Hsieh contributed to the design and implementation of the research, the analysis of the results, and the writing of the manuscript.

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