Impact of the IoT Integration and Sustainability on Competition Within an Oligopolistic 3PL Market

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***Abstract*—The third party logistics (3PL) sector holds a crucial role in modern supply chains, streamlining the movement of goods and optimizing logistics operations. The 3PL industry's journey towards digitalization and sustainability reflects a crucial strategy to create an efficient and resilient supply chain. It is increasingly integrating Internet of Things technologies (IoT) within its operations. This latter is a cutting-edge technology widely used in the supply chain realm as it offers numerous advantages namely traceability and real-time decision-making capability. In view of growing concerns for the environment and the social welfare, supply chain actors are seeking to make various initiatives to shift to more sustainable practices. This paper studies the competition within an oligopolistic market of 3PL firms. Through the lens of game theory, we construct a mathematical model where a supply chain composed of n firms competes through pricing, IoT integration efforts and sustainability efforts. Results show that the IoT integration and sustainability efforts impact the pricing decisions of the firm. Moreover, this study highlights how the rivals' decisions on the IoT integration and sustainability efforts impact the firm's decision-making processes. Furthermore, a comparison of the model decision variables within a duopoly and an oligopolistic setting is conducted. This paper concludes to the significant impact of the rivals' strategies on the firm's decisions and profitability.**

***Keywords*—Third party logistics; internet of things; sustainability; oligopoly; game theory**

I. Introduction

The modern business world has changed drastically in the twenty-first century. Globalization and rapid economic expansion have heightened competition across both global and local markets. Coupled with escalating customer expectations and shorter product lifecycles, supply chains have evolved and become increasingly demanding to manage. Considering the growing complexity of the supply chains, firms are now urged to focus on their core business in order to maintain competitiveness.

Outsourcing logistics activities is considered a practical strategy for companies to reduce their operational costs, decreasing inventory, eliminating capital investment in logistical assets, minimizing labor expenses, and enhancing service standards through enhanced logistical proficiency and broader geographical reach [1]. The realm of third-party logistics is a firmly established business sector. They offer a large range of services from picking and packing to managing and coordinating the whole supply chain [2]. While warehousing and transportation remains their main activity, they also provide services such as product collection, brokering, shipping, material management storing, alongside offering expertise in supply chain strategy and access to technological resources [2]. Over the past few years, the 3PL market has seen substantial growth, resulting in heightened competition and a notable transformation in its competitive environment. 3PLs that prioritize standard services might face a notable reduction in their market share in the coming years. Additionally, external competitors are increasingly venturing into management-focused 3PL activities, potentially diminishing the role of 3PLs to simpler forwarding functions [3]. 3PL firms are thus urged to optimize their service and their strategic models to remain competitive.

In light of the growing interdependence among companies on a global scale, companies are expected to take responsibility for the environmental and social impact of their operations, extending scrutiny throughout their entire supply chain, both incoming and outgoing [4]. Consequently, 3PLs are now facing new challenges in managing their supply chain and processes in a sustainable manner. As sustainability has become a major concern, companies have started adopting new innovative environmentally friendly and socially responsible practices throughout their value chain.

Over the past years, numerous Third-Party Logistics (3PL) companies have adjusted their operations and strategies to prioritize sustainability in their activities. The environmental handling of transportation plays a pivotal role in establishing a greener supply chain, urging corporations to enhance their performance metrics and to mitigate adverse external influences stemming from their logistics operations, like carbon emissions.[5]. There are various approaches to shift to a more environmental and social operations namely, using cleaner fuel, using low-emission vehicles, reduce travel distances and improve vehicle efficiency. Given all the above, 3PL firms predict that shifting to a more sustainable operations will become a standard benchmark in their decision-making process [5].

On the other hand, Third-Party Logistics (3PLs) have faced growing challenges posed by disruptive business models and the emergence of digital technologies [3]. Globally, a rising interest has been on digitalization, creating value across various industries and supply chains. Implementing disruptive technologies with the value chain can optimize business advantages and unveil novel forms of value. Nonetheless, technological transformation presents a distinct set of challenges [6]. Logistics service providers face digital challenges stemming from emerging technologies like

Blockchain, Data analytics, IoT, autonomous vehicles and 3D printing. These technologies range from mature to emerging and create several opportunities for the supply chain sector, however simultaneously changing logistics needs and expectations [3].

One of the main industry 4.0 technologies utilized in the supply chain sector is the Internet of things technologies. The primary technologies utilized for IoT include sensors, smart chips, wireless transmission networks, machine-to-machine communication (M2M), and notably, high-speed communication channels, robust computing capabilities, and expansive data storage capacities. IoT finds application in various logistics activities, i.e. cargo tracing, warehouse and fleet management, predictive asset maintenance, route optimization, smart containers, optimizing capacity usage, truck platooning[7].Furthermore, these technologies are now being employed to oversee and manage environmental risks and human rights concerns, promoting sustainable production and consumption [4].

The competitive dynamics within the industry and the industry 4.0 technologies are evolving swiftly, paving the way for entirely new participants, and transforming the role of 3PLs [8].Consequently, Third-Party Logistics (3PLs) must respond to these changes to hold their position as primary providers of logistics solutions. Digitalization is constructing a fresh competitive landscape as it impacts the business models of Third-Party Logistics [9] . In addition to the shift to sustainable practices, 3PL firms are faced with numerous challenges. One of the main hurdles 3PL face is the high investments needed to meet the digitalization and sustainability requirements and a great pressure on pricing and quality of service [3]. Moreover, they are challenged by finding the balance between the customers' continuous need for standardized services and the necessity to offer more advanced services to remain competitive. Finding this balance puts great pressure on the strategic evolution of the 3PL [2].

Researchers have continuously showed interest in this area of research. However, there has been limited utilization of mathematical modelling to address the problem, with most focus placed on conceptual and statistical analyses instead [10]. Given the complexity of the supply chains encompassing several participants, researchers have used game theory to analyze the complex interactions within the supply chain. This research will consider an oligopoly market of 3PLs investigating the competition among the 3PL firms regarding their pricing strategies, integration of IoT efforts, and sustainability efforts aimed at maximizing profits and maintaining competitiveness within the market.

This research investigates the following questions:

- How do IoT integration and sustainability initiatives into the 3PL service affect the pricing decisions?
- How does competition's strategy affect the firm's decision-making process in terms of price, IoT and sustainability efforts?
- To what extent do IoT and sustainability investments influence the firm's profitability?

This paper will be structured as follow: Section II will present a literature review of our scope of research, the description of our mathematical model will be presented in Section III, we will then present some analytical results and insights of our model in Section IV, and lastly Section V will present a conclusion of our findings.

II. LITERATURE REVIEW

This paper is related to three main streams of research: Internet of Things in supply chain, sustainable supply chain and Third-party logistics.

A. Internet of Things and Sustainability in Supply Chains

The rapid growth of digitalization under the banner of "Industry 4.0" has reshaped and redesigned the nature of businesses. Companies worldwide have shifted their focus to digitalization due to the significant benefits it offers. Utilizing digitalization is a vital tool in achieving efficient and sustainable logistics ecosystems through enhanced transportation systems and new value-added services [2], [11]. Industry 4.0 has introduced a wide range of revolutionary technologies namely Blockchain, Artificial intelligence, Internet of Things, Augmented reality, Data Analytics, and others. These latter have proved numerous advantages in the logistics industry enabling real-time transparency along the entire value chain, enhanced efficiency and visibility, autonomous decision-making, intelligent integrated planning systems and smart warehousing and procurement [11].

Throughout the years, these technologies have shifted the business paradigm in various industries notably in the logistics world. To capitalize on the opportunities presented by digitalization in the business world, companies should consider the appropriate approaches and tools required to transition toward the Digital Supply Chain [6].

IoT is emerging as a rapidly advancing technology that an increasing number of industries are eager to embrace in the aim of enhancing their operational efficiency. It offers numerous valuable avenues to enhance traditional SC such as improved asset utilization, enhanced supply chain performance and greater reliability [12] Moreover, it enables the development of an intelligent infrastructure within supply chains, bringing together vast volumes of data, information, and all supply chain processes, providing real-time decision-making processes [4], [13].

IoT exhibits potential applications within supply chains, yet it confronts various hurdles during implementation. Most emerging technologies introduce several risks and challenges in the process of implementation. These factors should be considered and outline the essential measures for establishing the technology infrastructure. Clearly defining the infrastructure's characteristics during the implementation phase can also aid in better understanding of the technological needs and priorities [6]. Key challenges preventing the full exploitation of IoT in supply chains involve issues related to security, privacy, and scalability. IoT relies on wireless technology, and its applications are constructed using a multitude of sensor nodes [12].

Sustainability has become a major concern for all businesses and sectors in view of customers' requirements and new strict regulations. Companies are progressively paying more attention to social and environmental issues that surround their value chain, i.e. human rights abuses, child labor, deplorable work environments, unethical practices like corruption and bribery, or failure to adhere to environmental regulations [4]. Achieving a sustainable supply chain is ensuring the compliance to environmental and social conditions of all the stakeholders across the whole value chain while maintaining economic profitability. In this context and in view of the expansion of global supply chains, companies are faced with multiple challenges upon adopting more sustainable practices in every possible stage of the value chain.

The introduction of the sustainable development concept has motivated managers and policymakers across various sectors to incorporate environmental and social concerns alongside economic goals in their strategic planning [14]. It has become vital to improve the design and management of supply chain and logistics methods. To enhance the environmentally friendly and sustainable supply chain, a holistic and integrated approach to transportation and environmental policies is essential. This approach should integrate crucial regulations and economic incentives in a transparent manner across all modes of transportation [15].

Furthermore, the rapid development of the industry 4.0 technologies is expected to lead to a significant transformation in how businesses approach their strategies and operations in logistics. It has generated a demand for a new business model focused on a digitally connected, intelligent, exceptionally efficient, and environmentally responsible logistics system that provides complete transparency to all stakeholders [11]. The logistics sector is one of the most concerned with sustainability since it is considered one of the less sustainable sectors and one of the main sources of CO2 and GHG emissions [16]. Digitization alone presents a significant potential to decrease emissions in the logistics sector, with the potential to achieve emissions reductions of approximately 10 to 12% by 2025, as well as contribute to the decarbonization of the global economy [11]. Organizations can employ data to facilitate communication among different supply chain functions, such as procurement, manufacturing, distribution, sales and marketing, and post-sales services. From an economic standpoint, sustainable logistics can reduce costs by preserving product quality during transportation, ensuring product availability, and optimizing processes [15].

Digitalization in logistics enables among others cooperation, connectivity, adaptiveness, integration, and autonomous control. These latter impacts various sustainability criteria in all three dimensions. From an economic stand view, it helps achieve optimized logistics costs, delivery time, forecast accuracy, flexibility, and reliability. In terms of environmental concerns, it encourages a better emission and waste management as well as energy and resource efficiency. As of the social point of view, it promotes better labor patterns and health and safety conduct [11]. In particular, the implementation of IoT technologies has proved its direct and indirect benefit in leveraging sustainability in the supply chains. With its capacity to sense monitor and track in real time, IoT technologies contribute majorly to an optimized real time and decentralized decision-making process. With ensuring a transparent efficient value chain, greener supply chains, decreased emissions, better lead times and optimized costs, the adoption IoT promotes the sustainability of organizations [15], [17], [18].

B. Third Party Logistics

The emergence of 3PL service providers can be traced back to the outsourcing trend of the early 1990s. This subject remains a steadily expanding area of concern and engagement, particularly within the fields of logistics and supply chain management [19]. Logistics is a crucial component of any company's supply chain. Outsourcing enables businesses to be more agile and concentrate on their core operations, improve customer service, and reduce assets [20]. Furthermore, it helps companies in reducing expenses, enhancing efficiency, sustainability, customer satisfaction, and overall profitability [1]. As more companies are seeking 3PL services to stay competitive in the global market landscape, 3PL market has grown significantly and has become notably competitive and diverse. It encompasses numerous companies, varying in size and specialization in logistics services, including transportation, inventory management, warehousing, and distribution. Cost and service quality are frequently the primary factors to consider when assessing a logistics partner [21], however in view of the growing sustainability pressure, social and environmental sustainability will become a crucial criterion for 3PL evaluation [20].

Out of all the methods to meet sustainability objectives within a supply chain, collaborating with third-party logistics firms has garnered considerable interest. Through the delivery of environmentally friendly and effective transportation services, 3PLs can assist various types of supply chains, including regular, closed loop, and circular ones, in achieving higher profits while maintaining sustainability, particularly in the distribution and collection/recycling phases [14]. Consequently, the pursuit of sustainable practices by third-party logistics (3PLs) companies has evolved into a substantial and intricate issue [22].

The literature has showed increasing interest in sustainability in relation to 3PL, particularly in the assessment and selection of 3PL. various decision-making models for evaluating and selecting 3PL from a sustainability point of view have been proposed in the literature [16], [23], [24], [25], [26]. Carbon emissions and delivery time for customer satisfaction are the leading criteria taken into consideration while selecting 3PL. Environmental sustainability of the 3PL have drawn the most interest of the academia, while social sustainability remains under-researched. 3PL companies are now urged to offer more environmentally friendly and socially appropriate services to stay competitive.

The service industry tends to expand and evolve alongside with globalization, technological developments, and the increasingly competitive markets. These factors challenge businesses to maintain high service quality [27]. As the third-party logistics market has expanded considerably, competition has increased. Shifting to a smart tech driven 3PL provider is a must. Researchers showed their interest in the adoption of the

IoT technologies to enhance their performance and decision-making process. IoT technologies can be used in different core processes of 3PL services enabling real time logistics, enhanced flexibility, and overall improved efficiency of logistics operations.

C. Related Works

Supply chain remains a complex system considering it involves numerous players or groups of decision-makers, ergo they are suitable to be examined through the prism of Game theory [28]. This latter provides a framework for modelling these complex interactions and has been widely used among researchers in analyzing supply chain issues [14], [28], [29].

Price is one of the main criteria considered in decision making [14], hence game models for pricing problems is mature [30]. Multiple games in the literature have dealt with pricing in logistics under various factors in addition to costs variables, namely sustainability indicators, risk, competition indicators etc.[30]. Most scholars have showed their interest in investigating pricing models of two echelon supply chains. The latter is composed mainly by manufacturer/supplier/producer and retailer and three echelon supply chains composed of manufacturer/supplier/producer and retailer and 3PL.

Investigating pricing strategies considering the environmental sustainability, closed loop supply chain and green production has been the focus of various papers [5], [14], [29], [31], [32]. [33]. The economic growth and environmental protection are extensively considered in the literature, whereas the social responsibility dimension of sustainability remains under explored comparably. The author in [10] explored the influence of transparency on the demand function and examines how transparency and corporate social responsibility affect the choices made by supply chain members and their profits concerning an environmentally friendly product. The author in [33] explores a supply chain framework featuring both a Green Supply Chain (GSC) and a Non-Green Supply Chain (NGSC), each consisting of a manufacturer and a retailer. The paper introduces a novel competitive mathematical model where the government acts as a leader, discussing pricing policies, greening strategies, and government tariffs under competitive conditions influenced by governmental financial policies. The author in [34] proposes two models; Model 1 aims to assess the optimal green quality, selling price, and business approach in green marketing in a cooperative business strategy between a manufacturer and a retailer involved in marketing green products. Whereas model 2 examines the price competition between two CSR firms, regular producer, and a green producer.

On the other hand, digitalization, and the use of IoT has also attracted attention of researchers in decision making models. The proposed models explored investment decisions [35], [36], [37], as well as outsourcing decisions [38]. Furthermore,[39] examined how integrating IoT can affect the quality of service of the 3PL firms in a duopoly market setting, while [40] has combined both digitalization and sustainability in its game model. This latter investigated the effectiveness of competitive sustainability services, digitalization services, and pricing decisions in a 2-tier supply chain structure of a manufacturer and a retailer.

Through the lens of game theory, researchers have explored the competition in pricing strategies in 2-tier supply chains, focusing on monopolistic and duopolistic settings. Fewer researchers have focused on pricing decision games in an oligopoly market structure. Reference [41] focused on aligning pricing and advertising decision in a multi-product, multi-echelon supply chain comprising several suppliers, one manufacturer, and multiple retailers with horizontal and vertical competition. While [42] considered competition between multiple supply chains, each composed of a manufacturer and a salesperson.

Game theory, a critical tool in supply chain management, has been extensively utilized across various scenarios. However, its specific application to 3PL and sustainability within the context of the IoT remains relatively nascent. This gap highlights an emerging area of interest where the interactions between 3PL providers, sustainability practices, and digital technologies can be explored through the lens of game theory. Research focusing on how 3PL companies make decisions regarding sustainability and the integration of IoT technologies is still in its early stages, particularly when examining these factors within an oligopolistic market context. Additionally, while the concepts of sustainability and digitalization have begun to attract academic attention, much of the existing literature remains theoretical frameworks. Another significant gap in current research is the exploration of competitive pricing strategies for 3PL services in a market where multiple players compete for advantage. Our research aims to fill these gaps by providing insights into the pricing dynamics of 3PLs in competitive markets, particularly focusing on how these companies can leverage IoT and sustainability within their strategic decision process.

III. Model Description

We consider a competitive setting of n 3PL firms, which is denoted $i = \{1, \dots n\}$, offering homogenous service. Fig. 1 illustrates the market setting and competitiveness in our proposed model.

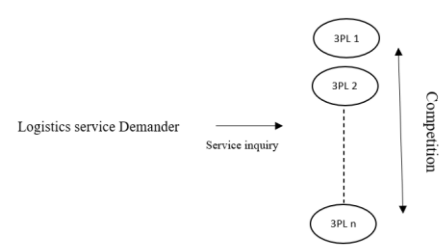

Fig. 1. The proposed model.

In light of more competitive and demanding customers, in terms of quality, service and sustainability, and in addition to a competitive environment the 3PL firms are constrained to make complex strategic decisions.

Let us consider the 3PL firms compete through price, technology, and sustainability. In our paper, we consider an IoT integration effort β. On the other hand, sustainability has become a perquisite concern for all supply chain entities. Since sustainability encompasses three aspects, namely economic, environment and social, diverse actions and approaches can be considered to make supply chain operations more sustainable. In line with [40] and to keep our model simple, we will consider a sustainability effort level σ that covers different sustainability initiatives that can be taken.

To remain competitive, 3PL needs to determine the optimal choices in terms of price and services. In our paper, we aim to investigate the optimal price, IoT integration and sustainability effort to maximize the profit.

Similar to [40], [43], the inverse demand function for firm i is expressed as follows:

$$D_i = \frac{a}{n} - \alpha p_i + \frac{\gamma}{n-1}\sum_{k\neq i}^{n} p_k + T_i\beta_i - \frac{1}{n-1}\sum_{k=1}^{n} T_k\beta_k + S_i\sigma_i - \frac{1}{n-1}\sum_{k=1}^{n} S_k\sigma_k \ \ (k \neq \mathrm{i}) \tag{1}$$

We assume the firm's demand function is a decreasing function of its own price and increasing on its competitors' price. Moreover, the firm's demand is influenced by IoT integration and sustainability efforts, where higher efforts of the firm will increase their demand while the rivals' efforts will bring down the firm's demand.

The total market demand is expressed as follows where it is solely influenced by the price of the firms. $D_T = \sum_{i=1}^{n} D_i$

$$D_T = a + (\gamma - \alpha)\sum_{k=1}^{n} p_k \tag{2}$$

A. Notations

1) Input parameters

D_i	Demand function of firm i
a	Market share
α	Self-price sensitivity
γ	Cross-price sensitivity
T_i	Market sensitivity of firm i to the IoT integration
S_i	Market sensitivity of firm i to the sustainability effort
λ	IoT integration cost factor
θ	Sustainability initiative cost factor

2) Decision variables

p_i	3PL firm i's price
β_i	3PL firm i's IoT integration effort
σ_i	3PL firm i's sustainability effort

The cost of the service for firm i is composed of a fixed cost dependent of the demand Ci and demand independent costs encompassing the costs of IoT integration C_i^T and sustainability effort C_i^S. Choosing to invest in such technology and sustainable practices can bring a competitive edge to the firms however it is still financially challenging. As employed widely in the literature [10], [40], we consider quadratic cost functions for firm i expressed as follows:

$$C_i^T = \frac{\lambda {\beta_i}^2}{2} \tag{3}$$

$$C_i^S = \frac{\theta {\sigma_i}^2}{2} \tag{4}$$

Based on the above, the 3PL firm i's profit function is modelled as follows:

$$\pi_i = (p_i - C_i)D_i - C_i^T - C_i^S \tag{5}$$

$$\max_{p_i,\beta_i,\sigma_i} \pi_i = (p_i - C_i)\left(\frac{a}{n} - \alpha p_i + \frac{\gamma}{n-1} p_{k_i} + T_i\beta_i - \frac{1}{n-1}\sum_{k=1}^{n} T_k\beta_k + S_i\sigma_i - \frac{1}{n-1}\sum_{k=1}^{n} S_k\sigma_k\right) - \frac{\lambda\beta_i^2}{2} - \frac{\theta\sigma_i^2}{2} \tag{6}$$

This paper addresses modelling various decision-making strategies employed by 3PL firms under competition in an oligopoly setting. It aims to identify the most advantageous decisions related to price IoT technology and sustainability efforts to maximize their profits.

All the firms decide on their price, IoT integration and sustainability efforts simultaneously, the optimal price, IoT integration and sustainability effort of firm i are calculated as follows:

$$p_i, \beta_i, \sigma_i \underset{p_i,\beta_i,\sigma_i}{\in} \arg\max \pi_i(p_i, \beta_i, \sigma_i) \tag{7}$$

$$\frac{\partial \Pi_i}{\partial p_i} = \frac{a}{n} + \frac{\sum_{k=1}^{n} T_k\beta_k}{n-1} - \frac{\sum_{k=1}^{n} S_k\sigma_k}{n-1} - 2\alpha p_i + C_i\alpha + T_i\beta_i + \frac{\gamma p_{k_i}}{n-1} + S_i\sigma_i \tag{8}$$

$$\frac{\partial \pi_i}{\partial \beta_i} = (p_i - C_i)T_i - \beta_i\lambda \tag{9}$$

$$\frac{\partial \pi_i}{\partial \sigma_i} = (p_i - C_i)S_i - \theta\sigma_i \tag{10}$$

In order to analyze the concavity of the function we use the hessian matrix expressed as follows:

$$H_i = \begin{bmatrix} \frac{\partial^2 \pi_i}{\partial p_i^2} & \frac{\partial^2 \pi_i}{\partial p_i \beta_i} & \frac{\partial^2 \pi_i}{\partial p_i \sigma_i} \\ \frac{\partial^2 \pi_i}{\partial \beta_i p_i} & \frac{\partial^2 \pi_i}{\partial \beta_i^2} & \frac{\partial^2 \pi_i}{\partial \beta_i \sigma_i} \\ \frac{\partial^2 \pi_i}{\partial \sigma_i p_i} & \frac{\partial^2 \pi_i}{\partial \sigma_i \beta_i} & \frac{\partial^2 \pi_i}{\partial \sigma_i^2} \end{bmatrix} \tag{11}$$

$$H_i = \begin{bmatrix} -2\alpha & T_i & S_i \\ T_i & -\lambda & 0 \\ S_i & 0 & -\theta \end{bmatrix} \tag{12}$$

We have

$$\frac{\partial^2 \pi_i}{\partial p_i^2} < 0 \quad \frac{\partial^2 \pi_i}{\partial \beta_i^2} < 0 \quad \frac{\partial^2 \pi_i}{\partial \sigma_i^2} < 0 \tag{13}$$

And

$$\det H_i = {T_i}^2\theta + {S_i}^2\lambda - 2\alpha\theta\lambda \tag{14}$$

$$\det H_i > 0 \ if \ {T_i}^2\theta + {S_i}^2\lambda - 2\alpha\theta\lambda > 0$$

We suppose

$$S_i^2 - 2\alpha\theta > 0 \tag{15}$$

Since $\lambda > 0$ and $T_i^2\theta > 0$ hence $\det H_i > 0$

Accordingly, the hessian matrix H_i is negative definite. Hence the profit function of firm i is concave in p_i, β_i, σ_i.

By utilizing the function described in equation (6), we can calculate the equilibrium price p_i^* , IoT integration effort β_i^* and sustainable effort σ_i^* of firm i by examining the first-order conditions associated with each of these variables:

$$\frac{\partial \pi_i}{\partial p_i} = 0 \xrightarrow{yields} p_i^* = \frac{a(n-1)-n\sum_{k=1}^{n} T_k\beta_k - n\sum_{k=1}^{n} S_k\sigma_k - C_i n\alpha + C_i n^2\alpha - nT_i\beta_i + n^2T_i\beta_i + p_{k_i}n\gamma - nS_i\sigma + n^2S_i\sigma_i}{2n\alpha(n-1)}$$

$$p_i = \frac{a(n-1)+n(-\sum_{k=1}^{n} T_k\beta_k - \sum_{k=1}^{n} S_k\sigma_k + C_i\alpha(n-1)+(n-1)T_i\beta_i + p_{k_i}\gamma + (n-1)S_i\sigma_i)}{2(n-1)n\alpha} \quad (16)$$

$$\frac{\partial \pi_i}{\partial \beta_i} = 0 \xrightarrow{yields} \beta_i^* = \frac{(p_i - C_i)T_i}{\lambda} \quad (17)$$

$$\frac{\partial \pi_i}{\partial \sigma_i} = 0 \xrightarrow{yields} \sigma_i^* = \frac{(p_i - C_i)S_i}{\theta} \quad (18)$$

By solving (16) (17) and (18) simultaneously, the optimal equilibrium solutions $(p_i^*, \beta_i^*, \sigma_i^*)$ can be derived:

$$p_i^* = \frac{C_i{T_i}^2\theta + \lambda(C_i{S_i}^2 - \theta(\frac{a}{n} + C_i\alpha + \frac{p_{k_i}\gamma}{n-1} - \frac{\sum_{k=1}^{n} T_k\beta_k}{n-1} - \frac{\sum_{k=1}^{n} S_k\sigma_k}{n-1}))}{{T_i}^2\theta + \lambda({S_i}^2 - 2\alpha\theta)} \quad (19)$$

$$\beta_i^* = \frac{T_i(a\theta - an\theta + n\theta\sum_{k=1}^{n} T_k\beta_k + n\theta\sum_{k=1}^{n} S_k\sigma_k - C_i n\alpha\theta + C_i n^2\alpha\theta - p_{k_i}n\gamma\theta)}{n(n-1)({T_i}^2\theta + {S_i}^2\lambda - 2\alpha\theta\lambda)} \quad (20)$$

$$\sigma_i^* = \frac{S_i(a\lambda - an\lambda + \sum_{k=1}^{n} T_k\beta_k n\lambda + n\lambda\sum_{k=1}^{n} S_k\sigma_k - C_i n\alpha\lambda + C_i n^2\alpha\lambda - p_{k_i}n\gamma\lambda)}{n(n-1)({T_i}^2\theta + {S_i}^2\lambda - 2\alpha\theta\lambda)} \quad (21)$$

To simplify the optimal equilibrium solutions, we consider the following variables: B is the sum of rivals' IoT integration effort function, W is the sum of rivals' sustainability effort, and G is the sum of rivals' price. The equilibrium values of the decision variables are thus expressed as follows:

$$p_i^* = \frac{C_i{T_i}^2\theta + \lambda(C_i{S_i}^2 - \theta(\frac{a}{n} + C_i\alpha + \frac{G\gamma}{n-1} - \frac{B}{n-1} - \frac{W}{n-1}))}{{T_i}^2\theta + \lambda({S_i}^2 - 2\alpha\theta)} \quad (22)$$

$$\beta_i^* = \frac{T_i(a\theta - an\theta + n\theta B + n\theta W - C_i n\alpha\theta + C_i n^2\alpha\theta - Gn\gamma\theta)}{n(n-1)({T_i}^2\theta + {S_i}^2\lambda - 2\alpha\theta\lambda)} \quad (23)$$

$$\sigma_i^* = \frac{S_i(a\lambda - an\lambda + Bn\lambda + n\lambda W - C_i n\alpha\lambda + C_i n^2\alpha\lambda - Gn\gamma\lambda)}{n(n-1)({T_i}^2\theta + {S_i}^2\lambda - 2\alpha\theta\lambda)} \quad (24)$$

IV. Analytical Results and Insights

This section includes the execution of analytical and parametric sensitivity analyses alongside their corresponding corollaries and implications. To answer our research questions, we first examined the impact of the IoT integration and sustainability efforts of a firm i on its own price. Furthermore, we analyzed the impact of IoT integration and sustainability efforts of rival firms (B,W) on the firm's price, IoT integration and sustainability efforts. Given that the IoT implementation and sustainability practices costs are significant investments, we also explored the impact of their cost factors on the firm's decisions on price, IoT integration and sustainability efforts.

A. Impact of the IoT Integration Effort on the Equilibrium Price

Proposition 1: Increasing the IoT integration efforts of a firm leads to an increase in their price.

Corollary 1: The increase of the IoT integration effort of a firm leads to an increase in their price. This is due to the high costs associated with the technological investments and maintenance. Moreover, the magnitude of the effect of the integration effort on the price is influenced by the ratio of firm's demand sensitivity to the IoT integration and its price elasticity. This suggests that the degree of effect depends on how significantly sensitive is the 3PL market to the technology integration. In a more competitive technology-oriented market, the impact of integrating the IoT technology will be more significant.

Proof 1: By calculating the derivative of the equilibrium price of firm i by the IoT integration rate β_i, we can analyze how the changes in the integration rate can affect the price of firm *i*. Based on (16) we get:

$$\frac{\mathrm{d}p_i^*}{\partial \beta_i} = \frac{n^2T_i - nT_i}{2(n-1)n\alpha} = \frac{T_i}{2\alpha} \quad (25)$$

Since $\frac{T_i}{2\alpha} > 0$, hence the proposition.

B. Impact of the Sustainability Effort on the Equilibrium Price

Proposition 2: Increasing the sustainability efforts of a firm leads to an increase in their price.

Corollary 2: Changes in the sustainability effort positively affect the pricing of the service. As the effort increases the price increases as well. This is due to the costs associated to incorporating more sustainable practices in the 3PL services. Furthermore, the significance of the impact on the price depends on how the market is sensitive to the proposal of more sustainable service.

Proof 2: To analyze the impact of sustainability practices on the pricing, we calculate the derivative of the equilibrium price with respect to its sustainability effort.

$$\frac{\partial p_i^*}{\partial \sigma_i} = \frac{-nS_i + n^2S_i}{2n\alpha(n-1)} = \frac{S_i}{2\alpha} \quad (26)$$

Since $\frac{S_i}{2\alpha} > 0$, hence the proposition

C. Impact of the IoT Integration Level and Sustainability Effort Level of Rival Firms (B,W) on Price

Proposition 3: Equilibrium price goes up with the increase of IoT integration and sustainability effort level of rival firms *(B,W)*.

Corollary 3: The pricing strategy is significantly influenced by the IoT integration and sustainability efforts adopted by rival firms. As IoT integration and sustainability initiatives of competitors increase, the equilibrium price goes up. Understanding and being aware of these strategies implemented by competitors becomes crucial for firms aiming to maximize their profits. Such insights allow firms to strategize their IoT integrations and sustainability efforts and set their prices, leveraging the market trends. Encouraging cooperative models among firms emerges as an appealing approach. This enables firms to adapt collectively to market changes, ensuring better profitability while meeting evolving customer preferences for digitalization and sustainability.

Proof 3: The derivative of the equilibrium price with respect to the rivals' integration and sustainability efforts is calculated as follows:

$$\frac{\partial p_i^*}{\partial B} = \frac{\theta\lambda}{(n-1)(T^2\theta+(S^2-2\alpha\theta)\lambda)} \quad (27)$$

$$\frac{\partial p^*}{\partial W} = \frac{\theta\lambda}{(n-1)(T^2\theta+(S^2-2\alpha\theta)\lambda)} \quad (28)$$

According to (15) we have $(T^2\theta + S^2\lambda - 2\alpha\theta\lambda) > 0$ and since $\theta\lambda > 0$ hence the proposition.

D. Impact of the Average IoT Integration Level and Sustainability Efforts of Rival Firms (B,W) on IoT Integration Level

Proposition 4: As the IoT integration and sustainability effort of rivals increases, the equilibrium IoT integration effort increases.

Corollary 4: When the efforts of sustainability and IoT integration among rival firms increases, it positively influences the equilibrium IoT integration level. This scenario signifies the market landscape where sustainability and IoT implementation norms are escalating impacts the firm's strategic choices on the level of IoT integration. As rivals collectively intensify their focus on sustainability and digitalization initiatives, it exhibits a positive impact on the equilibrium integration level of the firm. To remain competitive and align with evolving market standards, the firm is urged to increase its IoT integration efforts.

In the context of 3PL market, when a firm increases its IoT integration rate and gain competitive advantage, the other firms tend to follow to stay competitive. Moreover, this also suggests the possibility of cooperation between the firms in investing on the implementation of IoT technology in their fleet and warehouses.

Proof 4: The derivative of the equilibrium IoT integration effort with respect to the rivals' average integration and sustainability efforts is calculated as follows:

$$\frac{\partial \beta^*}{\partial B} = \frac{T\theta}{(-1+n)(T^2\theta+S^2\lambda-2\alpha\theta\lambda)} \quad (29)$$

$$\frac{\partial \beta^*}{\partial W} = \frac{T\theta}{(-1+n)(T^2\theta+S^2\lambda-2\alpha\theta\lambda)} \quad (30)$$

According to (15) we have $(T^2\theta + S^2\lambda - 2\alpha\theta\lambda) > 0$and since $T\theta > 0$ hence the proposition.

E. Impact of IoT Integration Level and Sustainability Effort Level of Rival Firms (B,W) on Sustainability Efforts

Proposition 5: As the IoT integration and sustainability level of rivals increases, sustainability effort level increases.

Corollary 5: When the efforts of sustainability and IoT integration among rival firms increases, it positively influences the sustainability effort level. This scenario signifies the market landscape where sustainability and IoT implementation norms are escalating impacts the firm's strategic choices on the level of IoT integration. As rivals collectively intensify their focus on sustainability and digitalization initiatives, it displays a positive impact on the equilibrium sustainability effort of the firm. To remain competitive and align with evolving market standards, the firm is urged to increase its IoT integration efforts.

Proof 5: The derivative of the equilibrium price with respect to the rivals' average integration and sustainability efforts is calculated as follows:

$$\frac{\partial \sigma^*}{\partial B} = \frac{S\lambda}{(n-1)(T^2\theta+S^2\lambda-2\alpha\theta\lambda)} \quad (31)$$

$$\frac{\partial \sigma^*}{\partial W} = \frac{S\lambda}{(n-1)(T^2\theta+S^2\lambda-2\alpha\theta\lambda)} \quad (32)$$

According to (15) we have $(T^2\theta + S^2\lambda - 2\alpha\theta\lambda) > 0$ and since $S\lambda > 0$, hence the proposition.

F. Impact of IoT Integration and Sustainability Effort cost Factor (λ,θ) on IoT Integration Effort

Proposition 6: IoT integration effort decreases with the increase of the IoT implementation cost factor if the following is established:

$$B + W > (n-1)\left(\frac{a}{n} - C\alpha\right) + G\gamma \quad (33)$$

Corollary 6: The cost factor of the IoT integration of a firm is an influencing factor in the decision making of the IoT integration effort, under certain conditions linked to both customer sensitivity to the sustainability effort and the rival strategies. Under these conditions, an increase in the IoT integration cost factor leads to a decrease in the equilibrium level of IoT integration. This case is expected as firm will face the barrier of high implementation costs. However, in the case when (33) is not met, the equilibrium IoT integration level increases although the IoT integration cost increases. In that scenario, the customers are less sensitive to the sustainability effort and rivals' IoT integration and sustainability efforts are low.

Proof 6: Based on (23) the derivative of the IoT integration effort β^* with respect to its cost factor λ can be calculated as follows:

$$\frac{\partial \beta^*}{\partial \lambda} = -\frac{\mathrm{T}\theta(S^2-2\alpha\theta)(\frac{a}{n}-a+B+W-C\alpha+Cn\alpha-G\gamma)}{(n-1)(T^2\theta+S^2\lambda-2\alpha\theta\lambda)^2} \quad (34)$$

$(S^2 - 2\alpha\theta)(a/n - a + B + W - C\alpha + Cn\alpha - G\gamma) > 0$ implies $\frac{\partial \beta^*}{\partial \lambda} < 0$. Accordingly to (15), $\frac{\partial \beta^*}{\partial \lambda} < 0$ when $(a/n - a + B + W - C\alpha + Cn\alpha - G\gamma) > 0$ .On the other hand, when $\left(\frac{a}{n} - a + B + W - C\alpha + Cn\alpha - G\gamma\right) < 0$ it implies $\frac{\partial \beta^*}{\partial \lambda} > 0$.

Proposition 7: IoT integration effort increases with the increase of the sustainability level sensitivity if the following is established:

$$B + W > (n-1)(\frac{a}{n} - C\alpha) + G\gamma) \quad (35)$$

Corollary 7: In comparison to the observed impact of IoT integration cost factor, the impact of sustainability effort cost factor on IoT integration levels within firms are predominantly influenced by in the competitions' strategies. In addition, when the sustainability cost factor is greatly low the equilibrium IoT integration level approaches zero. In this scenario, when the sustainability investments are low enough, firms will favor sustainability efforts over IoT integration strategy.

Proof 7: Based on (23) the derivative of the IoT integration effort $\beta^*$with respect to its sustainability cost factor θ can be calculated as follows:

$$\frac{\partial\beta^*}{\partial\theta} = \frac{S^2T\lambda(a/n-a+B+W-C\alpha+Cn\alpha-G\gamma)}{(n-1)(T^2\theta+(S^2-2\alpha\theta)\lambda)^2} \tag{36}$$

Also, when the cost factor is low and $\theta \to 0$ we have: $\lim_{\theta\to 0}\beta^* = 0$.

G. Comparison of a Duopoly and Oligopoly Market

To further analyze our model, we will compare the equilibrium decision variables; price, IoT integration and sustainability efforts and profit in two special cases. The first is a duopoly market setting, for this latter we consider $n = 2$. We will then compare it to the case when the number of firms n is considerably high, in this case we will calculate the equilibrium decision variables and profit when n approaches ∞. We assume the parameters $(C, \mathrm{T}, \mathrm{S}, \theta, \lambda, \alpha)$ are equal in both scenarios.

Duopoly case: We denote the price, IoT integration effort, sustainability effort and profit fir firm i in this case as p_2^*, β_2^* σ_2^* and π_2^* respectively. And B^d, W^d, G^d and $a^d$the rival's IoT integration effort, sustainability effort, price, and market share in the duopoly market respectively.

Oligopoly case: We denote the price, IoT integration effort, sustainability effort and profit for firm i in the case where n is considerably high as p_n^*, β_n^* σ_n^* and π_n^* respectively.

Proposition 8: The ordinal relationship of the decision variables (price, IoT integration effort and sustainability effort) in the duopoly case and oligopoly market setting are related as follows: $p_2^* < p_n^*$. $\beta_2^* < \beta_n^*$ and $\sigma_2^* < \sigma_n^*$ when the following is established: $2(B^d + W^d - G^d\gamma) < a^d$. Whereas $\pi_2^* > \pi_n^*$ when $\left(a^d - 2(B^d + W^d - G^d\gamma)\right)\left(a^d - 2(B^d + W^d + 2C\alpha - G^d\gamma)\right)(-T^2\theta - S^2\lambda + \alpha\theta\lambda) > 0$.

Corollary 8: The equilibrium price, IoT integration and sustainability efforts increase as the number of firms n increases. This suggests firms could charge higher prices even in competitive markets with differentiating their service by engaging in technological and sustainable operations. However, when $2(B^d + W^d - G^d\gamma) > a^d$ is established, the equilibriums values are higher in the duopoly setting. This inequality suggests a highly competitive intensity and a saturated market where firms are investing significantly in IoT and sustainability efforts. This scenario may lead to diminishing returns on investment and the need to careful strategic consideration to align with market potential. Accordingly, the price, IoT integration and sustainability efforts are higher in an intense competitive duopoly market compared to highly competitive market with numerous firms.

Proof 8: We calculate the limits of the decision variables and profit when $n = 2$ and when n approaches ∞.

We have:

$$\lim_{n\to\infty} p^* = \frac{CT^2\theta+CS^2\lambda-C\alpha\theta\lambda}{T^2\theta+S^2\lambda-2\alpha\theta\lambda} \text{ and}$$

$$p_2^* = \frac{-(a^d - 2\theta\lambda(B^d + W^d - G^d\gamma)) + 2C(T^2\theta + \lambda(S^2 - \alpha\theta))}{2(T^2\theta + (S^2 - 2\alpha\theta)\lambda)}$$

Hence, we have:

$$p_2^* - p_n^* = \theta\lambda\frac{2(B^d+W^d-G^d\gamma)-a^d}{2(T^2\theta+(S^2-2\alpha\theta)\lambda)} \tag{37}$$

We have

$$\lim_{n\to\infty}\beta^* = \frac{CT\alpha\theta}{T^2\theta+S^2\lambda-2\alpha\theta\lambda} \text{ and } \beta_2^* = \frac{T(-a^d\theta+2B^d\theta+2W^d\theta+2C\alpha\theta-2G^d\gamma\theta)}{2(T^2\theta+S^2\lambda-2\alpha\theta\lambda)}$$

Hence,

$$\beta_2^* - \beta_n^* = T\theta\frac{2(B^d+W^d-G^d\gamma)-a^d}{2(T^2\theta+\lambda(S^2-2\alpha\theta))} \tag{38}$$

We have:

$$\lim_{n\to\infty}\sigma^* = \frac{CS\alpha\lambda}{T^2\theta+S^2\lambda-2\alpha\theta\lambda} \text{ and } \sigma_2^* = \frac{S(-a^d\lambda+2B^d\lambda+2W^d\lambda+2C\alpha\lambda-2G^d\gamma\lambda)}{2(T^2\theta+S^2\lambda-2\alpha\theta\lambda)}$$

Hence,

$$\sigma_2^* - \sigma_n^* = S\lambda\frac{2(B^d+W^d-G^d\gamma)-a^d}{2(T^2\theta+\lambda(S^2-2\alpha\theta))} \tag{39}$$

We have:

$$\lim_{n\to\infty}\pi^* = -\frac{C^2\alpha^2\theta\lambda}{T^2\theta+(S^2-2\alpha\theta)\lambda} \quad \pi_2^* = \frac{\theta\lambda\left[\left(a-2(B^d+W^d+C\alpha-G^d\gamma)\right)^2(-T^2\theta-S^2\lambda+\alpha\theta\lambda)+4C^2\alpha^3\theta\lambda\right]}{4(T^2\theta+(S^2-2\alpha\theta)\lambda)^2}$$

$$\pi_2^* - \pi_n^* = \frac{(a-2(B^d+W^d-G^d\gamma))(a-2(B^d+W^d+2C\alpha-G^d\gamma))\theta\lambda(-T^2\theta-S^2\lambda+\alpha\theta\lambda)}{4(T^2\theta+(S^2-2\alpha\theta)\lambda)^2} \tag{40}$$

V. NUMERICAL ANALYSIS

To deepen our understanding and analysis of the model, we conducted a numerical analysis. For the subsequent analyses, we will employ the following values for the parameters.

- Total market size a =80.
- Number of Competitors $n = 5$.
- Self-price Sensitivity $\alpha =$ -1.0.
- Cross-price Sensitivity γ: 0.5.
- Market Sensitivity to IoT Integration T_i: 0.5.
- Market Sensitivity to Sustainability Effort S_i: 0.5.
- IoT Integration Cost Factor λ= 0.2.
- Sustainability Initiative Cost Factor θ= 0.2.
- Price p_i: 100.
- Sustainability Effort σ_i= 0.5.
- C_i=50.
- G=400.

A. Effect of β_i Variation on Firm i 's Profit Across Different B Scenarios

The initial analysis examined the effect of β_i variation on firm i 's profit across different scenarios, adjusting the values of B accordingly. Fig. 2 represents the variation of the profit with β_i.

The profit exhibits fluctuations with rising β_i, suggesting that the firm's investment in IoT integration impacts profitability in varying ways, contingent on the competitive environment. As B increases the profitability of the firm tends to diminish. This suggests the need to consider competitor's strategy when planning its own emphasizing the importance to have strategic flexibility to both competitive pressures and market demand.

B. Profit Variation Across Different Scenarios

Through the analysis of multiple scenarios, we examined the profitability of Firm i considering different scenarios related to IoT and sustainability efforts by both Firm i and its competitors.

Scenario 1: Firm i implements both IoT and sustainability practices while competitors don't: in this scenario we consider $\beta_i = 0.5$, $\sigma_i = 0.5$ while $B = 0$, $W = 0$.

Scenario 2: Firm i implements only IoT while competitors don't: in this scenario we consider $\beta_i = 0.5$, $\sigma_i = 0$ while $B = 0$, $W = 0$.

Scenario 3: Both Firm i and its competitors implements both IoT and sustainability: in this scenario we consider $\beta_i = 0.5$, $\sigma_i = 0.5$ while $B = 3$, $W = 3$.

Scenario 4: Firm i only implements IoT and its competitors implements both IoT and sustainability: in this scenario we consider $\beta_i = 0.5$, $\sigma_i = 0$ while $B = 3$, $W = 3$.

Scenario 5: Firm i implements both IoT and sustainability and its competitors only implement IoT: in this scenario we consider $\beta_i = 0.5$, $\sigma_i = 0.5$ while $B = 3$, $W = 0$.

Scenario 6: Both Firm i and its competitors only implement IoT: in this scenario we consider $\beta_i = 0.5$, $\sigma_i = 0$ while $B = 3$, $W = 0$.

Combining sustainability efforts with IoT integration can provide strategic benefits, particularly when competitors lag in sustainability initiatives or concentrate exclusively on technological advancements. The scenarios highlight the importance of aligning the firm's strategy with market dynamics, competitor actions, and the opportunity to differentiate.

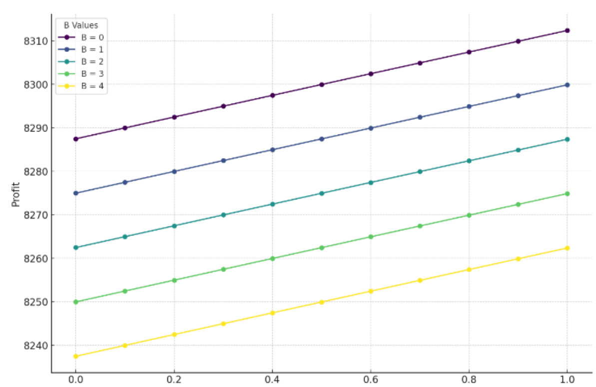

Fig. 2. β_i variation on Firm i 's profit across different B scenarios.

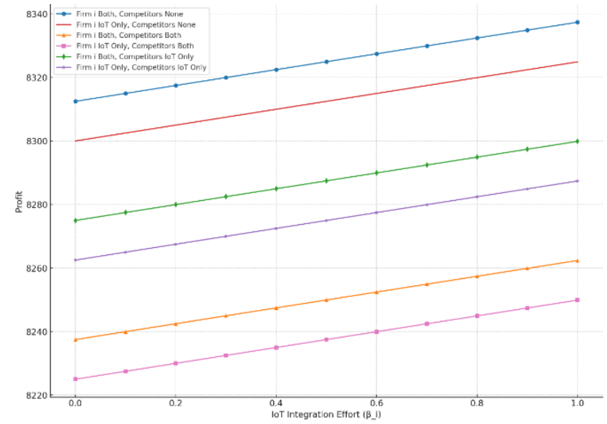

Fig. 3. Profit variation across different implementation scenarios.

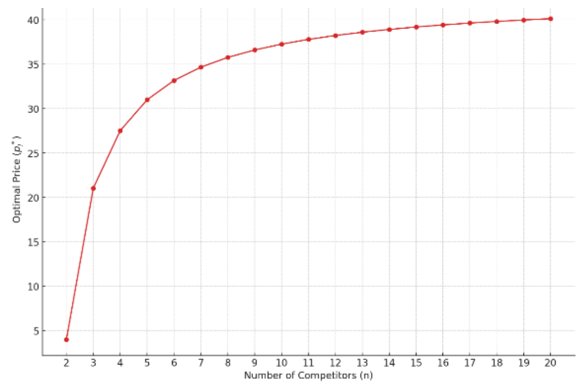

Fig. 4. Optimal price with the variation of the number of firms.

Fig. 3 shows the profit across the different scenarios.

C. Influence of the Number of Competitors on Optimal Price

This analysis aims to examine the impact of the number of firms on the equilibrium price. For this we will proceed with the previously mentioned values with: $B = 2, W = 2, T_i = 0.5, S_i = 0.5$ and the result is showed in Fig. 4.

As the market sees an increase in the number of competitors, the optimal price tends to rise. However, in a more saturated market, the influence of additional competitors on price changes diminishes, with the impact becoming minimal.

D. Sensitivity Analysis

We conducted a sensitivity analysis of the firm i's profit in relation to Market Sensitivity to IoT Integration and sustainability efforts (T_i, S_i) as well as IoT Integration and sustainability effort Cost Factors (λ, θ).

1) Market sensitivity to IoT integration and sustainability efforts: For this analysis we will proceed with the previously mentioned values with minor adjustments $\beta_i = 0.5$, $\sigma_i = 0.5$ $B = 3$, $W = 3$, and the results are presented in Fig. 5.

The profit increases as the sensitivity for the IoT and sustainability increases. This emphasizes the importance of aligning firm's decision with market expectations.

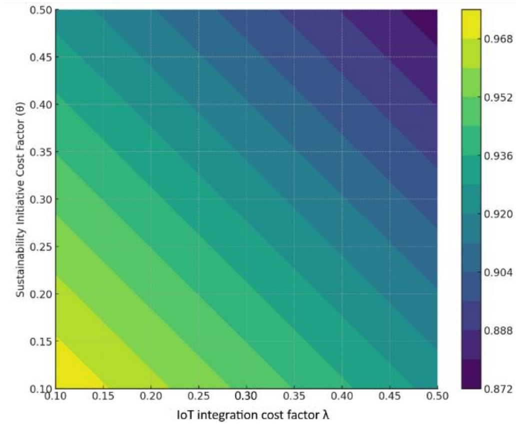

Fig. 5. Market sensitivity to IoT integration and sustainability effort.

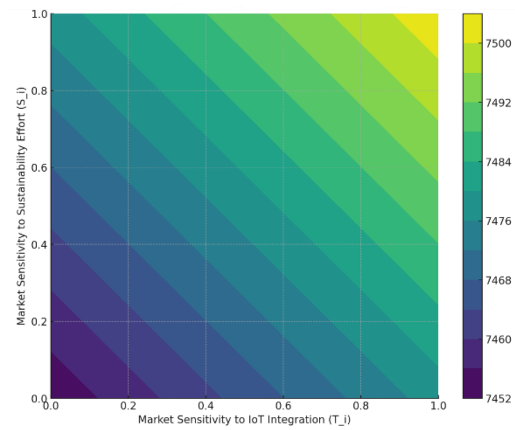

Fig. 6. Market sensitivity to IoT integration and sustainability cost factors.

2) IoT integration effort and sustainability effort cost factors: For the sensitivity analysis of the cost factors, several key parameters have been adjusted to reflect the market conditions and strategic responses more accurately. The self-price sensitivity parameter α has been modified to -0.5. The cross-price sensitivity γ has been lowered to 0.3. To allow for greater pricing flexibility, the total market size a has been increased to 100, G = 300, B =2 W =2. Fig. 6 showcases the results of this sensitivity analysis.

As cost factors rise, profit tend to decrease. Companies must weigh the strategic advantages of these investments against their cost and value to maximize profitability.

VI. Conclusion

In this paper, we explored the impact of integrating the IoT technologies and more sustainable initiatives into the 3PL firm's service on its pricing strategies and profitability. In this research we studied the competition of the 3PL firms in an oligopolistic market setting through price, IoT integration efforts and sustainability effort. The horizontal competition between the firms is modelled as a simultaneous game. We formulate equilibrium strategies for players within this game-theoretic framework and examine the resulting equilibrium outcomes. Our analysis has proved the firm's price increases with the IoT integration and sustainability efforts. Furthermore, our study has showed that the price of the service, the IoT integration and sustainability efforts of the firm increase with the increase of the rivals' IoT integration and sustainability efforts. On the other hand, under certain conditions, the cost of the investments of IoT technology and sustainability initiatives decreases the firm's IoT technology and sustainability efforts. Moreover, we have conducted a comparison between a duopoly setting and an oligopoly market, proving that under certain circumstances, the price, IoT integration and sustainability efforts as well as the firm's profit decreases with the intensity of competition. To achieving a favorable outcome demands careful balance between strategic investments in technology and sustainability, pricing strategies that are aligned with market sensitivity and a keen understanding of the competitive landscape. This study underlines the importance of strategic adaptability and agility for firms to constantly adjust their strategies to keep pace with shifting market trends and competitive pressures.

While this research has provided valuable insights in understanding the impact of IoT integration and sustainability efforts within a 3PL oligopolistic market, it is crucial to recognize its limitations. To simplify complex mathematical calculations, few assumptions have been made. Moreover, to keep out model simple we have considered the sustainability; future research can further develop the model by considering each dimension of the sustainability effort in order to investigate the impact and interrelation of each dimension. Our study focused on a non-cooperative ecosystem, further research can explore how collaborative efforts for integrating IoT technologies within the service as well as sustainable practices within the 3PL firms impact pricing strategies and profitability. Furthermore, the 3PL sector operate in various industries; healthcare, e-commerce food, etc. investigating how digitalization and sustainability efforts in each industry influence their decision-making processes can bring significant insights. Similarly, further research can be conducted taking into consideration digitalization and sustainability trends and regulations differences in the global 3PL market.

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