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The Synergy of Ambidextrous Leadership, Agility, and Entrepreneurial Orientation to Achieve Sustainable AI Product Innovation

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Abstract: This study aims to explore potential mechanisms of ambidextrous leadership (AL) in product innovativeness from the perspective of organizational agility (OA) and entrepreneurial orientation (EO) in firms operating in the artificial intelligence (AI) industry. A quantitative research method was used with 405 questionnaires, and the respondents were randomly selected from reputable databases. Structural equation modeling was employed to evaluate the model fit and conduct hypothesis testing. The findings suggest that ambidextrous leadership demonstrates a significant positive influence on product innovativeness and OA; also, through the mediating role of OA, it is possible to analyze both the direct and indirect relationships among the factors. Additionally, the moderating effect of EO on the intercorrelations among these factors was explored. This study enhances existing knowledge on leadership dynamics in the context of new product development, highlights the importance of adaptability in leadership, and sheds light on the interplay between OA, EO, and new product innovation. This study highlights the role of product innovativeness in sustainable AI product development. Enhanced product innovativeness not only sustains AI product development but also promotes environmental sustainability. This is achieved through the minimization of energy use, reduction in material requirements, and prevention of pollution. Firms are using these insights to develop sustainable and eco-friendly products, as well as create new market opportunities while reducing environmental impact. This research underscores the interconnectedness of factors in this study and sustainability, providing a new perspective on sustainable AI product development.

Keywords: ambidextrous leadership (AL); organizational agility (OA); product innovativeness (PI); entrepreneurial orientation (EO); sustainable product development; AI Industry

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1. Introduction

Over the past decade, artificial intelligence (AI) has become prevalent in sustaining our daily lives. This has increasingly attracted the attention of researchers in academia, business, and governance. However, the business environment is continuously evolving. A firm that dominates the AI industry one day could cease to exist the next day. Therefore, firms need to innovate products and processes in a volatile environment to survive, grow, and sustain competitive advantages [1].

Exploration and exploitation of ambidexterity are two key components to obtaining greater product innovativeness [2]. This allows firms to reconfigure their assets and develop new skills to address emerging threats and opportunities [3]. However, few studies have examined the leaders of ambidextrous organizations. Based on contingency theory studies, followers are affected by the behavior and characteristics of leadership in the context of innovation creation [4]. According to Schaubroeck et al. [5], leaders are responsible for allocating and controlling organizational resources. The degree of effectiveness with which these resources are allocated is a key determinant of the level of investment in R&D activities within an organization [6]. This study investigates how the ambidextrous leadership

model affects product innovativeness. The ambidextrous leadership model proposed by Rosing et al. [7] introduces two types of leadership behavior: opening and closing, which respectively emphasize exploration and exploitation. This model highlights the importance of the flexible application of both leader behaviors based on situational demands, as supported by Zacher and Rosing [2]. Several promising pieces of evidence demonstrate a positive correlation between these two factors, indicating that ambidextrous leadership contributes to better innovation performance [2,8]. Additionally, Tuan Luu [9] contends that the emotional equilibrium between the continuity and fluctuation of employees can be promoted by an ambidextrous leadership style, leading to reduced employee unease toward uncertainty and enhanced self-assurance to engage in innovative and risk-taking activities. Consequently, ambidextrous leadership has the potential to cultivate proactive, innovative, and risk-taking behaviors in firms.

A large body of literature finds that firms experience a failure rate of approximately 40% in their product innovations due to the absence of a focus on the ever-changing market environment [10,11]. Accordingly, organizational agility (OA) is closely linked to dynamic capability, a critical success factor for firms operating in unpredictable business environments [12,13]. OA empowers firms to promptly respond to valuable market information when making product innovation decisions and efficiently execute new innovation plans [10]. Two examples are Dell EMC's accelerated IT innovation and Apple's strategically fast investment in the Apple Watch, which captured 75.5% of the global smartwatch market share [14].

Nevertheless, in an ever-changing world marked by geopolitical upheavals, global talent shortages, and the complexities of big data management, high-tech organizations constantly face new challenges in sustaining their competitiveness and relevance. Rosing et al. [7] point out that limited research demonstrates how leaders can effectively balance exploring new opportunities by exploiting current advantages. Consequently, there is limited practical and theoretical knowledge on how leaders can effectively implement ambidexterity to enhance product innovativeness. The underlying drivers are little understood. In other words, does ambidextrous leadership directly impact product innovation or work through intermediate mechanisms [6,15]? Hughes et al. [16] argue that there is a lack of rigorous empirical analysis and inadequate demonstration in the literature regarding the importance of ambidextrous leader behaviors in the innovation process.

Li et al. [15] advocate that leaders must be capable of flexibly adjusting their behaviors to suit the evolving spatial situations and distinct qualities of their subordinates, such as their abilities, expectations, roles, and personalities. Therefore, there is a certain level of alignment between ambidextrous leadership and OA. Aurélio de Oliveira et al. [17] assert that leadership plays a crucial role in determining employees' and teams' agility and flexibility, which are essential factors affecting organizational performance. Denning's [18] study on strategic management highlights that agility is the driving force behind innovation. Several studies also indicate that leaders can deploy agility by establishing organizations that can adapt their structure, redistribute resources, and hire employees primed to embrace and navigate change. This implies that OA could act as a mediating factor between ambidextrous leadership and product innovativeness. However, achieving OA is challenging for most firms despite its crucial role [10,19]. Whether ambidextrous leadership plays a vital role as an OA antecedent remains ambiguous. Few studies focus on developing OA for product innovation despite its recognized importance [20]. Studies in the field of entrepreneurship have primarily focused on investigating the relationship between a firm's performance and its entrepreneurial orientation. However, the relationships between product innovativeness and the moderating effects of entrepreneurial orientation, synergistically working on ambidextrous leadership and OA, were underexplored.

The primary objective of this study is to assess the factors contributing to product innovativeness in firms operating in the AI industry. Furthermore, this study aims to elucidate a suitable mechanism to explain the potential connections between these crucial organizational factors. Particularly, the purpose of this study is to (1) explore the impact

of ambidextrous leadership on product innovativeness, (2) examine the role of OA as a potential mechanism in the possible linkages, and (3) explore the moderating effect of entrepreneurial orientation on the intercorrelations among these factors.

From an academic perspective, this study makes several contributions to existing research. First, it highlights the significance of Rosing et al.'s [7] model of ambidexterity and leadership in product innovation. Second, by offering a better understanding of the role of leadership in OA, this study helps organizations adapt and respond to changing circumstances, which is essential for achieving long-term success. This study provides practical guidance for companies, such as encouraging them to create customized training programs for leaders to enhance OA and boost product innovation. It also offers valuable AI insights for R&D decision-making and suggests ways to enhance efficiency and effectiveness in long-term AI product development.

This study is organized as follows. The following section presents a literature review and hypothesis development, followed by the theoretical background of the research model. Subsequent sections encompass the research methodology, data analysis, discussions, and implications.

2. The Literature Review and Hypothesis Development

2.1. Ambidextrous Leadership

The concept of ambidextrous leadership has attracted the attention of scholars over the last decade. It originated from a study by Rosing et al. [7] and has been addressed as a crucial dimension of innovation. It is defined as the capacity to foster both exploration and exploitation while also being flexible in transitioning between the two. The foundation of the concept can be traced back to a study conducted by Bass in 1990 concerning adaptable, transformational leadership [21]. A great leader cannot solely apply singular, transactional leadership behaviors to all situations. Ambidextrous leaders should switch between transformational and transactional leadership depending on the situation [2].

The concept of ambidextrous leadership encompasses three core dimensions: (1) opening leadership behaviors to cultivate exploration; (2) closing leadership behaviors to cultivate exploitation; and (3) versatile leadership that adapts by choosing between open and closed behaviors as needed [2,7]. The "opening" metaphor refers to exploration and variance in ambidextrous leadership by identifying new approaches and breaking up routines. By contrast, closing leadership behaviors involve setting specific guidelines, implementing corrective actions, and monitoring the achievement of goals [2,7]. Closing refers to exploitation in ambidextrous leadership by reducing variance through streamlining and scoping down. Ambidextrous leadership is a contradictory, yet complementary, leadership style that aims to enhance the interaction effects of both styles.

2.2. Organizational Agility

In 1991, the concept of agility was first introduced in the report "Twenty-first Century Manufacturing Enterprise Strategy Report" by Roger Nagel, Operations Director of Lehigh University [22]. The report's main objective was to seek solutions for the declining global competitiveness in the US manufacturing industry. Thus, agile manufacturing or production was proposed to replace mass production. Scholars have since applied and extended this concept to managerial or organizational processes. It is also associated with OA and strategic agility. OA, to date, has no unified definition, although agile organizations have been observed to have similar characteristics to this construct. Sharifi and Zhang [23] define OA as an organization's capacity to adapt to unexpected changes, seize emerging opportunities, and maintain competitiveness amid uncertainty and threats, ensuring survival and growth. Kumkale [24] stated that organizations interact with their environments as an open system, and it is essential for organizations to respond quickly to the environment's rapidly changing internal and external situations. The various definitions provided by related studies [13,25–27] have several shared characteristics. First, OA is the capability to effectively and efficiently cope with constant and unpredictable changes in dynamic and

turbulent environments. Second, these studies have focused on speed and responsiveness from an operative perspective, indicating the proactive characteristics of OA. Third, their primary goal is to maintain and enhance competitiveness to survive and prosper. Finally, to maintain, improve, and sustain their competitive positions, agile firms are willing to satisfy consumers' needs by introducing high-quality, innovative, or diversified products with efficient production and lower costs. This research reviews OA's dimensions through the lens of a four-dimensional scale developed by Sharifi and Zhang [23]. The scale is as follows:

Competency. Core competence is one of the four required characteristics for achieving agile manufacturing capability; it is associated with the workforce of corporations as well as the improvement in capabilities through the organization's effort and management of changes and uncertainties [28]. Additionally, competence is the ability to ascertain efficiently and effectively the objectives and goals of firms [26]. Nejatian et al. [27] identify the importance of business practices that are developed through multi-venturing and that are difficult to replicate. For Sharifi and Zhang [23], the competency of agile organizations refers to their ability to enhance productivity, accomplish objectives, and fulfill intentions and goals efficiently and effectively;

Flexibility. Sharifi and Zhang [23] define flexibility as the ability of firms to process different products and accomplish different objectives using the same facilities. Scholars have extended this concept to include the ability to fulfill various objectives by performing different tasks using the same set of resources and facilities accessible to organizations [29]. Yusuf et al. [28] propose that by embracing flexibility and agility, an agile firm can swiftly transition between focusing, diversifying, configuring, and realigning its businesses to effectively pursue diverse objectives and seize opportunities. Kumkale [24] explains that flexibility is the ability to initialize different processes in response to changing situations based on the firms' strengths and drawbacks. As a result of constantly conducting internal and external environmental analyses, the firms in that study were able to be proactive and react quickly, making the most efficient use of opportunities that emerged in new environments;

Responsiveness. Responsiveness is the capability to take advantage of changes by recognizing and responding swiftly, either proactively or reactively, in order to recover [23]. This dimension has a few sub-capabilities: sensing; perceiving and anticipating changes; immediate reaction to change by adapting them into the system; and recovery from changes [23]. Kumkale [24] suggests that responsiveness is not only linked to products but is also influenced by other factors, such as stakeholder expectations, sensitivity to detecting various issues, government policies, and reactive or proactive attitudes, in dealing with changes in competition. A higher degree of firm responsiveness is associated with a higher degree of dissemination of proactive behavior;

Quickness. According to Sharifi and Zhang [23], quickness, the fourth fundamental capability of OA, refers to firms' ability to operate at high speed in the shortest possible period and accomplish their missions [29]. Three related sub-capabilities are quickness in new products' time to market, quickness and timeliness in product and service delivery, and short operational lead times [23].

2.3. Product Innovativeness

The level of innovativeness manifests in the distinctness between the current technology or procedures and the novelty of the products in the organization [30]. Brockman and Morgan [31] defined product innovativeness as the extent of a product's newness and the generative capacity of organizations. Novelty is perceived from two positions: the firm; and the customer [32]. Novelty affects customer adoption risks, innovation attributes, and behavioral patterns, whereas it affects a firm's technology and marketing, environmental familiarity, and project–firm fit [33]. Consequently, we obtain sustainable competitive advantages and increased profits by more effectively meeting customer needs through the launching of new products and organizational development.

2.4. Entrepreneurial Orientation

An organization's entrepreneurial orientation is shown through its risk-taking in investments and strategies, its innovation in products and services, and its competitive and pioneering nature in the industry [34]. The three fundamental constructs of entrepreneurial orientation are innovativeness, proactiveness, and risk-taking. Proactiveness illustrates the desired attitudes or stances for future market acquisitions by creating competitive advantages over competitors. Bhandari et al. [35] asserted that long-term needs must be satisfied by sustainable competitive advantage; thus, firms are compelled to generate new demand, shape trends, and cultivate an innovation-driven culture when exploring new business models or opportunities and creating resources. Lastly, risk-taking constitutes the last core element of entrepreneurial orientation, encompassing both the enthusiasm for expending enormous resources to achieve goals and the recognition of significant undesired losses [36].

2.5. Ambidextrous Leadership and Product Innovativeness

The ambidextrous leadership approach aims to satisfy the need for complexity alongside innovation activities in the organization [2,7]. Several empirical studies indicate that innovativeness can be obtained when leadership, context, and structure are immersed in the concept of ambidexterity [37]. In the interaction of opening and closing or exploration and exploitation, leadership behaviors tend to be more beneficial than a single leadership style in facilitating the innovation of individuals and teams [2]. This has been confirmed by numerous studies [2,38,39]. Furthermore, to create innovative and creative ideas, exploration with experimentation, diverse thinking, and openness to new knowledge is crucial; to implement these ideas favorably, exploitation with adherence to guidelines and standards and a clear goal focus is essential [31,40]. Opening leadership behaviors tend to support employees in challenging current approaches, taking risks, offering opportunities to implement independent creativity, and creating a psychologically secure workplace in which employees can meet creativity requirements without worrying about negative repercussions [7,41]. Closing leadership behaviors tend to control or supervise deadlines and goal accomplishments to ensure that employees fulfill these tasks under constraints and guidelines [7,41]. Hence, product innovativeness should benefit from the support of participating in fatal processes and/or activities of innovation by engaging both behaviors of ambidextrous leadership to a large extent. Thus, we propose the following hypotheses:

H1. *Ambidextrous leadership positively correlates with product innovativeness, reaching its peak when both opening and closing leadership behaviors are high.*

H1a. *Opening leader behavior is positively related to product innovativeness.*

H1b. *Closing leader behavior is positively related to product innovativeness.*

2.6. Ambidextrous Leadership and Organizational Agility

Several studies have illustrated that ambidextrous organizations pursue OA by aligning these antecedents of ambidexterity with OA's four dimensions. It has been suggested that leadership is inevitably required in managing completely different and inconsistent organizational alignments with exploitation and exploration [42]. On the one hand, competencies needed for exploration include a short-term time perspective, efficiency, discipline, incremental improvement, and continuous innovation. On the other hand, the alignment required for exploration emphasizes a longer time perspective, more autonomy, flexibility, risk-taking, and less formal systems and control [3]. This standpoint matches ambidextrous leadership's main characteristics. Specifically, exploitation and exploration play an essential role in achieving the following components of OA: flexibility; quickness; responsiveness; and competencies. Lu and Ramamurthy [19] state that ambidexterity naturally contains agility, allowing for adaption to market changes while preserving customer satisfaction. In

addition, in an ambidextrous organization, organizational and technical flexibilities and the capability of the firm to conveniently adapt to change have been demonstrated to be critical competitive attributes of agility [43,44]. OA appears as long as leaders reinforce it as a strategy or value for the organization. According to Rigby et al. [45], in their book *Doing Agile Right: Transformation without Chaos*, organizational success hinges significantly on the collaborative efforts of agile teams from the sample practices. However, the role played by leaders and top management is equally important in effectively managing the formation and operation of these agile teams, thereby fostering OA.

Thus, it is essential for organizations to become more agile in dynamic and competitive environments, and the leadership of organizations is demonstrated as the fundamental determinant among the various factors that influence agility. In addition, ambidextrous leadership was introduced and defined specifically for innovation in organizations [7]. Ambidextrous leadership is superior and advantageous compared to other traditional leadership styles in explaining variables and rationales for studies related to innovation. Based on the above theory, we propose the following hypotheses:

H2. *Ambidextrous leadership is a strong predictor of organizational agility, with agility reaching its highest when both opening and closing leadership behaviors are high.*

H2a. *Opening leader behavior is positively related to organizational agility.*

H2b. *Closing leader behavior is positively related to organizational agility.*

2.7. Ambidextrous Leadership, Organizational Agility, and Product Innovativeness

Product innovativeness represents firms' willingness or desire to acquire new ideas openly, enabling them to introduce and develop new products based on these novel ideas and processes [46]. A culture of innovativeness or innovation in firms can be fostered by developing OA among teams [47,48]. Hoonsopon and Puriwat [47] contend that OA empowers organizations to allocate different resources and utilize different capabilities in responding to fast-changing environments to discover new values and outcomes, which is innovativeness. Moreover, Teece et al. [13] find that when firms develop product innovations, OA plays a critical role in the success of teams developing new products. Several unforeseen uncertainties from the perspectives of technology and marketing may arise in new product development by cultivating radical innovations [47,49]. In organizations with OA, teams and their members consistently dedicate themselves to uncovering customer needs, behaviors, and preferences in the market. They apply new ideas, transform them into prototypes, and responsively adapt the products until a final product is ready for market release [50].

Moreover, several studies have shown that OA may facilitate the development of incremental and radical innovations in organizations [51]. According to Martínez-Sánchez et al. [52], firms embedded in OA innovate and collaborate externally to a greater extent than non-agile firms. Furthermore, organizations benefit from various aspects of OA, such as sensing and responding rapidly to environmental and market changes [10]. This allows firms to generate feasible creative ideas in product innovation when agility pushes them to align with current trends or changes in the market. Higher innovation performance can be achieved through OA to foster organizations by rapidly recognizing changes in demand and satisfying customers' unfulfilled needs or preferences [12]. Thus, we propose the following hypothesis:

H3. *Organizational agility positively influences an organization's product innovativeness.*

Most studies differentiate between the two innovation processes in their theoretical models: creativity, also called idea generation; and idea implementation [53,54]. Idea generation and explorative activities are tightly connected. Carrying out new ideas alongside established routines is uncommon because creative tasks are usually ambiguously

defined [7,55]. It is essential to develop new ways to tackle any resistance during idea implementation. With these outcomes carried out by ambidextrous leadership in organizations, OA as a dynamic capability would be strengthened, as the characteristics of agility, competency, and flexibility must be improved alongside these new ideas, processes, and implementation policies during innovation processes. In constantly changing environments, leaders must constantly switch flexibility back and forth to deal with the different requirements of creativity and innovation [56]. Vandenbosch and Clift [57] state that there is a demand for a higher level of flexibility and responsiveness when leaders encourage the rapid development of highly innovative products. The author believes that ambidextrous leaders may lead firms to be agile and inspire team changes by producing more creative and innovative products. Therefore, ambidextrous leadership may indirectly affect product innovativeness through OA. Thus, the following hypothesis is proposed:

H4. *Organizational agility positively mediates the relationship between ambidextrous leadership and product innovativeness.*

2.8. The Moderating Effect of Entrepreneurial Orientation

Entrepreneurial orientation involves a willingness to take risks and explore new ideas and opportunities [58]. Ambidextrous leadership, which combines exploratory and exploitative activities, is crucial for managing the inherent tension between innovation and efficiency [7]. Leaders with entrepreneurial orientation are more likely to exhibit risk-taking behavior, which aligns with the need to explore and experiment with new ideas and practices [58]. Bhandari et al. [35] also claim that managers must empower individuals, groups, and organizations to innovate through delegation and decentralization to activate entrepreneurial orientation and enable sustainable competitive advantage through the interaction of associated autonomy. These entrepreneurial characteristics are highly identical to the purpose of OA, which allows teams or individuals to respond flexibly and quickly to ongoing changes. Therefore, this conceptualization provides evidence that agility has a greater influence on the product innovativeness of AI firms because OA shares homogeneity with entrepreneurial orientation in terms of product innovativeness. Ambidextrous leadership requires leaders to exhibit adaptability and flexibility in managing exploration and exploitation activities [7]. Entrepreneurial orientation emphasizes adaptability and the ability to respond to uncertain and changing market conditions [58]. Leaders with entrepreneurial orientation are more likely to embrace change, adapt their leadership styles, and respond quickly to emerging opportunities and challenges [58]. This adaptive and flexible leadership style is essential for the effective implementation of innovative ideas and driving product innovation. Risk-taking is the last main construct of the entrepreneurial approach, which, alongside enthusiasm for expending an enormous number of resources to achieve goals, undesirable losses may arise [36]. To outcompete competitors and thrive in a chaotic market environment, managers need to pay attention to embedding risk-taking behavior into learning, adaptation, and innovation, which may be classified as a risk-taking culture [35]. This behavior may amplify the influence of OA on product innovativeness. Thus, we propose the following hypotheses:

H5. *Entrepreneurial orientation has a positive impact on the ambidextrous leadership of product innovativeness;*

H6. *Entrepreneurial orientation has a positive impact on the organizational agility of product innovativeness.*

3. Research Methodology

3.1. Research Framework

Based on ambidextrous leadership theory, this study proposes a framework to illustrate the antecedents of product innovativeness and OA (Figure 1). This model investigates

the potential mechanisms that explain the impact of ambidextrous leadership and OA on product innovativeness. Additionally, the moderating variable of entrepreneurial orientation is examined, as it is expected to positively influence the other variables. The proposed model suggests that through the mediating role of OA, it is possible to analyze both the direct and indirect relationships between ambidextrous leadership and product innovativeness.

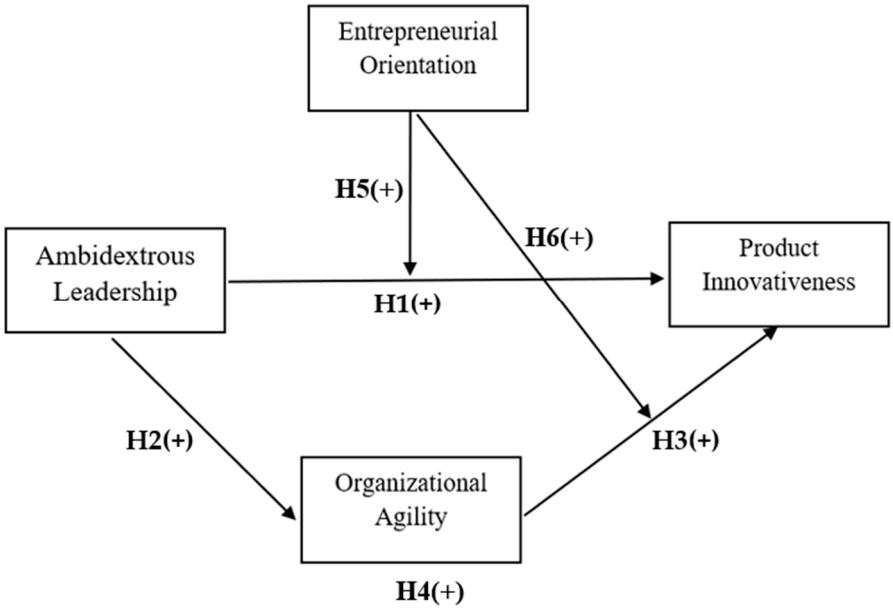

Figure 1. Proposed Research Framework.

3.2. Questionnaire Design

All scales were established in English. To ensure the accuracy and equivalence of the scales, the researcher followed Bernard's guidelines for back-translation techniques [59]. Specifically, two bilingual Chinese scholars helped the researcher translate the scales from English to Chinese and check the equivalence of translation against the original. A third bilingual scholar translated the scales back into English to ensure accuracy. These specialists provided valuable feedback, allowing the author to refine the constructs accordingly. The first part of the questionnaire was related to the respondents' sociodemographic characteristics: age; highest level of education; position; number of full-time employees; and length of business operations.

The measurement of ambidextrous leadership in this study involved using the 14-item scale developed by Zacher and Rosing [2], which is based on Rosing et al.'s [7] theory of ambidextrous leadership. To assess OA, we utilized Sharifi and Zhang's [23] scale, which consists of four sub-dimensions: competence; flexibility; responsiveness; and quickness. To evaluate the entrepreneurial orientation, we used Miller's [36] constructs, including innovation, risk-taking, and proactiveness. This study's measurement of product innovativeness is based on six items developed by Wang and Ahmed [32]. The four primary variables were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

3.3. Data Collection and Sampling

A quantitative research method was used. The target population included managers and employees responsible for developing new products in the AI industry in the Yangtze River Delta region (YRD). These AI firms met the criterion of demonstrating innovation in the development of AI products and R&D that employs advanced technology, as evidenced by their official websites. The unit of analysis in this study focused on the individual level [60]. We employed a simple random sampling method, as this approach allowed us

to recruit individuals efficiently and promptly. The firms chosen for this study adhered to the criteria and were randomly selected from reputable databases. Participants were sent an email containing a self-administered questionnaire with structured questions and a cover letter explaining the purpose and objectives of this study. The questionnaire was sent in a format linked to Wenjuanxing, a professional survey platform in China. Executives who received the invitation email were given the flexibility to personally complete the questionnaire or delegate the task to the relevant managers or senior employees involved in the new product development process within their firms. To ensure the participants' confidentiality, their personal information was kept private, and their anonymity was preserved by excluding their names or affiliated companies from the questionnaire. After completing the questionnaires, respondents were requested to submit them via a link to the survey platform. Furthermore, to reduce the potential impact of single-source bias, the researcher followed a methodology similar to that of Jia et al. [6]: at least two respondents per firm must be included. Before conducting the main survey, a pilot test (n = 51) was conducted, and there was no feedback regarding ambiguity in the illustrations of the questionnaire. In addition, the indicators have high reliability (α).

A total of 1050 questionnaires were distributed to randomly selected firms. Of these, 461 respondents returned. After screening and verification, 405 questionnaires were identified as complete and usable for the analysis. Thus, a response rate of 38.57% was achieved. Based on the demographic data, a significant proportion of respondents fell within relatively young age groups of 25–34 and 35–44 years, comprising 208 (51.4%) and 114 (28.1%), respectively. Two hundred and fifteen respondents held a bachelor's degree (53.1%), and 98 held a master's degree (24.2%). The majority of participants, 339 (83.7%), were the team members actively involved in the product innovation. This was followed by 58 respondents (14.3%) who had served as supervisors or team leaders engaged in product innovation. Concerning the years of work experience in the AI industry, 175 participants (43.2%) had one to three years of experience, and 157 (38.8%) had four to six years of experience. Regarding firm size, 27.2% of the respondents belonged to firms with 51 to 100 full-time employees, and 14.1% of the firms contained 151 to 200 full-time employees. Additionally, a significant proportion of respondents, 169 (41.7%), came from firms that had been in operation for one to three years. This was closely followed by firms with four to six years of business operations, accounting for 38.3% (155).

4. Data Analysis

Following the verification of data normality, data were analyzed using a structural equation model (SEM). Multicollinearity and outliers were absent, and SPSS 26 and AMOS 26 were used for the statistical examination of this model. The analysis incorporated both the measurement and structural models of SEM, as outlined by Hair et al. [61]. The measurement model was applied to assess the validity and reliability of this model, whereas the structural model was employed to evaluate the model fit and conduct hypothesis testing.

4.1. Measurement Model: Reliability and Validity

A quantitative examination of the measurement model was conducted to assess its discriminant validity, convergent validity, and internal consistency. Convergent validity was evaluated using factor loading, composite reliability (CR), and average variance extracted (AVE). To gauge discriminant validity, we followed the recommendation of Fornell and Larcker [62], which involved comparing the square root of the AVE with the correlation coefficients among variables. Furthermore, to ensure the reliability of measuring the same construct across all items, Cronbach's alpha was used to assess internal consistency.

Based on Table 1, all factor loadings are acceptable, ranging from 0.762 to 0.859, demonstrating a high degree of internal correlation among the items. Cronbach's alpha (α) of the constructs was also examined, ranging from 0.913 to 0.934, indicating excellent internal consistency. Further, to test convergent validity, the composite reliability (CR) and the average variance extracted (AVE) were tested; the CR value ranged from 0.845 to 0.933,

and all constructs met the criterion of 0.7 or higher [61]. The value of AVE ranged from 0.624 to 0.665, which also met the criterion of over 0.5 [61]. Based on Table 2, the square root of the AVE of each construct was greater than the correlation between the constructs; hence, discriminant validity was sufficient [62]. Overall, adequate convergent and discriminant validity and reliability of the conceptual model were presented. The Harman Single Factor test was conducted, revealing that the total variance extracted was 30.682% of this model, below the threshold value of 50%. Thus, no evidence of common method bias existed in this study.

Table 1. Measurement items, item loading, AVE, composite reliability, Cronbach's alpha.

Constructs	Item Loading	AVE	CR	α
Ambidextrous Leadership (AL)				
Opening Leader Behavior (OL)				
AL1: My leader allows for different ways of accomplishing a task	0.840			
AL2: My leader encourages experimentation with different ideas	0.797			
AL3: My leader motivates me to take risks	0.835	0.664	0.933	
AL4: My leader gives possibilities for independent thinking and acting	0.801			
AL5: My leader gives room for my ideas	0.805			
AL6: My leader allows for errors	0.827			0.934
AL7: My leader encourages error learning	0.798			
Closing leader behaviors (CL)				
AL8: My leader wants to monitor and control goal attainment	0.828			
AL9: My leader wants to establish routines	0.804			
AL10: My leader wants to take corrective action	0.789	0.641	0.926	
AL11: My leader wants to control adherence to rules	0.762			
AL12: My leader intends to pay attention to uniform task accomplishment	0.796			
AL13: My leader wants to sanction errors	0.807			
AL14: My leader wants to stick to plans	0.816			
Organizational Agility (AG)				
Competence				
AG1: Our company has a strategic vision that will achieve its long-term goals	0.803			
AG2: Our company has an adequate amount of efficacious technology following the requirements of the age	0.789			
AG3: Our company's product quality and the service quality for this product are high	0.790	0.624	0.930	
AG4: Our company aims to achieve the maximum output with the minimum input in all processes to achieve its goal	0.783			
AG5: Our company makes high-level product promotions	0.794			0.932
AG6: Our company has expert and authorized human resources	0.773			
AG7: All business processes in our company are defined simply, loudly, and clearly	0.800			
AG8: Our company attaches importance to providing and developing a cooperation environment inside and outside the business	0.789			

Table 1. *Cont.*

Constructs	Item Loading	AVE	CR	α
Flexibility				
AG9: Our company has the efficiency of producing different product models	0.816	0.646	0.845	
AG10: Our company has the flexibility of producing a different number of products and services	0.782			
AG11: Our company has flexibility within the scope of human resources policies	0.812			
Responsiveness				
AG12: Our company can respond quickly to changes in the customer's needs and preferences	0.830	0.657	0.852	
AG13: Our company feels and perceives the direction of change within the scope of environmental change and holds itself in readiness for these changes	0.796			
AG14: Our company's ability to adapt innovations and overcome environmental and technology-induced changes quickly and in a timely manner is higher than that of its competitors	0.805			
Quickness				
AG15: Our company is faster in production processes compared to its competitors	0.789	0.665	0.856	
AG16: Our company is fast in introducing new products to the market	0.859			
AG17: Our company distributes products and services to the customers quickly and on time	0.796			
Entrepreneurial Orientation (EO)				
EO1: Our company spends more time on long-term R&D than on short-term R&D	0.813	0.653	0.929	0.929
EO2: Our company is usually among the first in the industry to introduce new products	0.811			
EO3: Our company rewards risk-taking	0.818			
EO4: Our company shows a great deal of tolerance for high-risk projects	0.780			
EO5: Our company takes bold, wide-ranging strategic actions rather than minor changes in tactics	0.811			
EO6: Our company uses only "tried-and-true" procedures, systems, and methods (reverse-coded)	0.801			
EO7: Our company challenges, rather than responds to, its major competitors	0.822			
Product Innovativeness (PI)				
PI1: In new product and service introductions, our firm is often first to market	0.779	0.642	0.926	0.913
PI2: Our new products and services are often perceived as novel by customers	0.774			
PI3: New products and services in our company often put us up against new competitors	0.799			
PI4: Our recent new products and services are significant changes from our previous products and services	0.823			
PI5: In comparison with competitors, our company has introduced more innovative products and services during the past five years	0.799			
PI6: In comparison with competitors, our company is faster in bringing new products or services to the market	0.811			

Table 2. Discriminant validity.

Constructs	OL	CL	AG	EO	PI
OL	0.815				
CL	0.570	0.800			
AG	0.469	0.328	0.800		
EO	0.393	0.344	0.335	0.808	
PI	0.391	0.390	0.400	0.344	0.801

4.2. Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) was conducted to validate the measurement and factor structure of the model. Additionally, the conceptual framework was tested for goodness of fit indices. The estimated results of the measurement and structural models are presented in Table 3. In Model 1, "opening leader behavior" and "closing leader behavior" were treated as independent variables. By contrast, Model 2 tested the interactions of both dimensions together as a cohesive dimension. The CFA results of the measurement model and two proposed models all returned a good model fit, with all χ^2/df values being lower than 3, three RMSEA below the threshold limit of less than 0.05, all CFI above 0.95, all GFI greater than 0.8, and NFI above 0.9.

Table 3. Fitness indices of CFA and structural models.

Fit Indices	Measurement Values of CFA	Measurement Values of Model 1	Measurement Values of Model 2	Criterion
χ^2/df	1.032	1.206	1.195	<3
RMSEA	0.009	0.023	0.022	<0.05
CFI	0.998	0.984	0.989	>0.95
GFI	0.910	0.899	0.928	>0.8
NFI	0.928	0.916	0.935	>0.9

4.3. Hypothesis Testing

Table 4 presents the results of the path analysis from the two structural models. Hypotheses 1, 1a, 1b, 2, 2a, 2b, and 3 were supported by the data.

Table 4. The standardized path coefficients and probability levels of hypothesis testing.

X →	Y	Standardized Estimate (β)	S.E.	t-Value	*p*	Results
AL	PI	0.382	0.095	4.372	***	H1 Supported
OL	PI	0.125	0.049	2.326	0.020 *	H1a Supported
CL	PI	0.179	0.046	3.523	***	H1b Supported
AL	AG	0.577	0.080	7.454	***	H2 Supported
OL	AG	0.373	0.047	6.341	***	H2a Supported
CL	AG	0.217	0.044	3.906	***	H2b Supported
AG	PI	0.283	0.081	3.953	***	H3 Supported

Note: * $p < 0.05$; *** $p < 0.001$.

Additionally, to analyze the mediating effects, the PROCESS custom dialog box in SPSS (Model 4) was employed to assess the direct and indirect effects of the mediation process.

The mediating effect of OA on the model is presented in Tables 5 and 6. The results demonstrate a significant total effect, represented by "path c" ($\beta = 0.4979$, $p < 0.001$) when OA acted as a mediator. "Path c'" demonstrates a direct effect from ambidextrous leadership (X) to product innovativeness, and it shows a significant effect ($\beta = 0.3493$, $p < 0.001$). Table 6 shows the indirect effect of ambidextrous leadership on product innovativeness, indicating a significant impact ($\beta = 0.1485$, $p < 0.001$). This reveals that ambidextrous leadership not only directly influences product innovativeness but also has an indirect effect through OA,

accounting for 29.825% of the total effect. The bootstrap analysis, as indicated in Table 6, confirmed that the mediating effect is significant. Within the 95% confidence interval, the estimated confidence interval CI [0.098, 0.208] did not contain zero within its range, providing further support for the mediation effect. When the c' value is smaller than the c value, it suggests the presence of a mediating variable that partially explains the relationship between the independent variable and the dependent variable. This indicates that AG partially mediates AL and PI; therefore, Hypothesis 4 is supported.

Table 5. Results of the mediating effect of organizational agility.

Model 1				Model 2				Model 3			
	β	t	*p*		β	t	*p*		β	t	*p*
Constant	1.7456	6.7642	0	**Constant**	2.0096	9.1150	0	**Constant**	1.0112	3.7678	0.0002
AL → PI	0.4979	9.911	0	**AL →AG**	0.4064	9.4276	0	**AL→PI**	0.3493	6.6181	0
								AG →PI	0.3654	6.605	0
R		0.4494		**R**		0.4264		**R**		0.5295	
R^2		0.2019		**R^2**		0.1818		**R^2**		0.2804	
F		33.8214 ***		**F**		29.7055 ***		**F**		38.9688 ***	

***, $p < 0.001$.

Table 6. Indirect, direct, and total effects of AL on PI mediated by AG.

	Effect	BootSE	BootLLCI	BootULCI	Proportion
Indirect	0.1485	0.0281	0.098	0.208	29.825%
Direct	0.3493	0.0528	0.2456	0.4531	70.155%
Total	0.4979	0.0502	0.3991	0.5966	

Model 1 of the PROCESS custom dialog box in SPSS was applied to study the moderation effect. The results in Table 7 indicate that when AL and EO were entered into the regression model, a positive and significant effect was observed (β = 0.2493, $p < 0.05$). This explains the significant incremental variance (β R^2 = 0.0487, $p < 0.05$). Similarly, when AG and EO were included in the regression model, a positive and significant effect was observed (Δ = 0.2056, $p < 0.05$), which explains the significant incremental variance (ΔR^2 = 0.0385, $p < 0.05$).

Table 7. Results of the moderating effects of EO on AL and AG.

Model 4				Model 5			
	β	T	*p*		β	t	*p*
Constant	0.2173	1.2096	0.2271	**Constant**	0.2803	1.5602	0.1195
AL →PI	0.3336	7.2045	0	**AG →PI**	0.3461	7.6163	0
EO →PI	0.1751	3.7398	0	**EO →PI**	0.2124	4.6546	0
AL × EO	0.2493	5.2289	0	**AG × EO**	0.2056	4.6319	0
R		0.5372		**R**		0.5336	
R^2		0.2886		**R^2**		0.2847	
ΔR^2		0.0487		**ΔR^2**		0.0385	
F		32.3776 ***		**F**		31.7672 ***	

***, $p < 0.001$.

Furthermore, to assess whether the significant interaction effect aligned with the hypothesized patterns, we utilized a simple slope analysis [63]. Figure 2 demonstrates that the positive relationship between AL and PI is more pronounced when EO is high. Similarly, Figure 3 indicates that as EO increases, the relationship between AG and PI strengthens. Therefore, hypotheses H5 and H6 were validated.

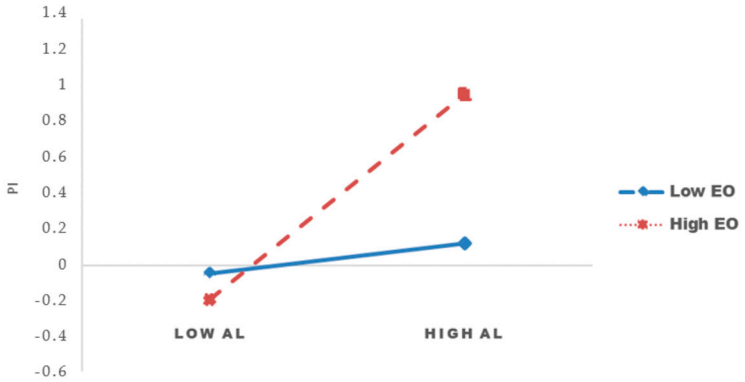

Figure 2. EO's moderating effect on the relationship between AL and PI.

Figure 3. EO's moderating effect on the relationship between AG and PI.

5. Discussion

This study explored the potential mechanisms of ambidextrous leadership in product innovativeness from OA and entrepreneurial orientation perspectives. This study offers preliminary support for the ambidexterity theory of leadership, OA, and entrepreneurial orientation as contributors to product innovativeness.

First, ambidextrous leadership demonstrates a significant positive influence on product innovativeness, consistent with the findings of related studies [6,7,64]. However, the results suggest that open leader behavior used alone exerts a less significant influence on product innovativeness. This may be because open leader behaviors are less goal-oriented, exhibit a high level of error tolerance, and involve experimentation with radical creativity despite risks. Consequently, firms may experience low product innovativeness due to a lack of communication among coworkers and substantial errors and failures in new product development. However, product innovativeness is enhanced when both types of leadership behaviors are engaged simultaneously. This finding is consistent with previous studies [2,7] that have highlighted the need for a combination or interaction of the two complementary sets of leadership behaviors to facilitate innovation, given the complexity of the process. Closing leader behaviors, which are goal-attainment-oriented and focus on unifying routines and rules to reduce errors, can synergize with opening leader behaviors to amplify the level of product innovativeness beyond what opening or closing leader behaviors alone can achieve.

Second, ambidextrous leadership significantly impacts OA, whereas closing leaders' behaviors alone are less critical in facilitating agility. This may be due to the controlling nature of closing leader behaviors, which restrict flexibility and quick responsiveness within an agile organization. Kumkale [24] reports that organizational ambidexterity directly and positively affects the four dimensions of OA. This implies that applying AL to firms can lead to higher competence, flexibility, speed, and responsiveness. Additionally, OA

directly positively influences product innovativeness and partially mediates the relationship between AL and product innovativeness. Thus, OA is an essential antecedent of PI and serves as a bridge between AL and PI. With both exploratory and exploitative leadership styles, a more agile organization promotes product innovativeness along the path.

Moreover, it has been proven that a positive synergy exists between EO and ambidextrous leadership and OA concerning product innovativeness. This finding aligns with a substantial body of research arguing for the numerous benefits of implementing EO regarding firm performance [65]. One of the main characteristics of EO is risk taking, which is closely linked to an opening leader's behavior and flexibility of the AG. This necessitates environments with loose routines and rule orientations and relies heavily on exploratory activities rather than exploitative ones. The responsiveness of AG is also consistent with open leader behaviors and risk-taking, as responsiveness is primarily triggered by changes in the business environment, requiring bold and decisive decision-making. The proactiveness of the EO signifies a stance that demands the speed of AG and goal attainment facilitated by closing leadership behaviors. All these effects contribute to a higher level of product innovativeness, enabling future market acquisitions and competition against rivals. AL further enhances the EO's innovativeness and the AG's competence, leading to higher levels of product innovativeness. Therefore, the interactions between AL, the four dimensions of AG, and EO are crucial factors that should not be overlooked. Their abilities, particularly in resource acquisition and allocation through exploration and exploitation, contribute to the successful development of new products within firms, ultimately sustaining business operations and introducing new, beneficial products to the world.

6. Implications

6.1. Theoretical Implications

There are several contributions to the literature on leadership and new product development that are vital for sustaining the competitiveness of firms and industries. First, very few studies have evaluated the impact of AG. This study further reveals the link between AL and PI, highlighting AG's partial mediating effects. This finding aligns with the concerns raised by Lu and Ramamurthy [19] and Cai et al. [10] regarding the importance of developing OA in product innovation alongside ambidextrous leadership, thus addressing the lack of comprehensive studies in this realm. Moreover, this study fills an empirical analysis gap in researching the role of ambidextrous leader behaviors in PI and AG, as noted by Hughes et al. [16] and Chakravarty et al. [20]. Consequently, this study provides a new direction for future research to further understand the underlying mechanisms. Overall, this study contributes to the existing literature by shedding light on the interplay between AL, AG, and PI, enhancing our knowledge of leadership dynamics in the context of new product development.

Additionally, this paper highlights the vital role of ambidextrous leadership in the context of new product development, presenting it as an exemplary model of effective leadership. The fusion of both opening and closing leader behaviors emerges as essential for driving innovation success, as these distinct leadership approaches cater to the dual needs of stimulating creativity and ensuring effective idea implementation [7,41]. This stands as a clear advantage compared to traditional leadership approaches when encountering innovation. The distinctive attributes of the ambidextrous leadership model establish a theoretical foundation for distinguishing it from traditional leadership styles, underscoring its significance within innovation processes as effective leadership.

This study also provides further support for the argument that both opening and closing leader behaviors significantly enhance innovation performance, consistent with prior research [2,8,41]. Importantly, the results contribute to the ambidextrous leadership literature by demonstrating the positive relationship between these behaviors within a Chinese context, thus broadening the scope beyond previous studies conducted in Germany [41], the USA [8], and Australia [2].

Moreover, although the influence of EO on innovation has been evaluated in prior studies, new evidence demonstrates that when employed to handle the difficulties of new product innovation, it can facilitate both AL and AG in enhancing product innovativeness more effectively. The link between these factors can be integrated into a new mechanism that allows for a better understanding of the moderating effect of EO on product innovativeness in ambidextrous and agile firms.

6.2. Practical Implications

This study offers several practical implications for product innovation teams. In terms of ambidextrous leadership, due to differences in follower perceptions, various types of task requirements, and the varying stages of the product innovation process, leaders must know how to adjust, switch, or combine different styles of behavior according to the capabilities, personal characteristics, expectations, and nature of tasks. A one-size-fits-all approach to behavior may not work for all team members in product innovation, especially in AI or high-tech industries. With the effect of AL, organizations become more agile. Leaders should be quickly aware of this and adjust their behavior to promote agility among team members. For example, they can exhibit open behaviors to facilitate flexibility and responsiveness in innovation tasks. Conversely, leaders must switch to closing behaviors to emphasize goal-attainment orientation among followers if a delay or slack occurs. Moreover, from the perspective of opening up leader behavior and EO, followers' risk-taking behaviors can be promoted to a certain degree, as innovation requires novel ideas and creativity. With the adoption of EO, innovation teams can become more proactive in exploring and exploiting existing or new resources to fulfill product innovation needs. Leaders can also encourage followers to explore novel ways or processes to address uncertainties and enhance product innovation. Furthermore, firms must incrementally foster a culture that connects these factors to enhance their overall potential to cope with the changes or complexities that emerge with new product innovations. With this agenda, firms can gain better resource allocation and utilization capabilities and attain competencies. New products should be strategically introduced into the industry, leading to sustainable development.

This study reinforces the understanding that ambidextrous leadership enables firms to thrive, whether in the short term or the long term, by creating a dynamic equilibrium in organizations that exclusively focus on exploration risk instability and resource depletion, conversely, in those overly fixated on exploitation become stagnant, missing out on crucial innovations. Furthermore, the findings underscore the pivotal role of ambidextrous leadership and product innovativeness in ensuring that core processes run smoothly, costs are controlled, and operational excellence is achieved. Consequently, resources are optimized, waste is minimized, products become more sustainable, and environmental impact is reduced. By studying these critical factors, firms can foster societal well-being and create a sustainable environment. Firms with higher innovativeness are adept at facilitating sustainability across all dimensions of our world—technological, market, and environmental.

7. Limitations and Future Directions

Ambidextrous leadership, a contradictory yet complementary leadership style, is insufficient in a cross-sectional study to determine the outcomes of product innovation based on independent factors. Therefore, a longitudinal study could further investigate the relationships between all dimensions. Additionally, AG partially mediates the relationship between AL and PI, implying that several other factors act as mediators in organizations' product innovation processes. Hence, future studies should include additional factors such as adhocracy culture and knowledge-based dynamic capabilities to gain a deeper understanding. This study provides a new direction for future research that combines these three factors and generates a unique synergy to impact innovation.

Finally, data for this study were collected exclusively from the Yangtze River Delta (YRD) region of China and focused solely on the AI industry. This geographical and

industry-specific restriction may limit the generalizability of our findings to other regions or industries. Future research could expand the scope of this study by collecting data from multiple regions within China and across different countries. Researchers could compare the similarities and differences in a wider range of regions. In addition, future studies could investigate sectors beyond the AI industry to help identify potential synergies and interdependencies between different industries, providing valuable insights into the broader impacts of ambidextrous leadership and its implications for achieving sustainable competitive advantages through product innovativeness.

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