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Research Article

From Innovation to Profit: Exploring the Relationship between Research Activities and Economic Performance in Iran's Pharmaceutical Industry using System Dynamics

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Abstract

Iran's pharmaceutical industry faces challenges such as low returns on R&D, lack of market exclusivity, and strict pricing regulations, which limit profitability and reduce incentives for innovation. Addressing these issues requires a strategic approach to managing the entire drug development cycle, balancing research and marketing efforts to drive sustainable growth. This study uses system dynamics modeling to evaluate the financial outcomes of pharmaceutical R&D activities in Iran. Through a comprehensive literature review and Delphi method, twelve key indicators related to R&D and marketing were identified. These indicators informed a validated system dynamics model developed in Vensim PLE, simulating company performance over 25 years. Results show that profits positively reinforce research activities, creating a feedback loop that supports growth in profitable products and intangible assets. Sensitivity analysis highlights the importance of business size and cash cow products in financial performance. While marketing boosts short-term sales and product profitability, long-term success relies on sustained R&D investment. Excessive marketing without innovation yields diminishing returns, whereas combined investment in R&D and marketing produces synergistic effects, significantly increasing sales and new product development. In conclusion, integrated strategies aligning R&D and marketing efforts are essential for fostering innovation-led growth and improving financial sustainability in Iran's pharmaceutical industry.

Keywords: Iran; Economic performance; Pharmaceutical industry; Research activities; System dynamics.

1. Introduction

The pharmaceutical industry faces significant global challenges, including rising research and development costs estimated at around US$1 billion per new drug [1] and substantial marketing expenditures, which exceeded US$27 billion in the United States in 2004. By 2016, pharmaceutical manufacturers had also spent approximately US$1 billion on payments to physicians for consulting and speaking engagements [2]. These global dynamics are mirrored, though with distinct local

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characteristics, in Iran, where a population exceeding 85 million and an annual growth rate of 1.2% [3] have created increasing demand for pharmaceuticals, further intensified by an aging demographic.

To understand the dynamics of pharmaceutical innovation, two key theories are relevant: the "market-pull" innovation theory [4], which suggests that market demand drives innovation, and Schumpeterian innovation theory [5], which emphasizes the need for continuous innovation under competitive pressure. These theories help frame the challenges faced by firms in aligning R&D efforts with market needs and maintaining growth under competitive conditions.

These payments are frequently viewed as a means to encourage product promotion and increase sales within the medical community [6]; reported figures vary, reflecting differences in national contexts such as financial capacity, regulatory frameworks, and scientific infrastructure [7]. Marketing activities encompass intricate details, and the "core commercialization program" indicates the core team's responsibility (research, development, medical, regulatory, marketing, commercial development, product management, marketing research, and advertising) for nurturing a product from its initial conception to market availability [8]. All of these reflect the complexity of the pharmaceutical system from idea to launch. On the other hand regulations significantly shape investment decisions in drug development [9]. In Iran, all pharmaceutical manufacturers produce generic drugs, and given the country's regulatory system, the costs associated with developing a new drug for the market are relatively minimal [10]. However, for pharmaceutical firms, balancing R&D (research and development) expenditures with profitability in the market is crucial—particularly given modest potential returns, reported at less than 2%, which raises concerns about long-term investment sustainability [11]. Due to the low profitability in the pharmaceutical industry, companies must carefully decide which products to pursue in order to maximize their profits.

Beyond the costs of R&D, pharmaceutical companies also face expenses and risks during clinical development, with only a small fraction of projects ultimately achieving success [12]. In summary, two key factors drive drug development within companies, first the number of new drugs proposed and formulated by the R&D department and second the market success of these selected drugs and their potential to generate profits for the company [13]. Successful new drugs require long-term protection in the market to prevent competition from other companies [14]; however, in generic pharmaceutical systems like Iran, lack of market exclusivity for new to market medicines allows other companies to produce and sell the same drugs, thereby undermining the exclusivity typically granted by patents. In addition, official pricing system for pharmaceuticals aims to enhance accessibility and affordability of medicines for the public; it can also impose a ceiling on profitability [15]. This limitation may hinder the ability to recoup investments in research and development for new products [16]. Given such limitations, research processes must be conducted with greater precision, and adequate investment in R&D and marketing can serve as a guarantee for the company's profitability. To effectively review all the factors from research to profit, it's essential to engage in horizon scanning, which entails a systematic assessment and identification of all elements that impact the drug development process within a firm.[17] Given the complexity discussed above, the system dynamics approach offers a powerful means of analyzing the interconnected and feedback-driven nature of pharmaceutical systems. This method enables researchers to model causal relationships, feedback loops, and time delays that influence long-term performance and policy outcomes. It supports the development of conceptual frameworks, deepens understanding, and aids in predicting system behavior and decision-making across various stages—from idea generation to market entry—in pharmaceutical companies in Iran [18]. Therefore, this study employs system dynamics simulation models to illustrate the financial outcomes of research activities in Iranian pharmaceutical firms. Although many studies have discussed productivity challenges and market trends in the pharmaceutical industry, there remains a lack of guidance on how companies can strategically evaluate current opportunities to forecast future outcomes. This research provides a framework for pharmaceutical companies to model the impact of R&D investment on profitability within Iran's regulatory context. The framework aims to improve long-term consistency and profitability for these firms.

2. Material and Method

Modeling healthcare systems and making decisions regarding healthcare products are complex and challenging [19]. The pharmaceutical industry involves unique complexities, owing to the intricate link between research activities and subsequent market outcomes for drug products [20]. Marketing is fundamentally a research-driven discipline that relies on empirical evidence, rigorous analysis, and real-world applicability [21]. Therefore, economic models analyzing this sector must comprehensively address key influencing factors accurately elucidate the impact of research activities on company's financial performance [22]. For the purposes of this paper, both research and development (R&D) and marketing activities will be collectively referred to as "research activities" [23, 24]. Both are demonstrably critical for a company's economic success, business scaling, and achievement of optimal market share [25, 26].

1. Literature review and Delphi method: The research process began with a comprehensive literature review to identify potential indicators in R&D and marketing that influence the economic performance of pharmaceutical companies. The findings of this review are summarized in **Table 1**. Building on this foundation, the Delphi method was employed to validate and refine these indicators [27]. The Delphi process was conducted over two rounds with five experts, including three industry experts and two academic experts, all of whom had more than 15 years of experience in pharmaceutical management and policy. Panelists were selected for their expertise in R&D strategy, market analysis, and financial performance. The initial indicator list was derived from a comprehensive literature review (**Table 1**). In each round, Experts evaluated the indicators using a five-point Likert scale, ranging from very low to very high importance. Anonymity was maintained throughout, and the round 1 results (mean scores and frequency distributions) were shared with participants for re-evaluation. Consensus was defined as ≥70% agreement on the importance of each indicator. Variables receiving less than 70% consensus were excluded from the model to maintain focus on indicators with stronger expert agreement. Although these factors may influence performance, their exclusion minimizes subjectivity and ensures the model reflects robust expert consensus.

Table 1. List of indicators.

No.	Variables	Reference	Delphi Percentage of consensus (%)	Approved to use in model: >70%
1	Research activities	(31, 32)	100	Yes
2	Number of New products	(33)	91.6	Yes
3	Type of products	(34)	91.6	Yes
4	Publication & Patents	(37, 44, 46-48)	75	Yes
5	Intangible assets	(49, 50)	83.3	Yes
6	Intellectual Capital	(54)	41.6	No
7	Behavior (Culture)	(41, 51)	75	Yes
8	Costs	(32, 36)	100	Yes
9	Business Size	(37-39)	91.6	Yes
10	People	(40-43)	83.3	Yes
11	Training programs	(55)	16.6	No
12	Personnel work experience	(56)	58.3	No
13	Annual sale	(36, 42)	100	Yes
14	Profit	(32, 35, 37, 44, 45)	100	Yes
15	Initial Investment	(32, 35)	100	Yes
16	Fix assets	(36)	66.6	No
17	People cost	(36)	33.3	No
18	Assets	(43)	58.3	No
19	Financial statements	(52, 53)	50	No
20	Balance sheet	(52, 53)	58.3	No

2. Conceptualization: The first phase involved defining the system's core architecture and boundaries, which were visualized through a causal network map representing the cause-and-effect relationships among key system variables. This stage established the foundation for identifying critical variables, feedback loops, and interdependencies relevant to the pharmaceutical R&D–profitability relationship. To ensure conceptual validity, a panel of experts—comprising four professionals from the pharmaceutical industry and two academic specialists—reviewed the model structure in light of existing literature and their domain expertise [28, 29].

3. Stock-flow modeling: Building on the conceptual framework, the second phase translated the causal map into a quantitative stock–flow structure, characterized by level, auxiliary, and constant variables. This stage required formulating a calibrated model and defining mathematical equations that capture the interrelationships among variables based on literature evidence and expert input [30, 31]. Model validation was carried out through both structural and behavioral assessments, with iterative expert reviews and testing of model behavior under alternative formulations to ensure robustness [32]. The Vensim PLE (version 7.3.5) software package was employed for model execution, providing an accessible environment for developing and simulating system dynamics models [33]. A long-term simulation horizon of 25 years was selected to capture the delayed and cumulative effects typical of pharmaceutical R&D activities, including long development cycles, regulatory approval periods, and extended market lifetimes of successful products.

4. The final phase focused on evaluating the model's reliability and responsiveness through sensitivity testing. This step complemented the verification and validation process by examining how variations in key parameters influence system behavior. Direct structural tests—such as checks for historical fit, extreme conditions and dimensional consistency—were conducted on a major variable using Vensim software, ensuring internal consistency [34]. Moreover, an expert panel reviewed the model's structure and causal relationships multiple times to achieve an optimal configuration [35]. The results of these specific system dynamics tests are presented in the Results section.

3. Results and Discussion

The Results are organized into the following sections: (1) Findings from the literature review based on PRISMA guidelines, and outcomes of the Delphi rounds. (2) Results of the conceptual model evaluation. (3) Results of quantitative data analysis. (4) Sensitivity analysis results. (5) Model validation outcomes

3.1. Results of the Literature Review (PRISMA) and Delphi Rounds

A structured literature review was conducted in accordance with the PRISMA guidelines to identify potential indicators related to R&D and marketing activities influencing the economic performance of pharmaceutical companies. The literature search was performed in two major scientific databases, Google Scholar and PubMed. Combinations of the following keywords were used: "R&D investment", "pharmaceutical industry", "marketing performance", "economic performance", "system dynamics", "innovation management", and "drug development". The initial search identified 268 records, of which 241 remained after the removal of duplicates. Titles and abstracts were screened to assess relevance to the study objectives, resulting in the exclusion of 169 records. Subsequently, 72 full-text articles were assessed and included for detailed review and indicator extraction, resulting in a collection of 20 potential indicators. These indicators were then subjected to a Delphi model, with a consensus threshold of 70%. The Delphi process resulted in the acceptance of 12 indicators, which were subsequently incorporated into the final model.

The initial capital is recognized as a critical variable influencing the initial valuation within the model. Small and newly established companies were valued based on an assumed initial capital of $1 million. This study will primarily focus on the model's results pertaining to these companies.

3.2. Conceptual model

The basic assumption is that scientific and research activities come with financial costs, including personnel, equipment, and materials. As a company's profits increase, it can allocate more resources to research and development, leading to greater research activity. Moreover, high profits never reduce research efforts, meaning that profit always has a positive effect on research activities [36]. An increase in scientific and research activities within the marketing and sales sector can lead to a rise in profitable products and the growth of intangible assets like branding, ultimately resulting in higher sales and greater company profits.[37] Research activities in R&D section are influenced by three key factors:[38]

1. Employees working in the research and development (R&D) department
2. R&D assets and equipment
3. The organizational behavior governing the R&D sector [39].

Intangible assets, such as publications and brand names, contribute to increasing the company's value. This enhanced value, in turn, leads to greater investment in market research activities. Expansion of the business, as depicted in **Figure 1**, inevitably leads to increased expenditures encompassing both capital (CAPEX) and operational (OPEX) expenses. Research activities, being a component of these overall expenditures, will consequently experience a proportional rise [36]. The proposed concept has garnered endorsement from qualified experts.

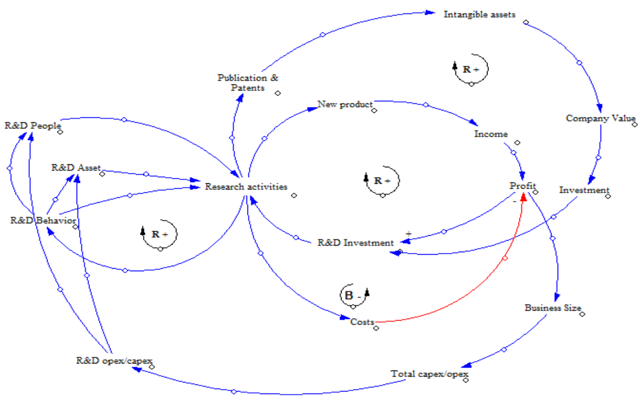

Figure 1: Conceptual Model.

3.3. The stock-flow model (**Figure 2**)

The quantitative model comprises two principal components:

1. Scientific research activities: scientific research activities are bifurcated into: (1) Research and development (R&D), culminating in the creation of novel products; and (2) Marketing activities, designed to promote products to target markets, thereby enhancing company profitability and revenue generation.
2. Financial dimensions, including revenue and return on invested capital. The profit of a company is derived from the difference between its revenues and costs, making it a stock variable. As the company's revenue increases, its profits rise, while higher costs result in reduced profits.

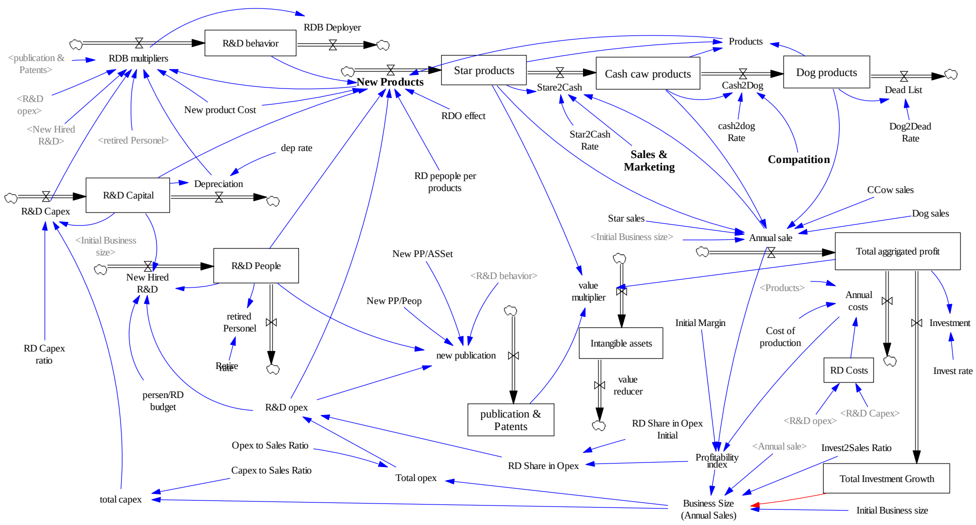

Figure 2: Stock-flow model.

3.3.1. Scientific research activities

Research activities (developing & promoting a product) impact the company's revenue and ultimately enhance its profitability [40].

3.3.1.1. R&D activities

Research activities in R&D section are influenced by three primary factors: the number of people employed in Research and Development (R&D), the assets and equipment available for R&D [38], and the prevailing organizational behavior within the R&D sector [39]. Each of these factors can independently change and affect the others. If the overall effect of these three variables is positive, research activities will increase, leading to the production of new products. Moreover, the count of publications and patents serves as a key indicator of R&D success [41]. While all three factors—R&D personnel, assets, and behavior—affect the number of new publications, organizational behavior and personnel are directly determining factors. [38, 39] Although not every publication results in a new product, it invariably contributes to the accumulation of intangible assets, thus enhancing the company's overall value [42].

Categorization of New Products (Marketing Point of View)

Not all new products of a company are equal in terms of profitability. Using the BCG (Boston Consulting Group) model, we categorize products into four distinct types based on market growth and market share [43]:
Dog Products: These products have slow market growth and low market share for the company. They do not generate significant profits, and the company generally lacks a strong interest in producing them.
Cash Cow Products: These products provide substantial income and profitability for the company, boasting a high market share. Cash cows are essential for maintaining a steady revenue stream.
Star Products: Star products exhibit high market growth potential and substantial market share. Often first-to-market innovations or products that undergo unique modifications compared to competitors, these items show strong sales and profit prospects.
Question Mark Products: These products have high market growth but low market share, resulting in uncertain futures. Over time, question marks may evolve into either star or dog products, depending on their competitive positioning and strategic management.
To understand the evolution of newly introduced products, one must recognize that they typically start as star products. Over time, by more marketing activities, they transition into cash cow products. If the competitive landscape *remains* unfavorable, these products may eventually degrade to the dog category, leading to reduced profitability and market relevance [44]. By focusing on enhancing cash cow and star products while managing or phasing out dog products, companies can improve overall profitability and maintain competitive advantages in the market. Market competition significantly impacts product positioning. Heightened competition can drive products towards the dog classification if a company lacks the competitive strength and resilience necessary for sustained market presence.
If the product quality is satisfactory and meets consumer expectations, it can lead not only to increased sales of that particular product but also boost sales of other products offered by the company. Consequently, the growth in the number of star products serves as a critical factor in enhancing intangible assets [45].

3.3.2. Financial dimensions

Annual sales are directly influenced by the sales performance of individual product categories, with the sum of each category's revenue constituting the total annual sales figure. Furthermore, while accumulated profits are strategically reinvested, these capital expenditures should not be regarded as sunk costs. Annual expenses encompass the cost of production, as well as research and development expenditures, comprising both operational and capital costs. Initial capital investment plays a significant role in determining the scale of the business and directly impacts annual sales volume. Total expenditures derived from sales revenue are divided into total operational expenditure (OPEX), which includes operational costs such as salaries and material expenses, and total capital expenditure (CAPEX), representing investments in assets like equipment. The CAPEX to sales ratio and OPEX to sales ratio provide insights into the proportion of total sales allocated to these respective expenditure categories.

The profitability index for each company is unique, serving as a metric to reflect annual sales performance, influenced by variables such as margin and annual Sale. The CAPEX to sales ratio and OPEX to sales ratio express the proportion of total sales that is allocated to operational and capital expenses, respectively. Operational expenses in the R&D sector are allocated towards personnel costs, necessary materials for developing new products, and the publication and dissemination of research outputs.

The core equations and variable definitions, developed under expert supervision, are included in the **Appendix** together with a simplified causal loop diagram to enhance reproducibility.

3.4. Validity and sensitivity analysis

A wide variety of tests is employed for the verification and validation of system dynamics (SD) models. These tests allow us to assess the model's structure, dimensional consistency, response to extreme conditions, and robustness under stress scenarios [35].

Sensitivity analysis was conducted to assess the impact of initial investment, utilizing company size as a proxy to evaluate model response to varying investment levels. Specifically, $1 million represented small companies, $25 million and $100 million medium-sized companies, and $500 million large companies. The model's output was then evaluated based on business size, number of cash cow products, and number of new products developed.

In **Table 2**, you can find a summary of how key parameters, such as R&D investment, marketing expenditure, and company size, affect major outcome variables like annual sales, cash cow products, and new product development under different simulation conditions

Figure 3 illustrates the impact of investment levels on business size, cash cow products, and new product development. Small companies (P.Inv001) reach around 200 annual sales after 20 years, while medium-sized (P.Inv025, P.Inv100) and large companies (P.Inv500) grow to 500-700 and 2000 units, respectively. Cash cow products follow a similar pattern, with small companies developing 20 products, medium-sized companies reaching 40-50, and large companies over 60. The results demonstrate consistent performance across these varying conditions.

Table 2. Effect of key parameters (R&D investment, marketing expenditure) on major outcome variables under different simulation conditions in small companies in year 10.

Simulation Condition	R&D Investment Share	Marketing Expenditure Share	Annual Sales (BT)	Cash Cow Products	Total Product
Low R&D, Low Marketing	1%	1%	70	6	22
Low R&D, moderate Marketing	1%	3%	102	10	23
Moderate R&D, Low Marketing	3%	1%	100	8	26
Moderate R&D, Moderate Marketing	3%	3%	130	15	28
Low R&D, High Marketing	1%	5%	100	10	23

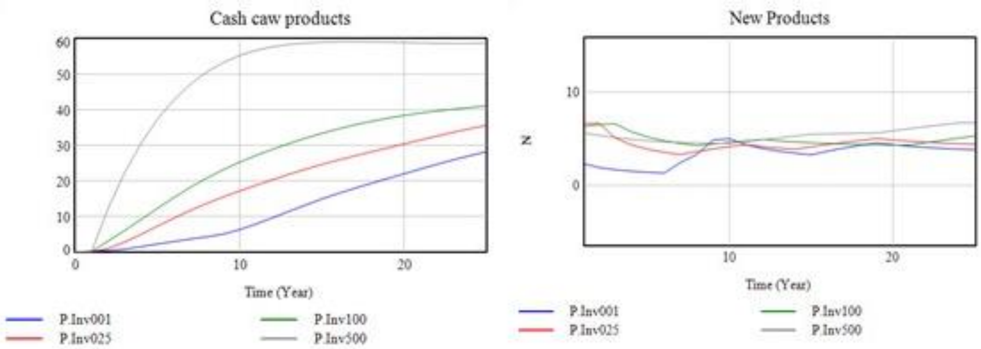

Figure 3: Business performance trends for companies with varying initial capital. (1, 25, 100, and 500 $ billion).
(Left): Annual sales (Business Size) over time. (Middle): Growth in number of Cash Cow products. (Right): Number of new products develop
Note: P.inv = Initial Investigation.
This figure illustrates the results of the sensitivity analysis over a 25-year period, focusing on the model's dependence on initial investment. The analysis revealed a significant relationship between business size and cash cow products, with larger companies experiencing greater growth in both metrics. This supports the model's assumption that larger companies with more resources tend to develop more profitable products. These findings were consistently validated through expert panel reviews, confirming the robustness of the model. In contrast, no significant relationship was found between initial investment and new product development, which further supports the model's prediction that initial investment alone may not drive innovation without complementary factors like R&D or marketing.

Results of Model Execution

3.4.1. Impact of marketing activity on business size, number of cash cow products and new products in small companies.

This section examines how varying levels of marketing activity affect the performance of small pharmaceutical companies, assuming a fixed level of R&D investment. **Figure 4** shows the results, increasing marketing expenditure leads to measurable growth in annual sales and the number of cash cow products. Over the 25-year simulation horizon, business size (annual sales) increased from approximately 270 BT under low marketing activity (SM) to 285 BT under moderate marketing (SM2) and 300 BT under high marketing (SM4)—representing an overall 11% rise. Similarly, the number of cash cow products grew from about 28 in the baseline scenario to 35 under moderate marketing and 38 under high marketing, indicating a 35% increase as marketing intensity doubled. In contrast, the number of new products remained nearly constant across all scenarios, suggesting that marketing expenditure primarily strengthens market performance and product maturity rather than directly stimulating innovation output.

Impact of research and development activities on business size, and number of new products in small companies.

This section explores how Research and Development (R&D) activities influence business outcomes. To isolate the effects of R&D, marketing activities were held constant in competitive vs. non-competitive markets. **Figure 5** illustrates the change in business size (left) and growth in the number of products developed (right) over a 25-year period for small pharmaceutical companies. All three scenarios show a steady increase in annual sales over time, with noticeable acceleration after year 10. The blue line (high R&D activities in a competitive market) demonstrates an annual sales increase of approximately 250 BT by year 20, while the green line (basic R&D activities in a competitive market) exhibits the slowest growth, only a 150 BT increase. In terms of product development, high R&D results in over 60 products by year 25, while basic R&D reaches 40. These trends highlight that higher R&D investment significantly drives business growth, particularly in competitive markets, with the differences being statistically significant.

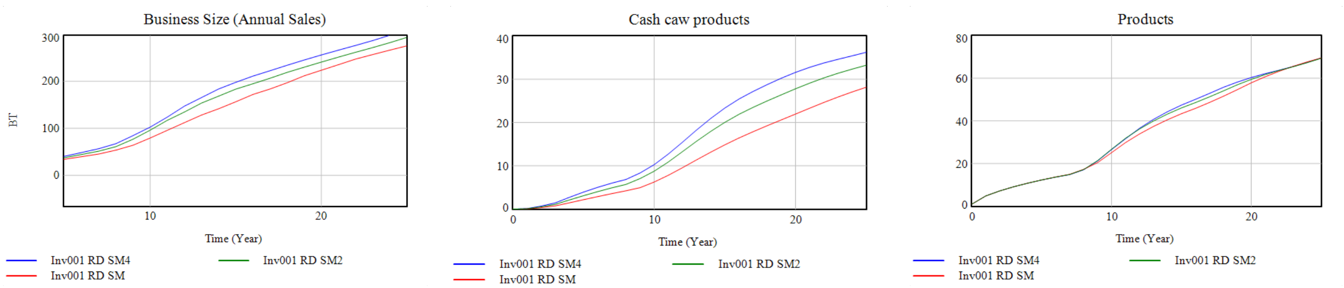

Figure 4: Effect of varying marketing (SM) levels on small pharmaceutical companies with fixed R&D.
(Left): Annual sales (Business Size) grow with increased marketing, though at a diminishing rate. *(Middle)*: Number of Cash Cow products increases significantly, showing marketing's role in enhancing product profitability. *(Right)*: Number of new products remains steady across all marketing levels.
Note: Inv = Investigation; RD = Research and Development activity level; SM = Marketing activity level.

These trends directly tie to the resource allocation aspect of the model, which hypothesizes that greater investment in sales and marketing should lead to higher business growth, product innovation, and a stronger product portfolio. The figure shows that as sales and marketing efforts increase (blue line, Inv001 RD SM4), the growth in business size and product development accelerates, supporting the hypothesis that effective marketing and sales strategies enhance business performance. This aligns with the theoretical relationship in the model suggesting that marketing efforts drive growth at a given investment level.

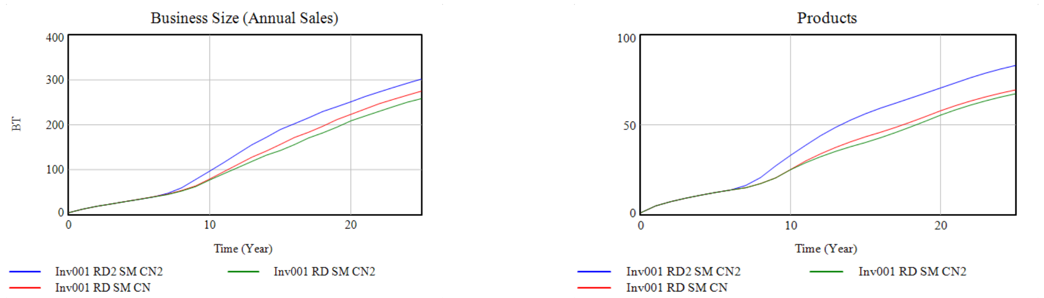

Figure 5: Effects of Research & Development (R&D) in competitive vs. non-competitive markets for small pharmaceutical companies, with constant marketing levels.
(Left): Annual sales are initially unaffected, but long-term R&D investment counteracts the negative impact of competition, driving higher growth. (Right): Total number of products decreases under competition, but R&D activity reverses this trend, boosting product retention and portfolio expansion. These trends support the hypothesis that higher R&D investment in competitive markets significantly enhances business growth and product development.
Note: Inv = Investigation; RD = Research and Development activity level; SM = Marketing activity level; CN = Level of Competition.

Impact of R&D and Sales & Marketing Activities Simultaneously on business size, number of cash cow products and new products in small companies.

In the previous sections, we analyzed the effect of marketing activities while keeping all R&D parameters constant, and similarly, we examined the impact of R&D activities while holding marketing parameters unchanged. This section investigates the combined effect of Research & Development (R&D) and Sales & Marketing (S&M) efforts on the performance of small pharmaceutical companies.

Figure 6 compares three key metrics—business size (annual sales), number of cash cow products, and new product growth—over a 25-year period for four scenarios. The blue line (high R&D activities and high marketing activities) shows the highest growth in annual sales with sales reaching 300 BT by year 20, this is followed by the green line (basic R&D activities and high marketing activities), which shows moderate growth, and the gray line (basic R&D activities and marketing activities) with the slowest growth, reaching just 150 BT by year 20.

In the middle figure showing the number of cash cow products, the green line, representing basic R&D and high marketing activities, reaches 45 products, consistently surpassing the red line representing high R&D and basic marketing activities, which reaches 30 In the right figure showing the number of new products, the red line surpasses the green, achieving 75 products compared to 60. These results highlight that higher R&D and marketing activities lead to greater growth, with statistically significant differences between scenarios.

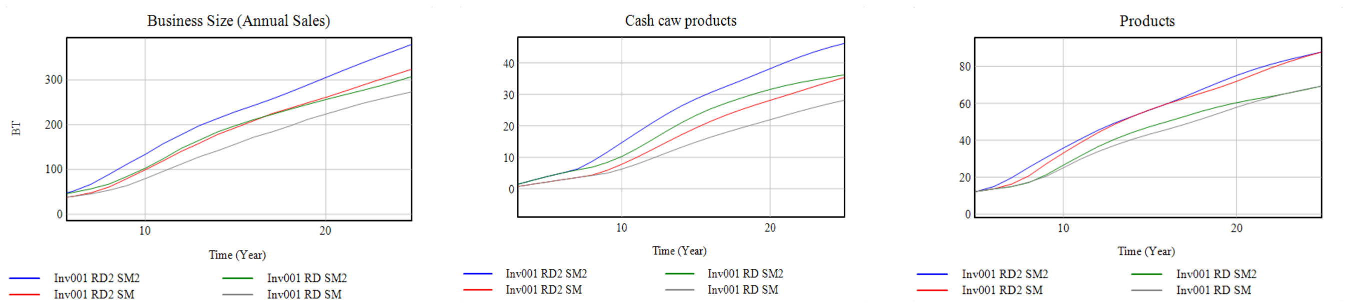

Figure 6: Combined effects of research & development (R&D) and marketing (SM) on small pharmaceutical companies. (Left): Annual sales (Business Size) increase with either R&D or SM, with R&D showing a stronger early impact; combined efforts yield the highest growth. (Middle): Number of cash cow products grows with both, with SM having an earlier effect. (Right): Number of new products rises significantly only when both R&D and SM are increased together; changing either one alone has minimal effect. These results demonstrate that greater combined investment in R&D and marketing drives significant improvements in business performance, particularly in terms of product innovation and market expansion.
Note: Inv = Investigation; RD = Research and Development activity level; SM = Marketing activity level.

Discussion

The model aims to support small pharmaceutical companies predict future trends and make informed decisions. The simulation results provide a comprehensive view of how R&D and marketing activities influence the growth trajectory of these companies.

Initial capital strongly determines the starting scale of business activities and shapes the long-term size of the company [46], especially in terms of annual sales and product portfolio. However, capital alone does not guarantee innovation or product profitability.

Marketing activities independently contribute to growth in business size (annual sale), highlighting their essential role in strengthening product profitability [47]. This aligns with "market-pull" innovation theory, which emphasizes the role of marketing capabilities in transforming technological assets into market value.[4] As observed, increases in marketing activity raise the number of cash cow products, indicating more effective exploitation of existing products. However, this relationship is nonlinear: doubling marketing efforts does not generate a proportional increase in sales, reflecting diminishing marginal returns and consistent with prior evidence in pharmaceutical commercialization [48].

In the early years (the first 10 years), small pharmaceutical companies experience minimal impact from higher R&D activities on annual sales. However, over time, these effects become more significant. Market competition tends to suppress sales performance [49], but sustained R&D investment not only offsets this negative impact but can also lead to stronger sales growth and business expansion [50]. This pattern aligns with Schumpeterian innovation theory, which posits that innovation becomes increasingly critical under competitive pressure.[5] As expected, increased R&D activity results in a higher number of new products [51], reflecting a "technology-push" dynamic [52] Yet, this relationship is also nonlinear, as doubling R&D does not simply double new product output.

When R&D and marketing are increased individually, they produce comparable improvements in sales (**figure 6**–left- green & red lines). When both are enhanced simultaneously, their combined effect produces substantially greater business growth (**figure 6**–left- blue line), This supports the dynamic capabilities framework, which emphasizes the importance of integrating complementary capabilities to sense opportunities (R&D), seize them (marketing), and reconfigure resources for competitive advantage [53].

The number of cash cow products is also positively affected by both R&D and marketing. Marketing demonstrates a more immediate effect (**figure 6**–middle-green & blue lines), reflecting its role in accelerating product uptake and lifecycle maturity. R&D effects emerge more gradually as products transition into later lifecycle stages. While doubling R&D or marketing individually does not double the number of cash cow products, doubling both together leads to nearly a twofold increase by year 20 (**figure 6**– middle **-** gray & blue lines). This finding is aligned with organizational ambidexterity theory, where firms must balance exploration (R&D/new products) and exploitation (marketing/cash cow products) [54].

The most substantial increase in the number of new products occurs when both R&D and marketing are doubled (**figure 6**–right- blue line). Doubling R&D activities significantly raises the number of new products, whereas doubling marketing alone does not meaningfully affect product count. This distinction reinforces the theoretical understanding that R&D drives exploration capabilities, while marketing enhances exploitation capabilities, and only their coordinated enhancement maximizes innovation performance.

However, several limitations should be noted. The model assumes linear relationships between variables (e.g., R&D, marketing, and sales), whereas these may be nonlinear in reality. Additionally, external factors like market competition and regulatory changes were treated as exogenous variables, which might not fully capture the dynamic nature of the pharmaceutical industry. The model is specifically designed for small pharmaceutical companies in Iran, and caution should be exercised when generalizing the results to larger firms or international contexts with different regulatory frameworks. Lastly, the model simplifies certain industry complexities, such as intellectual property and pricing regulations, which could affect performance.

4. Conclusion

This study aimed to explore how R&D and marketing activities influence the economic performance of small pharmaceutical companies in Iran. The model developed in this research effectively demonstrates the interrelationship between R&D investments, marketing strategies, and long-term business growth and how these variables shape the future of small pharmaceutical companies in a challenging market environment.

While marketing can drive short-term revenue and improve product visibility [55], it is R&D that fuels long-term competitiveness and innovation, especially when market conditions are challenging. The findings highlight the diminishing returns from excessive marketing expenditure, suggesting that overspending in this area without complementary innovation may not be a sustainable strategy. Similarly, R&D alone has limited impact unless supported by effective marketing channels to bring new products to market and sustain their successful sale.

The interaction between R&D and marketing revealed significant synergistic effects. For example, when both R&D and marketing efforts were increased simultaneously, the model predicted a 40% increase in annual sales, a 71% increase in the generation of cash cow products, and a 31% increase in new product development over a 25-year period. This underlines the importance of integrated planning between departments often seen as separate in early-stage companies. The model's insights fill a crucial gap in the literature by offering a clear, actionable framework for small pharmaceutical companies in Iran to balance R&D and marketing investments effectively, improving both short-term profits and long-term sustainability.

By explicitly demonstrating how integrated R&D and marketing activities can drive economic performance, this study offers valuable guidance for companies seeking to navigate the complexities of the Iranian pharmaceutical market. The findings underscore the need for strategic, coordinated investment in both areas to maximize business growth and ensure future competitiveness in a highly regulated and competitive industry.

Future research could test the model empirically with real company data to validate its predictions and extend it to larger pharmaceutical markets, both domestically and internationally. Additionally, incorporating regulatory dynamics into the simulation, such as pricing policies or market exclusivity, would enhance the model's applicability in diverse regulatory environments. Finally, testing the model under different market conditions or in other sectors could provide a broader understanding of the relationship between R&D, marketing, and business growth in dynamic industries.

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Conflict of interest

The authors declare to have no conflict of interest.

Data availability

The data supporting the findings of this study are included within the article.

Authors Contributions

Akbar Abdollahi Asl: Conceptualization, Methodology, Formal analysis, Supervision, Validation, and Project administration.
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Using artificial intelligence chatbots

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References

1. Adams, C.P. and V.V. Brantner, Spending on new drug development1. Health Econ, 2010. 19(2): p. 130-41.
2. Gagnon, M.-A. and J. Lexchin, The cost of pushing pills: a new estimate of pharmaceutical promotion expenditures in the United States. Plos medicine, 2008. 5(1): p. e1.
3. Iran population statistics. [cited 2025 02 February]; Available from: https://amar.org.ir/ (Accessed February 02, 2025).
4. Lubik, S., et al., Market-pull and Technology-push in Manufacturing Start-ups in Emerging Industries. Journal of Manufacturing Technology Management, 2013. 24: p. On line via EarlyCite at http://bit.ly/RBXjlb.
5. Śledzik, K., Schumpeter's View on Innovation and Entrepreneurship. SSRN Electronic Journal, 2013.
6. Brennan, T., Pharmaceutical Marketing Revisited—United States v. Biogen Idec. New England Journal of Medicine, 2022. 387(18): p. 1631-1633.
7. Sertkaya, A., et al., Costs of Drug Development and Research and Development Intensity in the US, 2000-2018. JAMA Network Open, 2024. 7(6): p. e2415445-e2415445.
8. JA., F., Promotion of pharmaceuticals: Issues, trends, options. Vol. 7. 1992: Pharmaceutical Products Press.
9. Sato, K., K. Kodama, and S. Sengoku, Driving Innovation Through Regulatory Design and Corporate Behaviour: A Case Study of Functional Food Industry in Japan. Foods, 2024. 13(20).
10. Davari, M., T. Walley, and A. Haycox, Pharmaceutical policy and market in Iran: past experiences and future challenges. Journal of Pharmaceutical Health Services Research, 2011. 2(1): p. 47-52.
11. Sood, N., K. Mulligan, and K. Zhong, Do companies in the pharmaceutical supply chain earn excess returns? Int J Health Econ Manag, 2021. 21(1): p. 99-114.
12. Colen, L., et al., Many are called, few are chosen: the role of science in drug development decisions. J Technol Transf, 2023: p. 1-26.
13. Dahlin, E., et al., Success rates for product development strategies in new drug development. J Clin Pharm Ther, 2016. 41(2): p. 198-202.
14. Jekunen, A., Decision-making in product portfolios of pharmaceutical research and development--managing streams of innovation in highly regulated markets. Drug Des Devel Ther, 2014. 8: p. 2009-16.
15. Eslamitabar, S., Pharmaceutical Pricing and Reimbursement in Iran: Providing a Solution to Improve Access and Production. Journal of Law and Health Studies, 2025. 1(2): p. 157-173.
16. Shaikh, M., P. Del Giudice, and D. Kourouklis, Revisiting the Relationship Between Price Regulation and Pharmaceutical R&D Investment. Appl Health Econ Health Policy, 2021. 19(2): p. 217-229.
17. Douw, K. and H. Vondeling, Selection of new health technologies for assessment aimed at informing decision making: A survey among horizon scanning systems. Int J Technol Assess Health Care, 2006. 22(2): p. 177-83.
18. Radzicki, M.J. and R.A. Taylor, Origin of system dynamics: Jay W. Forrester and the history of system dynamics. US Department of Energy's introduction to system dynamics, 2008.
19. Davahli, M.R., W. Karwowski, and R. Taiar, A System Dynamics Simulation Applied to Healthcare: A Systematic Review. Int J Environ Res Public Health, 2020. 17(16).
20. Rasekh, H.R., G. Mehralian, and A.A. Vatankhah-Mohammadabadi, Situation analysis of R & D activities: an empirical study in Iranian pharmaceutical companies. Iranian journal of pharmaceutical research: IJPR, 2012. 11(4): p. 1013.
21. Moorman, C., et al., JM as a Marketplace of Ideas. 2019, SAGE Publications Sage CA: Los Angeles, CA. p. 1-7.
22. Studdert, D.M., M.M. Mello, and T.A. Brennan, Financial conflicts of interest in physicians' relationships with the pharmaceutical industry—self-regulation in the shadow of federal prosecution. 2004, Mass Medical Soc. p. 1891-1900.
23. Mulinari, S. and P. Ozieranski, Unethical pharmaceutical marketing: a common problem requiring collective responsibility. Bmj, 2023. 382: p. e076173.
24. Jurd, S., The marketing of pharmaceutical agents: friend or foe? Australas Psychiatry, 2010. 18(2): p. 97-100.
25. Kao, A.C., et al., Effect of educational interventions and medical school policies on medical students' attitudes toward pharmaceutical marketing practices: a multi-institutional study. Academic Medicine, 2011. 86(11): p. 1454-1462.
26. Fulone, I., et al., Pharmaceutical policies: effects of policies regulating drug marketing. Cochrane Database Syst Rev, 2023. 6(6): p. Cd013780.
27. De Villiers, M.R., P.J. De Villiers, and A.P. Kent, The Delphi technique in health sciences education research. Medical teacher, 2005. 27(7): p. 639-643.
28. Abdollahiasl, A., et al., A system dynamics model for national drug policy. Daru, 2014. 22(1): p. 34.
29. Albin, S., J.W. Forrester, and L. Breierova, Building a system dynamics model: Part 1: conceptualization. 2001: MIT.
30. Zare Mehrjerdi, Y., R. Khani, and A. Hajimoradi, System dynamics approach to model the interaction between production and pricing factors in pharmaceutical industry. Journal of Quality Engineering and Production Optimization, 2020. 5(2): p. 163-188.

31. Kechagias, E.P., et al., Applying a system dynamics approach for the pharmaceutical industry: Simulation and optimization of the quality control process. arXiv preprint arXiv:2112.05951, 2021.
32. Kharaghani, M., M. Homayounfar, and M. Taleghani, A System Dynamics Approach for Value Chain Analysis in Pharmaceutical Industry. Journal of Industrial and Systems Engineering, 2023. 15(2): p. 124-139.
33. Sterman, J.D., System dynamics modeling: tools for learning in a complex world. California management review, 2001. 43(4): p. 8-25.
34. Lemke, J. and M. Łatuszyńska, Validation of System Dynamics Models–a Case Study. Journal of Entrepreneurship Management and Innovation (JEMI), 2013. 9(2): p. 45-59.
35. Barlas, Y., Formal aspects of model validity and validation in system dynamics. System Dynamics Review: The Journal of the System Dynamics Society, 1996. 12(3): p. 183-210.
36. Öman, C.B., K.S. Gamaniel, and M.E. Addy, Properly functioning scientific equipment in developing countries. Analytical Chemistry, 2006. 78(15): p. 5273-5276.
37. Curtis, A., S. McVay, and S. Toynbee, The changing implications of research and development expenditures for future profitability. Review of Accounting Studies, 2020. 25: p. 405-437.
38. Zaman, M. and G. and Tanewski, R&D investment, innovation, and export performance: An analysis of SME and large firms. Journal of Small Business Management, 2024. 62(6): p. 3053-3086.
39. Kegan, D.L. and A.H. Rubenstein, Trust, effectiveness, and organizational development: A field study in R & D. The journal of applied behavioral science, 1973. 9(4): p. 498-513.
40. Boiko, K., R&D activity and firm performance: mapping the field. Management Review Quarterly, 2022. 72(4): p. 1051-1087.
41. Chen, Y.-S. and K.-C. Chang, Analyzing the nonlinear effects of firm size, profitability, and employee productivity on patent citations of the US pharmaceutical companies by using artificial neural network. Scientometrics, 2010. 82(1): p. 75-82.
42. Kaur, T. and K. Dharni, Relationship between patent statistics and firm performance: a meta analytical review. Journal of Intellectual Capital, 2025.
43. Mohajan, H., An Analysis on BCG Growth Sharing Matrix. 2018.
44. Catana, S.-A., S.-G. Toma, and C. Gradinaru, The Product Life Cycle And The Boston Consulting Group'S Growth-Share Matrix In Marketing Simulations. Annals-Economy Series, 2022. 4: p. 319-324.
45. Chen, M.C., C.L. Hsu, and L.H. Lee, Service Quality and Customer Satisfaction in Pharmaceutical Logistics: An Analysis Based on Kano Model and Importance-Satisfaction Model. Int J Environ Res Public Health, 2019. 16(21).
46. Bercovitz, J. and W. Mitchell, When is more better? The impact of business scale and scope on long-term business survival, while controlling for profitability. Strategic management journal, 2007. 28(1): p. 61-79.
47. Rajput, K. and R.K. Pandey, Pharmaceutical marketing: A literature review. International Journal of Engineering and Management Research, 2022. 12(2): p. 56-63.
48. Kappe, E.R., The effectiveness of pharmaceutical marketing. 2011.
49. Covin, J.G., D.P. Slevin, and M.B. Heeley, Pioneers and followers: Competitive tactics, environment, and firm growth. Journal of business venturing, 2000. 15(2): p. 175-210.
50. Muchiri, G., P. Kibati, and P. Mwaura, Analysis of competitor factors affecting sales performance of small-scale trading enterprises in Kenya. International Journal of Business Management and Processes (ISSN 2616-3209), 2021. 5(5): p. 23-41.
51. Menon, A. and B.A. Lukas, Antecedents and outcomes of new product development speed: A propositional inventory germane to marketing. European Journal of Marketing, 2004. 38(1/2): p. 209-223.
52. Hötte, K., Demand-pull, technology-push, and the direction of technological change. Research Policy, 2023. 52(5): p. 104740.
53. Cavusgil, S. and S. Deligonul, Dynamic capabilities framework and its transformative contributions. Journal of International Business Studies, 2024. 56.
54. Tarody, D., Organizational ambidexterity as a new research paradigm in strategic management. Vezetéstudomány / Budapest Management Review, 2016. 47.
55. Hanssens DM, Dekimpe MG. 26 Short-term and long-term effects of marketing strategy. Handbook of marketing strategy. 2012:457.