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**Analysis of the dynamics of interaction between
profitability and liquidity using a predator-prey
model approach**

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Abstract

Profitability and liquidity are among the critical issues that must be studied and considered by the management of every organisation as their foremost task. This research aims to analyse the bidirectional dynamics of profitability ratios and liquidity ratios over time. This research also aims to present forecasted values of profitability and liquidity for the next five years. The data used in this study are obtained from the annual reports of PT. Indofood for the period 2011-2022. This research adopts a predator-prey model containing a pair of non-linear differential equations to describe the interaction between two species. The results of this study show that the predator-prey model can explain the bidirectional dynamics of profitability ratios and liquidity ratios with high accuracy. Besides, this study indicates that the type of relationship between profitability and liquidity is predator-prey. The forecasting results show that for 2023-2027, both profitability and liquidity tend to decrease. Based on the data, the company's profitability and liquidity dynamics periodically fluctuate over time. This indicates a positive sign for PT. Indofood's profitability and liquidity are in good condition. In the future, the company has to take preventive measures to continue stabilising its profitability and liquidity.

Keywords:

dynamics; forecasting; liquidity; predator-prey; profitability.

JEL Code: G30, C60, C¹

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Introduction ⁴⁷

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The non-oil and gas processing industry sector in Indonesia plays a crucial role in the national economy. The non-oil and gas processing industry still consistently provides a dominant contribution to the achievement of national export value. In 2023, manufacturing sector exports contributed 72.24 per cent of the total national export value of USD 258.82 billion (Kemenperin, 2024). One type of non-oil and gas processing industry is the food and beverage industry. The food and beverage industry is one of the key sectors supporting manufacturing growth and the national economy (Kemenperin, 2017). In 2022, the growth rate of the Gross Domestic Product (GDP) for the food and beverage industry reached 4.90 per cent, marking a higher GDP growth compared to 2021, which stood at 2.54 per cent (BPS, 2023). The demand for the food and beverage sector will continue to persist, given that consumption is essential for human survival. Consequently, the food and beverage industry needs to perpetually innovate to fulfil societal needs (Tseng et al., 2020). One of the methods to ensure the sustained longevity of companies is by evaluating the financial stability of the organisation. ³⁷

Liquidity plays an important role in the equity market. The significance of liquidity in the equity market is underscored by extensive research coverage within the field of financial economics (Pan, 2023). The financial stability of a company can be evaluated using liquidity ratios (Ježovita, 2015). The liquidity ratio is a metric that provides an overview of a company's ability to meet its short-term debt obligations within a year (Brigham & Houston, 2020). The short-term and daily business operations require a company's ability to generate sufficient cash to settle its maturing obligations. In this context, it is necessary to assess the company's competency in converting adequate non-cash assets into the required cash to fulfil obligations promptly (Ježovita, 2015). ²¹

The company's ability to maintain its capacity to meet short-term debt obligations is crucial for all users of financial statements. If the company fails to sustain its ability to meet long-term debt obligations, it will undoubtedly fail to satisfy shareholders (Ali Qadi & Khanji, 2018). The short-term financial policies of a company are focused on two main objectives. The primary goal of short-term financial management for any company is to maximise the excess revenue over costs (Jaworski & Czerwonka, 2021). Ideally, the ability to generate profits, namely profitability, should be accompanied by the capability

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to ensure short-term liquidity (Brealey et al., 2016). On the one hand, it relates to pricing policies and margins that can be realised at the appropriate level of working capital components (inventory, receivables, and cash) (Jaworski & Czerwonka, 2021). Liquidity is important for the short term; the more liquid a company is, the lower the risk of being unable to meet its short-term obligations (Hossain & Alam, 2019). The measure used for liquidity in this study is the current ratio (CR), which is the ratio of current assets to current liabilities. A high current ratio provides a good guarantee for short-term creditors, meaning the company has the ability to meet its short-term financial obligations at any time. However, a high current ratio will negatively impact the ability to generate profits, as some working capital remains idle or experiences unemployment (Martono & Harjito, 2014). Only an optimal level of liquidity can benefit the profitability of the company (Aqadi & Khanji, 2018).

Investors always pay attention to the company's ability to generate, maintain, and increase profits. Generally, a company's profit is assessed using profitability ratios. Profitability ratios are a group of ratios that indicate the influence of a combination of liquidity, asset management, and debt on operational results (Brigham & Houston, 2020). The measure used for profitability in this study is a return on assets (ROA), which is the ratio of net income to total assets.

The correlation between liquidity and profitability has emerged as a crucial concern across organisations. It revolves around the strategic management of current assets and liabilities to optimise profit margins. The interplay between liquidity and profitability is inherently interconnected. An increase in liquidity often corresponds to a decrease in profitability and conversely (Hossain & Alam, 2019). Liquidity and profitability are related to each other, so increasing profitability will tend to reduce the company's liquidity, and too much attention to liquidity tends to affect profitability. Although every company tries to maximise profitability by maintaining liquidity, increasing profits at the expense of liquidity can cause serious problems for the company, and these problems can also lead to financial bankruptcy (Gill, 2022). Hence, a financial manager will endeavour to balance the company's liquidity and profitability.

Research on the influence of profitability and liquidity on various variables has been extensively conducted in various cases (Husain, 2021; Jamal et al., 2022; Reschiwati et al., 2020; Righi & Vieira, 2014). Furthermore, research related to the relationship between profitability and liquidity has also been quite extensively conducted (Hossain & Alam, 2019; Jaworski & Czerwonka, 2021; Paul et al., 2021; Thinh et al., 2022). The research result of (Lim & Rokhim, 2021) states that, overall, liquidity, sustainable growth rate, firm size and market power had a positive impact on profitability, while the research result of (Thinh et al., 2022) concludes that liquidity has a positive

relationship with bank profitability, which includes return on assets, return on equity, and net interest margin. Furthermore, for net interest margin, the liquidity ratio of loans to deposits plus short-term loans and short-term debt has the opposite effect. Furthermore, a study by Hossain & Alim (2019) found that there is a relationship between liquidity and profitability. The cash conversion cycle has a strong negative correlation with all profitability ratios (NPM, ROA, and ROE). This study also found that liquidity ratios (CR and QR) are positively correlated with all profitability ratios in Bangladesh's cement industry. On the other hand, the findings from Jaworski & Czerwonka (2021), using meta-analysis, state that it is not possible to identify a common effect that describes the relationship between company profitability and financial liquidity measured by the current liquidity ratio.

Based on the several recent studies above, we can draw three main points: (1) that liquidity has a significant effect on profitability; (2) that liquidity can have a positive or negative relationship to profitability; and (3) that it is impossible to identify general effects that describe the relationship between profitability and liquidity. However, neither study determined the bidirectional dynamics of profitability ratios and liquidity ratios. Therefore, this study aims to fill this gap by analysing the bidirectional dynamics of profitability ratios and liquidity ratios over time.

The data used in this research are obtained from the annual reports of PT Indofood for the period 2011-2022 (INDF, 2023a). PT Indofood is a total food solutions company with operational activities covering all stages of food production processes, from raw material processing to the production of final products available in the market. PT Indofood is also a well-established and leading company in all of its business categories.

Based on the description above, the objective of this research is to examine the bidirectional dynamics between profitability ratios and liquidity ratios over time. Additionally, this study also aims to present forecasted values of profitability and liquidity for the next five years. These annual reports contain profitability ratios and liquidity ratios. Profitability ratios are measured using return on assets (ROA), while liquidity ratios are measured using the current ratio (CR).

Unlike other studies, in this research, we attempt to offer a new approach (a mathematical modelling approach) to examine the bidirectional dynamics of profitability ratios and liquidity ratios over time. The mathematical approach referred to is the predator-prey model approach (Braña & Castillo-Chavez, 2012; Lotka, 1910). This model is one derivative from the Lotka-Volterra model using a system of differential equations. By adopting this model, profitability ratios can be assumed as prey and liquidity ratios act as predators. The predator-prey model has been widely used in various fields (Wu et al., 2021) (Hung et al., 2017). Data processing and numerical simulations in

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this study are conducted using the Matlab application. It is hoped that the results of this research can contribute to providing information as a basis for consideration, support and contribution of thought to decision-makers in business in order to increase income and carry out business development.

Literature review

Profitability ratios are a group of ratios that indicate the influence of a combination of liquidity, asset management, and debt on operational results (Brigham & Houston, 2020). The measure used for profitability in this study is a return on assets (ROA), which is the ratio of net income to total assets. The liquidity ratio is a metric that provides an overview of a company's ability to meet its short-term debt obligations within a year (Brigham & Houston, 2020). The measure used for liquidity in this study is the current ratio (CR), which is the ratio of current assets to current liabilities.

Profitability and liquidity are among the critical issues that must be studied and considered by the management of every organisation as their foremost task (Pangeni, 2018). Studies on liquidity are crucial for internal and external analyses as it is closely related to day-to-day business operations (Al-Homaidi et al., 2020). Every manager needs to consider liquidity and profitability as primary components in all financial decision-making (Chaudhary & Raja, 2021).

The relationship between liquidity and the financial profitability of a company is based on working capital decisions. Strategies minimising the risk of liquidity loss involve implementing flexible short-term financial policies (Jaworski & Czerwonka, 2021). The more flexible policies a company adopts by enhancing its liquidity, the higher the costs are, limiting its profitability (Gill, 2022).

One concept regarding the relationship between liquidity and profitability is based on efforts to explain the occurrence of influence in both positive and negative directions. The relationship between profitability and liquidity is non-linear (Jaworski & Czerwonka, 2021) and can be represented by the Gentry curve, which resembles an inverted U shape, as observed in the study by Jaworski & Czerwonka (2021) titled "Meta-study on the relationship between profitability and liquidity on enterprises in a macroeconomic and institutional environment". One determinant of a company's direction and strength is the level of financial liquidity. Companies characterised by low liquidity primarily invest retained earnings in improving their payment ability. Therefore, with increased profitability, liquidity also increases (positive direction) (Jaworski & Czerwonka, 2021). Further investment in liquidity results in high maintenance and financing costs. Therefore, increased liquidity leads to a decrease in profitability or negative direction (Bwacha & Xi, 2018).

The mathematical modelling approach, particularly the predator-prey model, has been widely used across various fields, particularly in economics. Starting from the pioneering work of Lotka in 1925 with the Lotka-Volterra (LV) model (Lotka, 1925), it has been extensively utilised in ecology and biology to model population dynamics where one species competes with another for survival. In its development, the predator-prey model can also be applied in economics to examine market dynamics (Hung et al., 2017; Jamal & Suparno, 2022; Miranda & Lima, 2013).

Research method

Predator-prey model approach

This research adopts a predator-prey mathematical model that contains a pair of non-linear differential equations commonly used to describe the interaction between two species. The first species is called the prey, and the second one is called the predator (Brauer & Castillo-Chavez, 2012; Lotka, 1910). In this case, the prey variable is profitability, while the predator variable is liquidity.

By adopting this model, a predator-prey model that describes the interaction dynamics between profitability and liquidity is obtained as follows:

$$\frac{dx}{dt} = ax - bxy, \quad \frac{dy}{dt} = dxy - cy, \quad (1)$$

Where variables $x \geq 0$ and $y \geq 0$ are the profitability and liquidity of the company, respectively. The operators $\frac{dx}{dt}$ and $\frac{dy}{dt}$ represent the growth rate of both variables over time $t > 0$. The parameters $a > 0, b > 0, c > 0$ and $d > 0$ respectively represent the growth rate of profitability, the effect of liquidity on the growth rate of profitability, the decline rate of liquidity, and the effect of profitability on the growth rate of liquidity. The interaction of these two variables reduces the value of profitability. In addition, Model (1) has two equilibrium points: $E_0(x^*, y^*) = (0, 0)$ and $E_1(x^*, y^*) = (c/d, a/b)$.

In System (1), it is clear that the predator-prey model contains four parameters, namely a, b, c and d . To obtain those four parameter values, we performed a parameter estimation process based on the data by applying the Log Integral method (Kloppers & Greeff, 2013). Additionally, based on the obtained parameter estimation results, we tried to determine the two variables' stability properties by applying a mathematical approach (Ang et al., 2019; Jamal & Suparno, 2022; Mohammed et al., 2021). In this research, the parameter estimation and numerical simulation used the Matlab application.

To gain the best estimation of profitability and liquidity, we transform System (1) into a system of difference equations (Leslie, 1958). Thus, we obtained a new model as follows:

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$$\begin{aligned} x(t+1) &= \frac{\alpha x(t)}{1 + \beta y(t)}, & t = 1, 2, \dots, n-1 \\ y(t+1) &= \frac{\rho y(t)}{1 + \delta x(t)}, & t = 1, 2, \dots, n-1 \end{aligned} \quad (2)$$

where $a = \ln \alpha$, $b = \frac{\beta \ln \alpha}{\alpha - 1}$, $c = \ln \rho$, and $d = \frac{\delta \ln \rho}{\rho - 1}$.

After conducting the analysis, we evaluated the accuracy of the resulted Model (2). This accuracy evaluation was measured using the Mean Absolute Percentage Error (MAPE). The MAPE error measure is calculated as follows:

$$MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{h_i - p_i}{h_i} \right| \times 100\%, \quad i = 1 \dots n,$$

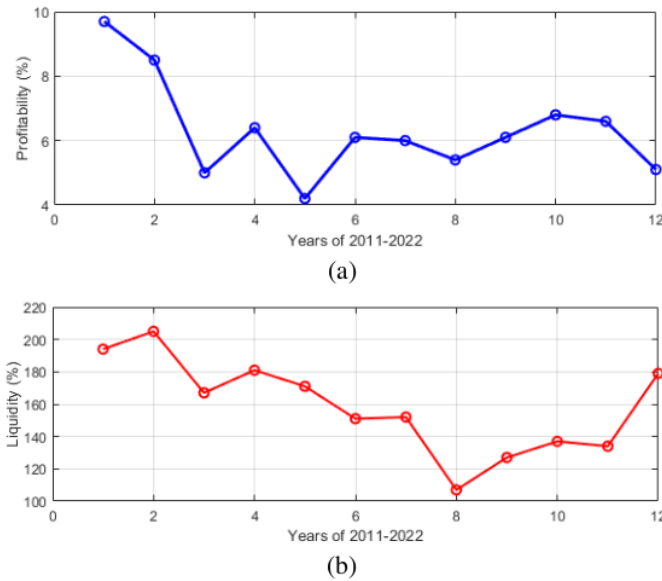
With h_i and p_i are historical data and estimated data respectively. The criteria for MAPE accuracy can be found in (Marasco et al., 2016; Wang & Wang, 2016).

Data description

PT. Indofood is a total food solutions company with operational activities covering all stages of food production processes, from raw material processing to the production of final products available in the market. PT Indofood is a well-established and leading company in all of its business categories. In conducting its operational activities, the company benefits from economies of scale and the business of its business model, consisting of four Strategic Business Groups that complement each other as follows: Consumer Branded Products (CBP), Bogasari, Agribusiness, and Distribution (INDF, 2023b). The data used in this study are obtained from the annual reports of PT Indofood for the period 2011-2022 (INDF, 2023). These annual reports comprised profitability ratios and liquidity ratios. Profitability was assessed using the return on assets (ROA) metric, whereas liquidity was evaluated using the current ratio (CR) (Martono & Harjito, 2014). For subsequent analyses, profitability and liquidity ratios of PT Indofood are referred to simply as the company's profitability and liquidity.

Based on Figure 1, the company's profitability and liquidity data from 2011 to 2022 seem to fluctuate. The highest profitability was gained by the company in 2011 at 9.7 per cent, while its lowest ratio was in 2015 at 4.2 per cent. On the other hand, the highest liquidity was achieved in 2012 at 205 per cent, while the lowest ratio was at 107 per cent in 2018 (INDF, 2023a).

Figure 1.
 Historical data on profitability and liquidity of PT Indofood



(a) Historical data on profitability and (b) liquidity of PT Indofood for the period of 2011-2022

Based on Figure 1, the company’s profitability and liquidity data from 2011 to 2022 seem to fluctuate. The highest profitability was gained by the company in 2011 at 9.7 per cent, while its lowest ratio was in 2015 at 4.2 per cent. On the other hand, the highest liquidity was achieved in 2012 at 205 per cent, while the lowest ratio was at 107 per cent in 2018 (INDF, 2023a).

Result and discussion

Parameter estimation and model stability

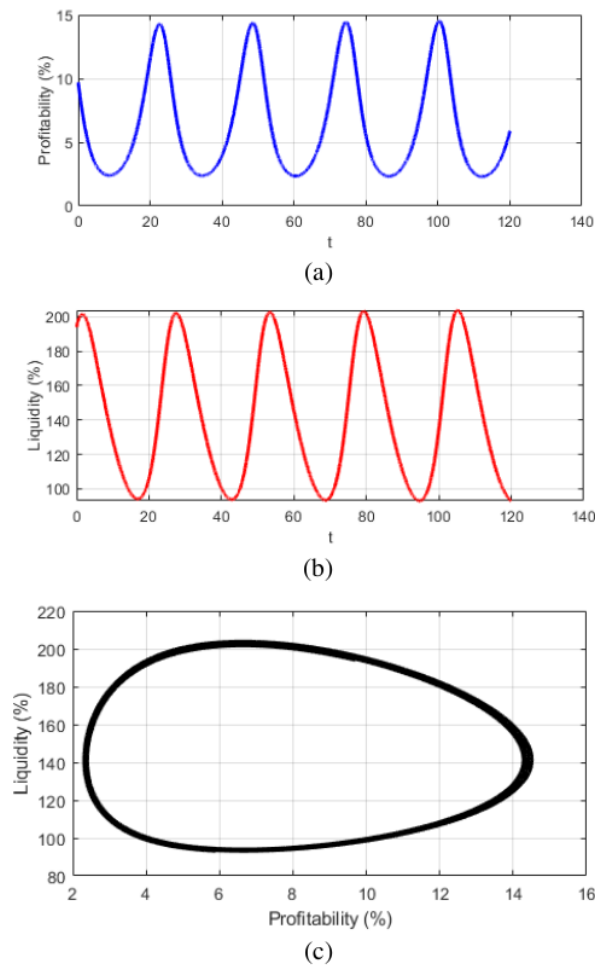
In System (1), it is clear that the predator-prey model contains four parameters, namely a, b, c and d. To obtain those four parameter values, we performed a parameter estimation process based on the historical data by applying the Log Integral method (Kloppers & Scheff, 2013). By applying this method, we obtained the parameter values of $a = 0.5789$, $b = 0.0041$, $c = 0.1097$ and $d = 0.0165$. Subsequently, values of these four parameters are substituted into Model (1), generating a predator-prey model that illustrates the interaction between profitability and liquidity:

$$\frac{dx}{dt} = 0.5789x - 0.0041xy, \quad \frac{dy}{dt} = 0.0165xy - 0.1097y. \quad (3)$$

The equilibrium point of Model (3) is obtained by solving the system $\frac{dx}{dt} = \frac{dy}{dt} = 0$. Model (3) has two equilibrium points, which are $E_0(x, y) = (0, 0)$ and $E_1(x, y) = (6.648, 141.195)$. The stability property of the equilibrium point E_0 is a saddle, and the non-zero equilibrium point E_1 is a centre (closed curve) in a counterclockwise direction. As the equilibrium point E_0 has no economic meaning, in the following discussion, we focus on the equilibrium point E_1 .

Figure 2.

(a) Dynamics of profitability change; (b) liquidity change; and (c) figure of phase between profitability and liquidity with initial values $(x_0, y_0) = (9.7, 194)$



Estimation results of profitability and liquidity

To determine the results of profitability and liquidity estimation based on Model (3), we transformed Model (3) into a system of difference equations (Leslie, 1958) with $\alpha = 1.7841$, $\beta = 0.00555$, $\rho = 0.8961$, and $\delta = -0.0156$. Thus, we obtained a new model as follows:

$$\begin{aligned} x(t+1) &= \frac{1.7841x(t)}{1 + 0.00555y(t)}, & t = 1, 2, \dots, 11 \\ y(t+1) &= \frac{0.8961y(t)}{1 - 0.0156x(t)}, & t = 1, 2, \dots, 11. \end{aligned} \tag{4}$$

By substituting the profitability and liquidity data into Model (4), we obtained the following profitability and liquidity estimation results.

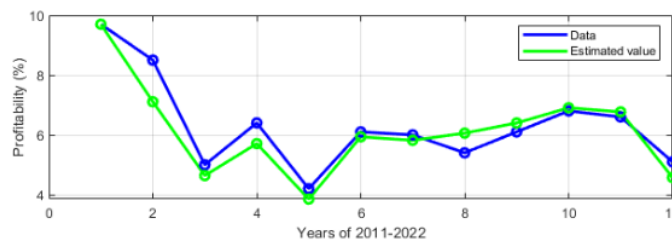
Table 1.

Data of profitability and liquidity vs. results of profitability and liquidity estimation are presented in the following table 1 below.

Year	Profitability data (%)	Estimated profitability (%)	Liquidity data (%)	Estimated liquidity (%)
2011	9.7	9.7	194	194
2012	8.5	7.108	205	211.8
2013	5.0	4.639	167	162.3
2014	6.4	5.708	181	180.2
2015	4.2	3.852	171	163.9
2016	6.1	5.933	151	149.5
2017	6.0	5.818	152	150.2
2018	5.4	6.057	107	104.7
2019	6.16	6.397	127	125.7
2020	6.8	6.906	137	137.3
2021	6.6	6.767	134	133.8
2022	5.1	4.574	179	174.2

Figure 3.

Historical data vs. estimated profitability and liquidity results



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Model accuracy

In this section, we tested the accuracy of Model (4) based on the Mean Absolute Percentage Error (MAPE) value of each variable (Marasco et al., 2016; Wang, Wang, 2016). The criteria for the accuracy value and the MAPE calculation results are presented in each of the following tables.

Table 2. The level of estimation accuracy by MAPE

MAPE (%)	Accuracy level
< 10	Very accurate
10 – 20	Good
20 – 50	Normal
> 50	Inaccurate

Table 3. MAPE values for profitability and liquidity

	Profitability (%)	Liquidity (%)
MAPE (%)	6.656	1.565

In Table 3, it can be seen that MAPE generates a profitability value of 6.656 per cent and a liquidity value of 1.565 per cent. It shows that the MAPE value for liquidity is smaller than that of profitability. However, based on Table 2, MAPE values are less than 10. Therefore, we can say that Model (3) has a very high level of accuracy.

Profitability and liquidity forecasting

Based on the MAPE calculation value, we found that Model (3) has a very high level of accuracy, allowing the model to be used to forecast future profitability and liquidity. The forecast results for the next five years are presented in the following appendix 1 below.

Discussion

The aforementioned predator-prey model indicates that it has a non-zero equilibrium point. The equilibrium point is $E_1(x^*, y^*) = (c/d, a/b)$. Based on this equilibrium point, if the reduction of liquidity rate (c) is greater

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than the effect of profitability on the growth rate of liquidity (d), then the company's profitability has a great opportunity to grow. This growth depends entirely on the company's level of liquidity. On the contrary, if the level of liquidity reduction (c) is smaller than the effect of profitability on the growth rate of liquidity (d), then the company's profitability only has a small opportunity to grow and may even reach zero.

On the other hand, the liquidity of the company will rise, given the effect of liquidity on profitability (b) is smaller than the growth rate of profitability (a). In other words, the amount of liquidity is determined by the growth of the company's profitability. However, an overly high liquidity will negatively affect the company's ability to earn profit, because some of the working capital does not circulate or is immobile. We have already perceived that there is no specific standard to determine the best current ratio (CR). However, as a precautionary principle, a CR of around 200 per cent is considered good (Martono & Harjito, 2014).

In Table 1, the estimation results of the company's highest and lowest profitabilities are 9.7 per cent and 3.852 per cent respectively, while their highest and lowest liquidity are 211.838 per cent and 125.796 per cent respectively. Based on these results, if we refer to (Martono & Harjito, 2014), the company's liquidity is still deemed good to sustain the company. In addition, the dynamics of the company's profitability over time fluctuate periodically for a relatively long time (see Figure 2.a). Similar dynamics can also be found in the liquidity of the company (see Figure 2.b). Furthermore, the figure of the interaction dynamics phase between profitability and liquidity in the long term forms a closed curve (see Figure 2.c). This indicates a positive signal for the company that its profitability and liquidity are in a good condition and can last for a long time.

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To sum up, the predator-prey model demonstrates that the correlation between profitability and liquidity is negative. This means that the company's liquidity always reduces its profitability. This result is in line with the study of (Hossain & Alam, 2019) (Chaudhary & Raja, 2021). The study of (Hossain & Alam, 2019) found that there is a relationship between liquidity and profitability. The cash conversion cycle has a strong negative correlation with all profitability ratios (NPM, ROA and ROE), while the research result of (Chaudhary & Raja, 2021) states that the profitability indicators are inversely correlated to the liquidity indicators.

In addition, the predator-prey model approach can be utilised to comprehend the interaction dynamics between profitability and liquidity. This is evident from the fact that the dynamics of the estimated profitability and liquidity results can follow the fluctuations in the historical data of PT. Indofood for the period of 2011-2022 (see Figure 3) with a very high accuracy (see Table 3).

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The results of profitability and liquidity forecasting show that for the period 2023-2027, profitability tends to decline. This results in the decline of liquidity value (see Appendix 2). This decline occurs because the company's liquidity depends on the profitability generated. In addition, the profitability experienced the largest decline in 2024 by 0.320 per cent and liquidity in 2026 by 7.755 per cent (see Appendix 1).

Considering the forecasting results obtained, the value of profitability and liquidity, which tends to decrease indicates that PT. Indofood must establish a policy to overcome this situation in the future. Such measure is urgently needed to counteract the predation activities of liquidity on profitability and to ensure that profitability can grow healthily. If the company cannot establish the right policy, then the profitability acquisition will not counterbalance the company's liquidity in the future. This situation will eventually lead the company to a considerable loss.

Conclusion

This research aims to examine the interaction dynamics between profitability and liquidity by utilising the predator-prey model approach. This model contains two variables, namely predator and prey variables. The model indicates that the relationship between profitability and liquidity is negative. This means that liquidity always reduces the amount of profitability of the company. The equilibrium analysis demonstrates that the growth of the company's profitability depends entirely on the company's level of liquidity, while the amount of liquidity is determined by the growth of the company's profitability. An overly high liquidity will negatively affect the company's ability to earn profits. Based on the data, the dynamics of the company's profitability over time periodically fluctuate for a long time. Similar dynamics is also found in the company's liquidity. This indicates a positive signal for PT. Indofood that its profitability and liquidity are in a good condition. On the other hand, the results of profitability and liquidity forecast show that for the period of 2023-2027, both profitability and liquidity tend to fall. Therefore, this is an important signal for the company to take preventive measures so that it can continue to stabilise its profitability and liquidity in the future.

For forthcoming studies, researchers can incorporate other assumptions, such as the existence of competition between variables, so that the model formed can be more comprehensive and complex. By adding assumptions, the model created can become a competition model that illustrates the actual reality. It is hoped that the results of this research can contribute to providing information as a basis for consideration, support and contribution of thought to decision-makers in business in order to increase income and carry out business development.

Author contribution

Sri Wahyuni Jamal¹ and Suparno⁵²: Writing—original draft and writing—review and editing. Fenty Fauziah, Umi Kartini Rashid and Azhar Lat²⁰: Investigation, validation, data curation, visualisation, and methodology. All authors have agreed to the published version of the manuscript.

Declaration of interest

The authors declare no conflict of interest.

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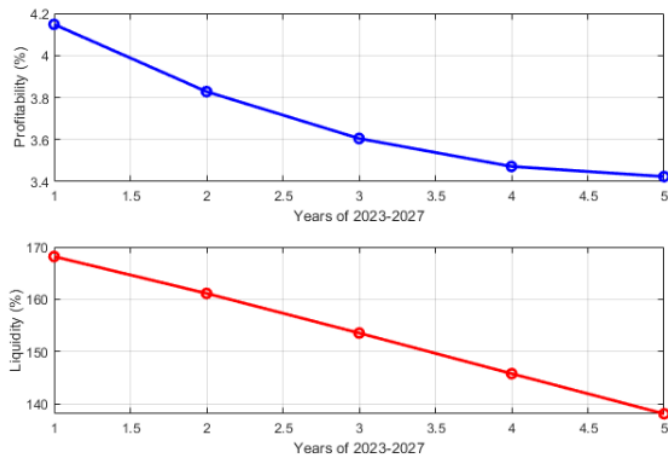
Appendix 1

Results of profitability and liquidity forecast

No.	Year	Profitability (%)	Liquidity (%)
1	2023	4.148	168.184
2	2024	3.828	161.136
3	2025	3.605	153.564
4	2026	3.472	145.808
5	2027	3.424	138.142

Appendix 2

Results profitability and liquidity values forecast



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