Flow-performance relationship in DeFi yield aggregator

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บริการทางการเงินแบบไร้ตัวกลาง เป็นโครงสร้างพื้นฐานทางการเงินแบบใหม่ที่มีผลิตภัณฑ์ทางการเงินคล้ายกับผลิตภัณฑ์ทางการเงินแบบปัจจุบัน เช่น การแลกเปลี่ยน การกู้ยืม ตราสารอนุพันธ์ และการบริหารจัดการสินทรัพย์ วิทยานิพนธ์ฉบับนี้ได้ทำการศึกษาความสัมพันธ์ระหว่างกระแสเงินทุนและผลการดำเนินงานของกองทุนในระบบการเงินไร้ตัวกลางที่มีการบริหารงานแบบเชิงรุก ในกรณีศึกษาของ Yearn finance เพื่อนำผลการศึกษามาเปรียบเทียบกับกองทุนรวมของระบบการเงินในปัจจุบัน ผลลัพธ์จากการศึกษาพบว่าความสัมพันธ์ระหว่างกระแสเงินทุนและผลการดำเนินงานมีความสัมพันธ์เชิงบวกและไม่เป็นความสัมพันธ์แบบเชิงเส้นสำหรับกองทุนที่รับเหรียญ Stablecoin เท่านั้น ดังนั้นจึงทำการศึกษาพฤติกรรมของนักลงทุนผู้ถือเหรียญ Stablecoin เพิ่มเติม และผลลัพธ์จากการศึกษาพบว่า นักลงทุนผู้ถือเหรียญ Stablecoin ชอบการลงทุนในกลยุทธ์แบบ Leverage ซึ่งให้ผลตอบแทนที่สูงกว่ากลยุทธ์ทั่วไป นอกจากนี้งานวิจัยฉบับนี้ยังได้ศึกษาการตอบสนองของนักลงทุนต่อการเปลี่ยนแปลงของปัจจัยภายในและปัจจัยภายนอก สำหรับปัจจัยภายใน เช่น การประกาศกลยุทธ์ใหม่ในการลงทุนสำหรับกองทุนที่รับเหรียญ Stablecoin และ Cryptocurrency ผลลัพธ์จากการศึกษาพบว่านักลงทุนไม่มีการตอบสนองอย่างทันทีต่อการเปลี่ยนแปลงนี้ แต่อย่างไรก็ตาม สำหรับปัจจัยภายนอก เช่น การประกาศของแพลตฟอร์มอื่นที่ต้องการลงทุนใน Yearn finance นักลงทุนมีการตอบสนองอย่างทันทีสำหรับการเปลี่ยนแปลงของปัจจัยภายนอกโดยเฉพาะกองทุนที่รับเหรียญ Stablecoin เท่านั้น

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Decentralized Finance (DeFi) is a new financial infrastructure with applications similar to traditional financial products, such as exchange, lending, derivatives, and asset management. This paper empirically investigates Yearn finance, one of the fastest-growing and largest in DeFi yield aggregator protocols for on-chain asset management, to demonstrate the flow-performance relationship and compare it with mutual funds in traditional finance. According to the findings, there is a positive non-linear relationship between fund flows and recent performance for using stablecoin deposited. In contrast, we cannot find this relationship for using cryptocurrency. Then, we look further into stablecoin holder behaviour and our findings show that, on average, they prefer the leverage strategy, which offers a chance of higher returns. Finally, we examine the event study of internal and external changes to see how investors respond. For the internal changes, the publication of deploying new strategies for both stablecoin and cryptocurrency vault does not affect investors' immediate reaction. However, only stablecoin holders have directly responded to protocol partners' announcement of the partnership with Yearn finance for external changes.

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CHAPTER 1
Introduction

1.1.Background and Significance of the problem

Decentralized Finance (DeFi) is one of the new issues in terms of new technology disruption in this era, and its applications cover almost the vast majority of traditional financial products. Chen and Bellavitis (2020) and Schär (2021) explain that DeFi is a new open financial application built on permissionless blockchain technology. Moreover, it provides more decentralized, transparent, borderless, innovative, and interoperable. The backbone of DeFi protocols and applications is smart contracts, simply programs or digital contracts stored on a blockchain. As a result, all transactions will be automatically executed when written smart contracts meet conditions. Finally, this new breed allows stakeholders to control their financial assets and allows them to verify transaction and protocol execution publicly.

This paper focuses on on-chain asset management in DeFi yield aggregators, a major growth driver in DeFi and mainly used for portfolio diversification. It employs various strategies, represented as fund managers in traditional finance, based on the combination of smart contracts to increase the value of pool funding or act in the investors' best interests. An example of DeFi yield aggregator is Yearn vaults, one of Yearn finance products.

Several papers investigate the flow-performance relationship of mutual funds in traditional finance. It claims that rational investors are the key market factor in dealing with high and low quality of the mutual fund industry to maintain high-quality products in the market with information problems. Ippolito (1992) reports that fund flows are sensitive to past performance in a positive linear relationship. Next, Chevalier and Ellison (1997); Sirri and Tufano (1998) also report a positive relationship, but in convexity. Furthermore, Berk and Green (2004) document that the flow-performance relationship is positive but not persistent. Lastly, Ivković and Weisbenner (2009) show that only inflow is related to performance.

We see much research explaining the fund flows and performance in traditional finance. Nevertheless, a few papers have been written to explain the conceptual level of DeFi yield aggregator. Thus, this paper will focus on fund flows at a transaction level in DeFi yield aggregator to see how the market in DeFi can respond to a flow-performance relationship.

1.2.Objective and Contribution

This paper investigates how fund flows respond to fund performances in DeFi yield aggregator: Yearn vault case study.

The contribution of this paper is that we would like to further analyze the insight protocol by looking at a transaction level to examine a flow-performance relationship in DeFi yield aggregator; whether this relationship is similar to traditional finance. Therefore, we can understand how the market handles many information problems through rational investors, which are the critical factor in the market equilibrium.

1.3.Scope of the study

To study how fund flows respond to fund performance, we focus on one protocol's product, Yearn vaults, since it is one of the fastest-growing DeFi protocols and has much connection to other protocols, almost covering the Ethereum network. We use the data in weekly frequency from January to December 2021 that retrieves from the blockchain.

We conduct 4 hypotheses in this research. The first hypothesis is to investigate whether there is no relationship between fund flows and recent performance using a fixed-effect model following Ippolito (1992) and variables following Sirri and Tufano (1998). Our dependent variable is fund flows, and the independent variable is the return on investment; both variables are measured in percentage. Finally, we use total net assets, incentive rewards, and BTC market price as control variables in a natural logarithm form. Suppose the flow-performance relationship does not exist in DeFi yield aggregator; we expect fund flows not to increase over time in the individual vault that generates high returns. Next, we examine the relationship curve; whether there is a linear relationship between fund flows and performance by relative ranking performance in the unbalanced quartile. Suppose there is a linear in a flow-performance relationship; we expect the size of fund flows not to respond very differently for all ranking performers

Finally, we also analyze the internal and external event study regressed by the difference-in-difference model to see how investors respond after the publication. Suppose there is no evidence that investors immediately react to the publication. Therefore, we expect investors not to invest more in the vaults after the publication only if they consider the investment policy for their asset allocation process.

1.4.Research Hypothesis

1.4.1 Flow-performance relationship in DeFi yield aggregator

The first hypothesis to examine how fund flows respond to fund performances is about the relationship. Since the market has many information problems, we can investigate how the market responds through rational investors. We conduct the statement:

H0: If a flow-performance relationship does not exist in DeFi yield aggregators, we expect fund flows not to increase over time in the individual vault that generates high returns. Hence, we should not see a statistically significant positive coefficient of recent performance.

1.4.2 Convexity in the flow-performance relationship

We test the shape of the relationship curve after doing the initial relationship analysis. Hence, our hypothesis is:

H0: If there is a linear relationship between fund flows and performance by ranking in the unbalanced quartile, we expect the size of fund flows not to respond very differently for all ranking performers.

1.4.3 Reaction to the new publication

This section tests the investor's reaction to internal and external changes to see how the market responds. Therefore, we conduct the hypotheses:

1.4.3.1 Internal event

H0: If there is evidence that investors do not immediately react to the publication of new strategies. We expect investors not to invest more in the vaults after launching new strategies that can generate high yields only if they consider the investment policy for their asset allocation process. However, this effect should not occur before publication.

1.4.3.2 External event

H0: If there is evidence that investors do not immediately react after protocol partners announce the investment policy to use Yearn finances as a backend for enhancing efficiency. We expect investors not to invest more in the vaults after the partnership announcement only if they consider the investment policy for their asset allocation process. However, this effect should not occur before publication.

CHAPTER 2
Literature Review

2.1 Decentralized Finance (DeFi): On-chain asset management

Decentralized Finance (DeFi) is a new financial infrastructure with applications similar to traditional financial products, such as exchange, lending, derivatives, and on-chain asset management. This paper focuses on yield aggregators, one of the on-chain asset management. It is similar to asset management in traditional finance, but a set of smart contracts develops it. Furthermore, all data are enforced to be stored in blockchain. The previous work by Cousaert et al. (2021) describes its mechanism that allows investors to invest in the pool funds managed by smart contracts to generate yield by investment policy. Since we cannot update all transactions, including interest, in the blockchain every time because of having a fee. Therefore, investors will receive the depository receipt, representing the recorded index for accrued interests after the deposit. When investors want to withdraw, they must use the same depository receipts to redeem their principal and yield at any point in time. In contrast, the pool funds in asset management in traditional finance, e.g., mutual funds, are managed by fund managers. Moreover, it does not require depository receipts for recording the accrued interests.

However, there are some risks that investors have to bear in traditional mutual funds. For example, investors lack liquidity for withdrawals and transparency in observing their transactions. Furthermore, Chevalier and Ellison (1997) investigate agency issues between investors seeking to maximize return and fund managers seeking to profit from increased inflows which investment behavior of fund managers might have the potential to deviate from investors' best interests. Although traditional mutual funds have investment policies, investors are uninformed of the investment portfolio for asset allocation, which is typically reported quarterly.

In comparison, Schär (2021) provides the benefits of on-chain asset management in dealing with traditional finance problems. For example, investors can withdraw their funds at any time (permissionless) and observe their token flows and balances by themselves (transparency). Moreover, it can reduce agency problems because smart contracts develop DeFi yield aggregators with public details of investment policy. As a result, investors can examine asset allocation by revealing smart contract codes.

2.2 Flow-performance relationship of mutual funds in traditional finance

Several previous papers study fund flows in mutual funds and past performance, which have a positive relationship. Mutual fund investors will invest in the funds depending on the manager's ability and fund management fees. Regarding manager ability, Ippolito (1992) shows the positive linear flow-performance relationship indicating that the investment behavior of rational investors denies poor-quality funds and allocates their capital to the best performers. Furthermore, Chevalier and Ellison (1997); Sirri and Tufano (1998) also report that the relationship result is similar to Ippolito (1992), but the relationship is convexity. Moreover, Berk and Green (2004) document that the flow-performance relationship is positive; however, this relationship is not persistent because it depends on individual manager ability and decisions. In addition, some papers studied individual fund-level inflows and outflows that are affected by performance differently. Ivković and Weisbenner (2009) show that inflows are only related to relative performance to other funds pursuing the same objective. In contrast, outflows are related to absolute returns and taxes after selling the shares of funds.

For the fund management fee, Berk and Green (2004); Sirri and Tufano (1998) show that as the fee increase, the funds with higher fees will be less attractive when compared with passive funds that affect a flow-performance relationship.

2.3 The slow information diffusion in the capital market

There are papers documenting the adjusting slowly in stock prices, which is affected by slow information diffusion. For example, Merton (1987) reports that paying information costs, such as collecting, analyzing, and transferring, might be the beginning of slow information diffusion because informed investors are the first group to know the data before others in the market. Moreover, Hong and Stein (1999) examine 2 groups of rational investors; news watchers and momentum traders. Finally, they discover that momentum traders can profit from the market in the short run because stock price response is gradually affected by new information diffusing slowly among interested investors.

CHAPTER 3
Data

3.1.Yearn finance

3.1.1 How Yearn vaults work

Yearn finance launched in 2020, and it is one of the fastest-growing DeFi protocols which are run on the Ethereum blockchain. As of February 7, 2022, Yearn finance on the Ethereum blockchain has a total value lock (TVL) USD in assets of $3.19 billion out of $14.53 billion, or 21.95 percent[1]. Moreover, according to Yearn finance report in the fourth quarter of 2021, over 95% of total major revenue is derived from Yearn vaults[2].

Yearn vaults, also known as yVaults, are a yield aggregator product of Yearn finance, in which the vaults are analogous to mutual funds and make their investment policies public via vault strategies written by smart contracts. It has recently migrated from version 1 to version 2 and has a total of 65 vaults with 197 strategies[3]. To do transactions with Yearn vaults, investors have to deposit underlying assets into the vaults as their preferences. The protocol will then use those bulk funds to distribute to related protocols on behalf of vault strategies to increase the vault value, even though investors cannot choose the strategy by themselves. Typically, one vault can have multiple strategies, and each strategy can have multiple related protocols based on written smart contracts. For example, USDC vault v.3.0. with 'StrategyGenericLevCompFarm' strategy has dYdX (a derivative protocol) and Compound (a lending-borrowing protocol) as related protocols. It allows investors to deposit and withdraw only USDC stablecoin. After the deposit, investors will receive a wrapped token, yvUSDC (or yvToken), as a depository receipt. Then, the bulk of USDC stablecoin will be distributed to related protocols to generate the yield. At maturity or anytime investors want to withdraw their funds, they must redeem yvUSDC back to the protocol to burn the depository receipt.

[1] Source: https://www.defipulse.com/projects/yearn.finance, accessed on February 7, 2022
[2] Source: https://github.com/yearn/yearn-pm/tree/master/financials/reports, accessed on February 7, 2022
[3] Source: https://yearn.watch/ , accessed on October 25, 2022

Yearn finance always specific an accepted underlying asset and individual vault version—for example, USDC yVault v.3.0. The USDC is the accepted token and v.3.0 is the vault version. There are many tokens that Yearn vault accepts, such as stablecoin (DAI, LUSD, RAI, sUSD, TUSD, USDC and USDT), cryptocurrency (BTC, ETH, WETH and others), protocol's governance token (COMP, 1INCH, and others) and its governance token (YFI). For the vault version, the v.3.0. abbreviates from version 3.0. because Yearn finance deploys a developed new version to improve the vault efficiency, and the data in the old version will be migrated to the new version to continue the transactions without duplication. In this paper, we study all Yearn vault versions if they are from January to December 2021.

3.1.2 Yearn vault performance

The concept of annual percentage yield (APY) does not apply to Yearn vault performance because the interest rate of Yearn vault does not fix, as it is in traditional finance. Thus, return on investment (ROI) is used instead to measure the performance of Yearn. The ROI is a ratio between net profit and cost; however, ROI is calculated indifferently in this case. Hence, ROI is a key performance indicator to evaluate investment efficiency, which can be comparable to different vaults, and to represent approximate returns in the short-term such as daily and weekly.

Let (1) F denotes the total amount of the tokens in the vault, the deposited amount, or the increment of the deposited amount. (2) I denotes the total amount of wrapped tokens held by investors, which this amount is constant. (3) P denotes the price of wrapped tokens (unit: token per yvtoken). Therefore, the input and output model for the vault is written as the following equation:

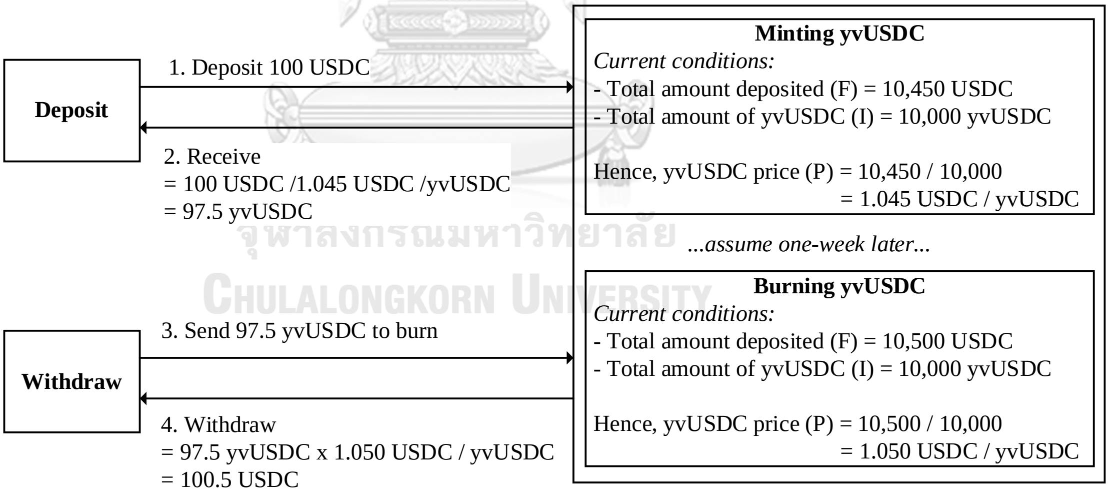
$$P = \frac{1}{I} \, x \, F \qquad (1)$$

We typically know F in the vaults, which are used to add the vault value. Given that I is constant in equation (1), P and F are a direct variation, meaning that P increases as F increases. Therefore, P will know by using the data from two points in our timeframe. Finally, we can construct a linear line under the linear assumption, which can extrapolate to show ROI.

Figure 1 illustrates an example; assume the investor deposits 100 USDC stablecoins in USDC vault v.3.0. At that time, F is 10,450 USDC and I is 10,000 yvUSDC by the current condition in the vault. Using equation (1), P will be 10,450 / 10,000 = 1.045 USDC/yvUSDC. Therefore, the investor will receive I, which equals 100 / 1.045 = 95.7 yvUSDC, and investor deposits are used to add the value of the vault. A few days later with no other deposits assumption, F in the vault is 10,500 USDC, and I is still 10,000 yvUSDC. Thus, P is 10,500/10,000 = 1.05 USDC/yvUSDC. Finally, the investor wants to withdraw to receive the principal and return, which is 95.7 yvUSDC x 1.05 USDC/yvUSDC = 100.5 USDC stablecoins, giving a return of 0.5% on the investment.

Figure 1: The mechanism of token flows and how Yearn vault works

This diagram shows the mechanism of token flows and how Yearn vault works. Start with the depositing process. Investors deposit 100 USDC into the USDC vault; then, the vault will mint(create) 97.5 of the wrapped token (yvUSDC) as the depository receipt for investors. Anytime investors want to withdraw, they send their 97.5 of yvUSDC to the vault for burning (redeeming process) and can withdraw the 100 USDC principal and 0.50 USDC return. The amount of minting and burning yvUSDC is computed from equation (1) under no other deposits assumption.



Next, we apply the ROI extrapolation concept with a linear equation (2) to Yearn vaults.

$$y = m * x + c \tag{2}$$

Let (1) y denotes the price of wrapped tokens similar to P in equation (1). (2) x denotes the block height similar to F in equation (1), and this block height number represents our timeframe which increases over time because of transactions in the blockchain increase. (3) c is a constant when x = 0 and y =1, then c =1. (4) m is a slope that comes from applying derivatives. Thereby, the approximating derivative of a linear function is :

$$y'(x) = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1} \tag{3}$$

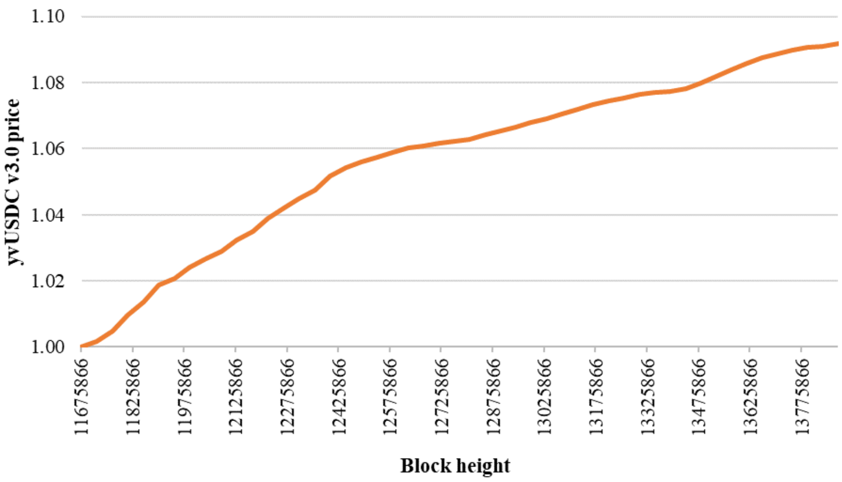
A result from slope estimation in equation (3) can represent ROI which varies depending on selected two points in the timeframe since Yearn vault performance is not linear in reality, as shown in Panel A in Figure 2. Moreover, Panel B in Figure 2 shows the ROI over block height which has a unit of the percentage of return on investment per block.

Since depository receipt (a wrapped token or yvToken) represents the recorded index for accrued interests, the Yearn vault performance slope in Panel A in Figure 2 is upward-sloping. While the percentage of return on investment over block height in Panel B in Figure 2 is downward-sloping because more investors are investing in the vault, causing a decrease in vault's liquidity share.

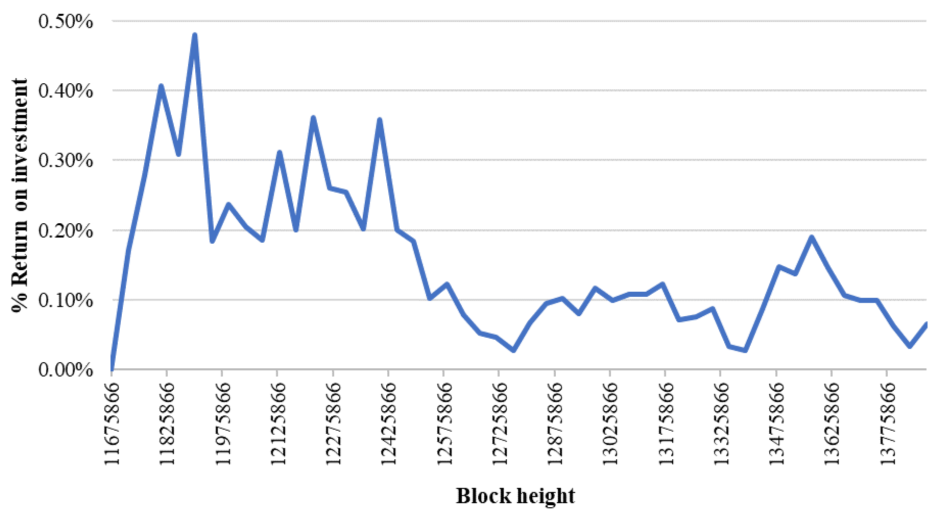
Figure 2: USDC vault v.3.0 performance

Panel A plots the graph between the yvUSDC price and the block height number from January 17, 2021, to December 31, 2021, which retrieved the data from the blockchain. Panel B shows the percentage of return on investment over time, calculated from equation (3). To calculate a one-week performance from January 18 to 24, 2021, the yvUSDC price at the last block height number is 1 USDC/yvUSDC at 11682362 and 1.00171 USDC/yvUSDC at 11721454, respectively. Thus, ROI is [(1.00171 - 1) / 1*(11721454 – 11682362)] x (11721454 – 11682362) x 100% = 0.171% per week.

Panel A: The wrapped token price (yvUSDC price) over block height



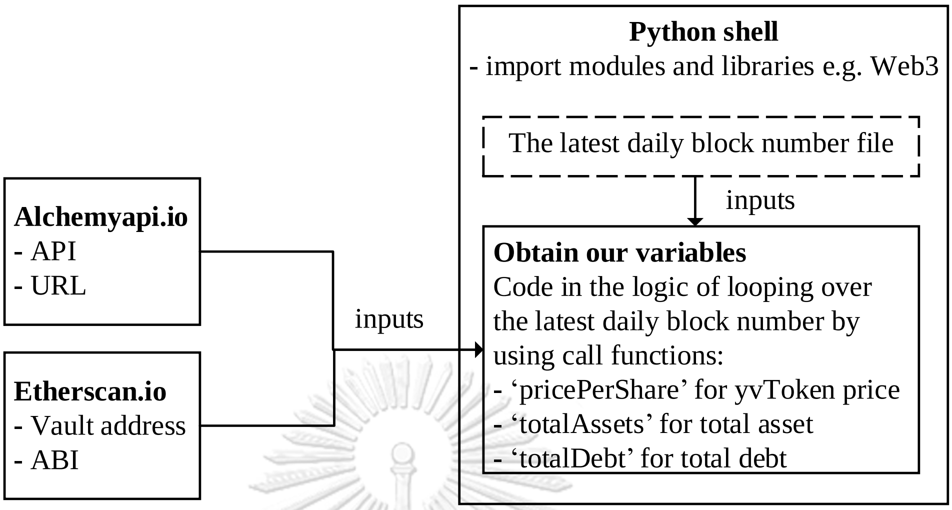
Panel B: The percentage of return on investment over block height



3.2.Fund flows, return on investment, total net asset

In Figure 3, we begin this part by explaining how to extract our observations using Web3.py, one of the python libraries, to communicate with the Ethereum blockchain and obtain the data in smart contracts. The Ethereum blockchain is a peer-to-peer network in which individual nodes can access all blockchain data. Hence, we use Alchemyapi.io as a free-node web service provider to obtain the API (Application Programming Interface) and the Ethereum network URL before we code in python to connect the blockchain nodes. Once we understand how to connect the blockchain nodes, we use python to get the latest daily block number of the Ethereum blockchain at the end of the day; since all transactions are stored in the blockchain. Moreover, we have to retrieve each vault address and ABI (Abstract Binary Interface) from the Etherscan.io website, and we also have to know how to call the function in smart contracts, which can see in the protocol document, to read the blockchain data. In this paper, we use 'pricePerShare', 'totalAssets', and 'totalDebt' functions to obtain the daily yvToken price, total asset, and total debt, respectively. When we have all our input variables, we go to the python shell and import the required python modules and libraries; then, we start to code in the logic of looping over the latest daily block number between January and December 2021.

Figure 3: Variable extraction flows from the Ethereum blockchain



We collect the daily data from the extraction process; therefore, we have to change our data on a weekly basis for our regression analysis. Since we already obtain the yvToken price from the Ethereum blockchain, we can compute the percentage of return on investment in a specific timeframe:

$$\mathrm{ROI}_{i,t} = \frac{\text{yvToken price}_{i,t} - \text{yvToken price}_{i,t-1}}{\text{yvToken price}_{i,t-1}} \quad (4)$$

Where (1) $\mathrm{ROI}_{i,t}$ is the percentage of return on investment of vault i at week t. (2) $\text{yvToken price}_{i,t}$ is the price of wrapped token of vault i at the end of week t. (3) $\text{yvToken price}_{i,t-1}$ is the price of wrapped token of vault i at the end of week t-1.

Again, we obtain the total asset and total debt from the Ethereum blockchain. We can calculate the total net asset (TNA) as part of the fund flows calculation.

$$\mathrm{TNA}_{i,t} = \text{total asset}_{i,t} - \text{total debt}_{i,t} \quad (5)$$

We aggregate the weekly fund flows for our dependent variable, which represents weekly cumulative change and is measured in percentages. Fund flows are calculated by following Sirri and Tufano (1998) under the reinvestment assumption.

$$\mathrm{Flow}_{i,t} = \frac{\mathrm{TNA}_{i,t} - \mathrm{TNA}_{i,t-1} * (1 + \mathrm{ROI}_{i,t})}{\mathrm{TNA}_{i,t-1}} \quad (6)$$

Where (1) $Flow_{i,t}$ is the percentage of the fund flows of vault i at week t. (2) $TNA_{i,t}$ is the total net asset of vault i at the end of week t. (3) $TNA_{i,t-1}$ is the total net asset of vault i at the end of week t-1. (4) $ROI_{i,t}$ is the percentage of return on investment of vault i at week t.

3.3.Incentive rewards, market conditions

We retrieve the Yearn finance governance token price as an incentive reward (daily YFI price) and market condition factor (daily BTC price) in USD dollars by directly downloading the excel file from the Coingecko website between January and December 2021. Then, we change our data on a weekly basis.

3.4.The effective date of the event study

We manually collect the announcement date of new strategies publication from Yearn watch website between January and December 2021 for internal event study. The majority of the announcement dates are close to the smart contract's implementation date. As a result, we should not be concerned about the time between the announcement and the implementation date. However, for the external event study, we use the existing source, e.g., the news, to retrieve the announcement date of the protocol partnership that uses Yearn as a backend.

3.5.Summary Statistics

Before we begin the analysis, we clean the data by trimming at 1% percentiles for the outliers and adjust our data by the mean and standard deviation of the individual vault to ensure that it is similar to a normal curve. Panel A in Table 1 summarizes the data statistics for all the main variables in weekly frequency used in our research from January to December 2021. We compute fund flows as the dependent variable following Sirri and Tufano (1998); the overall average fund flows are -30.2% per week (-1,570.4% per year), with a weekly standard deviation of 16.1% (837.2% per year). The independent variable is calculated using the Yearn finance instruction; the average lagged return on investment is 0.130% per week (6.76% per year), with a weekly standard deviation of 0.188% (9.78% per year). Finally, our control variables are reported in Panel A in Table 1. Moreover, Panel B in Table 1 reports the vault size of individual characteristics reported in the number of tokens (millions). The average and maximum value of the stablecoin vault size is larger than the cryptocurrency vault, both leverage and non-leverage. In contrast, the median is close to zero, and the minimum value is zero for all. Lastly, Table 2 displays the matrix of correlations for all variables, with the number indicating that no variables are correlated.

Table 1: Summary of Data statistics

Panel A reports the summary statistic of all main variables used in this research from January to December 2021. Panel B reports the summary statistic for the vault size of individual characteristics in the same period.

Panel A: All main variables in weekly frequency

Variables	Obs.	Mean	Std. Dev.	Min	Max	p5	Median	p95	Skew.	Kurt.
%Flow	1,184	-30.2	16.1	-69.8	24.8	-55.6	-30.5	-2.08	0.464	3.69
%Flow of Stablecoin	163	-33.0	17.4	-66.2	20.6	-62.3	-33.6	-2.58	0.474	3.53
%Flow of Cryptocurrency	1,021	-29.8	15.8	-69.8	24.8	-55.4	-30.1	-1.60	0.483	3.72
%lagged ROI	2,053	0.130	0.188	0.000	1.35	0.000	0.060	0.474	2.67	12.7
Lagged ln(TNA)	1,507	7.70	5.37	-13.1	19.8	-1.53	8.61	15.0	-0.660	3.34
ln(YFI price)	2,219	10.5	0.216	9.88	11.3	10.1	10.4	10.8	0.672	5.31
ln(BTC price)	2,219	10.8	0.205	10.3	11.1	10.4	10.8	11.1	-0.334	2.13
%BTC return	2,151	-0.449	9.82	-34.1	25.0	-16.7	-0.230	16.7	-0.335	3.77
%BTC volatility	2,152	3.76	1.16	1.69	8.23	2.20	3.58	5.99	0.867	4.00

Panel B: Vault size of individual characteristics reported in the number of tokens (millions)

Vault characteristic	Obs.	Mean	Std. Dev.	Min	Max	p5	Median	p95	Skew.	Kurt.
Stablecoin	268	11.0	52.5	0.000	415.7	0.000	0.273	16.0	6.04	39.4
Leverage	123	16.7	70.6	0.000	415.7	0.000	0.699	14.1	4.70	23.5
Non-leverage	145	6.13	28.8	0.000	236.6	0.000	0.000	16.0	6.60	47.2
Cryptocurrency	1,883	0.186	1.25	0.000	28.9	0.000	0.000	0.695	14.2	251.2
Leverage	1,714	0.202	1.31	0.000	28.9	0.000	0.000	0.734	13.6	228.9
Non-leverage	169	0.018	0.082	0.000	0.857	0.000	0.000	0.087	7.76	72.4

Table 2: Matrix of correlations for the main variables

Variables	(1)	(2)	(3)	(4)	(5)
(1) % Flow	1.000				
(2) %lagged ROI	-0.117	1.000			
(3) Lagged ln(TNA)	-0.069	0.116	1.000		
(4) ln(YFI)	0.024	0.038	-0.039	1.000	
(5) ln(BTC)	0.034	0.057	0.072	0.098	1.000

CHAPTER 4
Methodology

4.1.Flow-performance relationship in DeFi yield aggregator

The first hypothesis is about the relationship between fund flows and fund performance because we want to examine how rational investors respond to the DeFi market. Hence, if a flow-performance relationship does not exist in DeFi yield aggregators, we expect fund flows not to increase over time in the individual vault that generates high returns. In other words, we should not see a statistically significant positive in β_1 which represents the coefficient of a recent performance.

We use a fixed effect model in our regression following Ippolito (1992) and variables following Sirri and Tufano (1998) to investigate our first hypothesis. We observe the data between January and December 2021 and regress on a weekly basis. The regression is following:

$$\mathrm{Flow}_{i,t} = \beta_0 + \beta_1\,\mathrm{ROI}_{i,t-1} + \beta_2 \ln(\mathrm{TNA})_{i,t-1} + \beta_3 \ln(\mathrm{YFI})_{i,t} + \beta_4 \ln(\mathrm{BTC})_{i,t} + \beta_5 \mathrm{BTC\ return}_{i,t} + \beta_6 \mathrm{BTC\ vol}_{i,t} + \varepsilon_{i,t} \quad (7)$$

Where (1) $\mathrm{Flow}_{i,t}$ is the percentage of the fund flows of vault i at week t under the reinvestment assumption. (2) $\mathrm{ROI}_{i,t-1}$ is the percentage of the recent weekly vault i's performance. (3) $\ln(\mathrm{TNA})_{i,t-1}$ is a size of vault i at week t-1 in a natural logarithm form as a control variable. (4) $\ln(\mathrm{YFI})_{i,t}$ is Yearn finance governance rewards in a natural logarithm form. We use $\ln(\mathrm{YFI})_{i,t}$ as a control variable because Yearn finance began distributing YFI on July 17, 2020, and the token price increased from $30 to over $40,000 within two months [6]. Therefore, we include this incentive reward that might attract fund flows into Yearn finance. If incentive rewards increase fund flows, we should see a positive coefficient of ln(YFI). (5) $\ln(\mathrm{BTC})_{i,t}$, $\mathrm{BTC\ return}_{i,t}$, $\mathrm{BTC\ vol}_{i,t}$ are market condition proxies in the market price, return, and volatility.

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[6] Source: https://coinmarketcap.com/alexandria/article, accessed on October 25, 2022

However, we do not include the lagged fund flows in our regression because DeFi investors cannot select a strategy by themselves. It is not similar to traditional mutual funds in that investors definitely know which fund manager manages the fund. Furthermore, the week and vault dummy are included in the regression because the week dummy variable controls unobservable variables that change each week, which is common to all vaults in week t. In the same way, the vault dummy variable controls unobservable variables that change each vault, which is common all week in vault i.

4.2.Convexity in the flow-performance relationship

In the second hypothesis, we examine the shape of the relationship curve; whether there is a linear relationship between fund flows and performance. If the relationship curve is linear, we expect the size of fund flows not to respond very differently for all ranking performers; to put it another way, the magnitude of β_1 should not differ significantly across all rankings.

We also use a fixed effect model in our regression following Ippolito (1992) and variables following Sirri and Tufano (1998), which is the same as the above hypothesis, but now we change the independent variable from $ROI_{i,t-1}$ to $Rank^{k}_{i,t-1}$. The regression is following:

$$Flow_{i,t} = \beta_0 + \beta_1 Rank^{k}_{i,t-1} + \beta_2 \ln(TNA)_{i,t-1} + \beta_3 \ln(YFI)_{i,t} + \beta_4 \ln(BTC)_{i,t} + \beta_5 BTC\ return_{i,t} + \beta_6 BTC\ vol_{i,t} + \varepsilon_{i,t} \quad (8)$$

Where $Rank^{k}_{i,t-1}$ are:

$$Rank^{Poor}_{i,t-1} = Min(Rank_{i,t-1}, 0.25)$$

$$Rank^{Middle}_{i,t-1} = Min(Rank_{i,t-1} - Rank^{Poor}_{i,t-1}, 0.50)$$

$$Rank^{Top}_{i,t-1} = Min(Rank_{i,t-1} - Rank^{Poor}_{i,t-1} - Rank^{Middle}_{i,t-1}, 0.25)$$

(1) $Rank_{i,t-1}$ is a vault's fractional rank represented its quartile performance relative to other vaults in the same period, which ranges from 0 to 1. (2) $Rank^{Top}_{i,t-1}$ is the 1st or

top-performance quartile. (3) $\text{Rank}_{i,t-1}^{\text{Middle}}$ is the 2^{nd}-3^{rd} performance quartile. (4) and $\text{Rank}_{i,t-1}^{\text{Poor}}$ is the 4^{th} or bottom-performance quartile.

4.3.Reaction to the publication

4.3.1 Internal event

We want to examine how investors respond to changes for the internal event publication. Yearn developers aim to enhance vault capital efficiency by deploying new strategies to maximize yield for investors if they discover opportunities to deposit underlying assets into other protocols and allow those protocols to generate yields. As we stated above about the 'StrategyGenericLevCompFarm' strategy of USDC vault v.3.0, it is actually deployed after the 'SingleSidedBalancer staBAL3Pool USDC' strategy because the protocols associated with these 2 strategies differ in financial service and yield generation. Hence, if there is evidence that investors do not immediately react to the publication of new strategies, we expect investors not to invest more in the vaults after launching new strategies that can generate high yields only if they consider the investment policy for their asset allocation process. In other words, the coefficient at the publication date (γ_j) should not differ significantly compared to a prior period of publication. However, this effect should not occur before publication.

We employ the difference-in-difference model to examine the impact of internal events that occur at a specific time by comparing the variation of fund flows around the event date to the reference point. We use a baseline point at a prior period of the event date (T-1) and event window in the range [-3,3]. The regression is following:

$$\text{Flow}_{i,t} = \beta_0 + \beta_1 \text{ ROI}_{i,t-1} + \beta_2 \ln(\text{TNA})_{i,t-1} + \beta_3 \ln(\text{YFI})_{i,t} + \sum_{j=0}^{J} \gamma_j (D_j)_{i,t} + \beta_4 \ln(\text{BTC})_{i,t} + \beta_5 \text{BTC return}_{i,t} + \beta_6 \text{BTC vol}_{i,t} + \varepsilon_{i,t} \quad (9)$$

Where (1) $(D_j)_{i,t} = 1 \; [t = Event_i \pm j\,]\text{for } j \in \{0, \dots, J\}$. (2) $Event_i$ is the recorded week t variable when the new strategy is deployed in the vault i. (3) J equals 3 since we apply the event window in the range [-3,3].

4.3.2 External event

We want to investigate the investors' response to the external event publication that protocol partners announce the investment policy to use Yearn finances as a backend. If there is evidence that investors do not immediately react to the publication of the partnership. We expect investors not to invest more in the vaults after the partnership announcement only if they consider the investment policy for their asset allocation process. In other words, the coefficient at the announcement date (γ_j) should not differ significantly compared to a prior period of the announcement. However, this effect should not occur before publication.

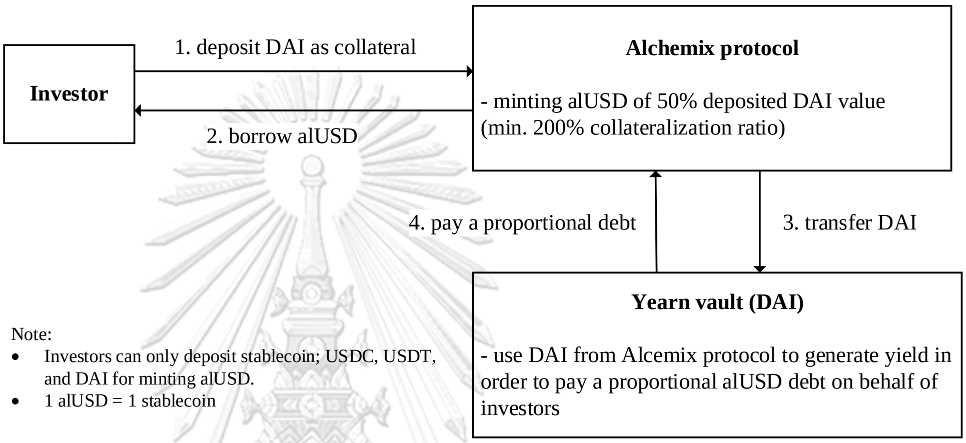
From the Messari report[7], the top 5 protocols, such as Sushi, Alchemix, BadgerDao, Ribbon+Opyn, and Frax, contribute tokens to Yearn vaults. For example, Yearn finance and Alchemix partnership in which Alchemix protocol claims to be a self-repaying loan to increase capital efficiency. The mechanism of token flows is that Alchemix will transfer the deposited collateral (USDC, USDT, and DAI) into a yield aggregator such as Yearn finance to generate yield. Then, Alchemix will mint its loan token, which is alUSD (1 alUSD = 1 stablecoin), for investors. Therefore, investors can use alUSD for some purpose; for example, they can trade alUSD in the exchange market for capital gain and hold it without concern about liquidation because the collateral is stablecoin. Moreover, if investors do not want to repay their debt for receiving all DAI collateral back, the yield aggregators can pay all those debts for investors from generated yield. Figure 4 shows token flows between Yearn finance and Alchemix. When investors deposit stablecoin as collateral into Alchemix, the protocol will mint alUSD for investors with 50% of the deposited

[7] Source: https://messari.io/report/yearning-for-yearn, accessed on December 2, 2022

collateral value; this condition is effective for only stablecoin deposited. Then, the deposited collateral will be transferred to Yearn vault to generate yield and pay the proportional debt on behalf of investors.

Lastly, investors can repay none or some or all debt to receive back their DAI collateral at any time.

Figure 4: Token flows between Alchemix and Yearn finance



Therefore, we use the same regression in the third hypothesis, the difference-in-difference model, to examine the impact of external events that occur at a specific time by comparing the variation of fund flows around the event date to the reference point. We use a baseline point at a prior period of the event date (T-1) and event window in the range [-2,2]. The regression is following:

$$\mathrm{Flow}_{i,t} = \beta_0 + \beta_1\,\mathrm{ROI}_{i,t-1} + \beta_2 \ln(\mathrm{TNA})_{i,t-1} + \beta_3 \ln(\mathrm{YFI})_{i,t} + \sum_{j=0}^{J} \gamma_j (D_j)_{i,t} + \beta_4 \ln(\mathrm{BTC})_{i,t} + \beta_5 \mathrm{BTC\ return}_{i,t} + \beta_6 \mathrm{BTC\ vol}_{i,t} + \varepsilon_{i,t} \qquad (10)$$

Where (1) $(D_j)_{i,t} = 1\ [t = \mathrm{Event}_i \pm j\,]\text{for } j \in \{0, \dots, J\}$. (2) Event_i is the recorded week t variable when partners announce the partnership with Yearn finance in the vault i. (3) J equals 2 since we apply the event window in the range [-2,2].

CHAPTER 5
Result

5.1.Empirical results for the flow-performance relationship in DeFi yield aggregator

We do the Hausman test to select the appropriate model between fixed and random effect models before doing an unbalanced panel data regression analysis. The P-value of the Hausman test is 0.011, indicating that the fixed effect model is suitable for our analysis.

Table 3 shows the estimation results of a flow-performance relationship using a fixed-effect regression model (7). If a flow-performance relationship does not exist in DeFi yield aggregators, we expect fund flows not to increase over time in the individual vault that generates high returns. In other words, we should not see a significant positive coefficient of recent performance.

Before we go to our main result, we should observe the market condition proxies: BTC price level, return, and volatilities. Column 1 of Table 3 illustrates the baseline regression of fund flows and market proxies. On average, fund flows do not relate to the movement of market conditions because our regressors are not statistically significant.

Next, we include the main regressor, which is recent performance. The result shows we can reject the null hypothesis that a flow-performance relationship does not exist in DeFi yield aggregators because the average weekly fund flows for only stablecoin activity exhibit a significant positive coefficient $ROI_{i,t-1}$ of 15.6% with a 5% significance level. It can imply that a 1% increase in recent performance is associated with a 15.6% increase in fund flows with a 5% significance level. The increase of 15.6% in fund flows is much higher than the weekly average of -30.2% per week. The result is consistent with several papers, for example, Berk and Green (2004); Chevalier and Ellison (1997); Ippolito (1992); Ivković and Weisbenner (2009); Sirri and Tufano (1998) show that fund flows are sensitive to past performance and have a positive relationship in mutual funds. For example, Ippolito (1992) reports that rational investors are sensitive to recent extreme performance and react to new information about product quality; thus, they will allocate their money to the most recent performance to maintain market equilibrium. Moreover, Sirri and Tufano (1998) document investor sensitivity to funding performance with a costless search in which investors can have mutual fund information at no cost. However, Ivković and Weisbenner (2009) show that only inflow is related to performance.

The result shows no flow-performance relationship in cryptocurrency vaults in Column 6 of Table 3. Therefore, we also regress the return on investment in dollars for only deposited cryptocurrency to confirm it. Table 4 reports the vault size of cryptocurrency ordered by the maximum number in million dollars for 15 vaults containing only 12 individual tokens. It demonstrates that WETH, WBTC, and YFI are the top 3 most popular cryptocurrencies in which investors have deposited more than $100 million. Other vaults accept mixed cryptocurrencies that cannot be traded in other protocols. As a result, there is no token price for these mixed cryptocurrencies. The estimated results are then reported in Table 5 after changing the independent variable from a percentage of return on investment to a dollar return on investment. Finally, we find no significant relationship between fund flows and dollar fund performance for individual cryptocurrencies because the coefficient of dollar recent performance is not statistically significant.

In DeFi, the return on investment does not reflect actual wealth for using cryptocurrency deposited, while it is valid for a stablecoin. Usually, the return on investment is positive, and the number of tokens increases after redemption. We can see its worth by multiplying it by the token price. Sometimes our wealth increases or decreases because of the token price fluctuations. Therefore, most people prefer to deposit stablecoin more than cryptocurrency. That is why our result shows a statistically significant in only stablecoin. Compared with traditional finance, stablecoin investment is the same as domestic portfolio investment since the percentage of return on investment has already reflected in the wealth. On the other hand, cryptocurrency investment is similar to foreign portfolio investment as the percentage of return on investment cannot tell actual investor wealth because of the exchange rate risk.

Finally, we include our control variables as regressors, and the estimated coefficient of recent performance is still statistically significant in a positive value. For the size of the vaults, the statistical result reports a negative value for only cryptocurrency vaults. It can imply that a 1% increase in vault size is associated with an 11.3% decrease in fund flows with a 1% significance level; this number is decreasing less than the average fund flows reported in Panel A in Table 1. On average, most investors prefer smaller vaults to larger ones. This result is consistent with Sirri and Tufano (1998). However, there is no relationship between fund flows and incentive rewards (YFI) since it is not statistically significant. Table 6 shows the correlation between YFI and stablecoin and popular cryptocurrency prices deposited are close to zero, implying that YFI may not be a significant factor in attracting investors.

In Table 7, we further investigate the stablecoin; since only stablecoin significantly impacts a flow-performance relationship, we can investigate what drives the returns. The statistical result shows that stablecoin vaults with only a leverage strategy play an essential role in a flow-performance relationship with a 10% significance level; the coefficient indicates that a 1% increase in recent performance corresponds to a 14.2% increase in fund flows, which is greater than the average value. Furthermore, the average percentage of recent ROI for stablecoin with leverage is 0.131% more than non-leverage, which is 0.109%.

Hence, we imply that the behavior of DeFi investors is similar to traditional finance investors; most investors prefer high returns because the leverage strategy offers a chance of higher returns, including higher risks. Therefore, before we go to an example of the vaults with leverage strategy, we would like to explain interoperability in DeFi. The capital movements in traditional finance will incur costs due to various financial institutions providing various financial services. However, DeFi applications have an interoperability characteristic across different financial services because they are built on permissionless blockchain technology and deployed by the smart contract.

Saengchote (2021) looks into the DAI stablecoin destination flows generated by MakerDAO (a lending-borrowing protocol) using collateralized accepted tokens. According to the findings, the Compound protocol (a lending-borrowing protocol) is one of the popular DAI destinations. Furthermore, Saengchote (2022) also investigates yield farming with the leverage of Compound investors by examining the redeposit of borrowed tokens in the cToken contract (Compound's depository receipt) into accepted protocols. Finally, the result shows that the yield aggregator is one of the investors who use leverage for yield farming.

An example of Yearn vaults with a leverage strategy is DAI v.4.3 with GenLevComp strategy, which has MakerDAO and Compound protocol doing yield farming with leverage by redepositing minted DAI from MakerDAO (use the underlying assets as collateral) to Compound protocol. However, we do not track the route of cToken minted from the Compound. If we compare it with traditional finance, the pawnshop is similar to yield farming by bringing investors' stuff to pledge for money. However, depositors cannot use their depository receipts to leverage it.

Table 3: Determinants of fund flows by token type

This table reports the regression results of fund flows in percentage from January to December 2021. Column 1 to 4 show the result of the overall token deposited in the vaults; Column 1 shows the baseline regression in BTC price level, return, and volatilities as market condition proxies, Column 2 includes the percentage of recent performance, and Column 3 and 4 include the vault size (ln(TNA)) and incentive rewards (YFI). Column 5 shows the only stablecoin deposited, such as DAI, LUSD, RAI, sUSD, TUSD, USDC, and USDT. Column 6 shows the only cryptocurrency deposited. The percentage of recent performance, size of the vaults, incentive reward, and market proxies are included in Column 5 and 6. Value in parenthesis indicates standard errors. Stars represent statistically significant levels, with *, **, and *** denoting 10%, 5%, and 1%, respectively.

VARIABLES	(1) All	(2) All	(3) All	(4) All	(5) Stablecoins	(6) Cryptos
ln(BTC)	1.80	1.61	2.78	1.89	-4.23	2.28
	(2.83)	(2.93)	(3.04)	(3.83)	(8.09)	(4.83)
%BTC return	-0.011	-0.003	-0.015	-0.013	-0.107	0.004
	(0.043)	(0.043)	(0.041)	(0.041)	(0.115)	(0.047)
%BTC volatility	0.352	0.379	0.398	0.374	0.227	0.300
	(0.321)	(0.327)	(0.323)	(0.340)	(1.25)	(0.358)
%lagged ROI		0.766	0.884	0.977	15.6**	0.919
		(2.06)	(2.05)	(2.07)	(5.73)	(2.18)
lagged ln(TNA)			-0.683***	-0.686***	-0.341	-0.704***
			(0.235)	(0.236)	(0.668)	(0.257)
ln(YFI)				1.75	16.7	0.780
				(3.24)	(10.4)	(3.30)
Constant	-55.2*	-48.1	-56.1*	-64.9**	-155.9	-59.4
	(30.4)	(31.9)	(32.9)	(31.9)	(90.2)	(35.6)
Observations	1,184	1,158	1,158	1,158	160	998
R-squared	0.053	0.052	0.064	0.064	0.368	0.066
Number of Vaults	65	65	65	65	9	56
Week Dummy	YES	YES	YES	YES	YES	YES
Vault Dummy	YES	YES	YES	YES	YES	YES

Table 4: Cryptocurrency vaults size reported in Million Dollars

Cryptocurrency	Obs.	Mean	Std. Dev.	Min	Max
WETH	75	64.0	119.4	0	391.5
WBTC	87	11.2	41.8	0	327.3
YFI	63	28.1	33.303	0	109.1
LINK	31	2.75	7.42	0	32.4
AAVE	22	0.478	1.10	0	4.94
UNI	36	1.39	1.38	0	4.81
COMP	22	0.988	1.09	0	2.91
1INCH	46	0.302	0.733	0	2.73
3Crv	37	0.202	0.426	0	2.07
SUSHI	22	0.285	0.567	0	1.72
SNX	37	0.288	0.408	0	1.70
HEGIC	52	0.115	0.106	0	0.477

Table 5: The dollar return on investment and fund flows for cryptocurrency vaults

This table reports the regression results of fund flows in percentage from January to December 2021 by strategy. Column 1 shows the result of all 12 cryptocurrencies deposited. Column 2 to 13 show the result of the individual cryptocurrency deposited, such as WETH, WBTC, YFI, LINK, AAVE, UNI, COMP, 1INCH, 3Crv, SUSHI, SNX and HEGIC. The dollar return on investment and size of the vaults are included in all columns. Value in parenthesis indicates standard errors. Stars represent statistically significant levels, with *, **, and *** denoting 10%, 5%, and 1%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
VARIABLES	Cryptos	WETH	WBTC	YFI	LINK	AAVE	UNI	COMP	1INCH	3Crv	SUSHI	SNX	HEGIC
$ROI	0.000	0.000	0.000	0.000	-0.018	-0.203	1.26	-0.025	-2.75	78,103.3	-1.56	-0.008	-36.8
	(0.000)	(0.020)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lagged ln(TNA)	-0.347	-1.06	-1.30	0.485	0.114	50.5	-1.45	4.11	-0.123	-43.2	-2.36	-2.97	-47.5
	(0.367)	(4.48)	(1.17)	(2.14)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-18.4***	-6.36	-11.2	-25.3	-29.3	-410.5	-2.99	-61.8	-18.5	540.1	-7.02	2.70	599.5
	(5.469)	(41.2)	(11.2)	(17.0)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	379	54	73	41	25	12	29	15	33	19	13	24	41
R-squared	0.095	0.578	0.590	0.452	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of Vaults	15	2	2	2	1	1	1	1	1	1	1	1	1
Week Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Vault Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table 6: Matrix of correlations between YFI and stablecoin and popular cryptocurrency prices

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) YFI	1.000								
(2) DAI	-0.143	1.000							
(3) LUSD	0.054	0.216	1.000						
(4) RAI	-0.063	0.192	0.181	1.000					
(5) sUSD	0.315	-0.003	0.129	-0.048	1.000				
(6) TUSD	-0.179	0.376	0.249	0.338	-0.059	1.000			
(7) USDC	-0.082	0.470	0.199	0.253	-0.047	0.729	1.000		
(8) USDT	-0.055	0.057	-0.041	-0.075	-0.056	0.050	0.064	1.000	
(9) BTC	0.168	-0.072	-0.243	0.527	-0.008	0.015	0.017	-0.099	1.000

Table 7: Determinants of fund flows by strategy

This table reports the regression results of fund flows in percentage from January to December 2021 by strategy. Column 1 and 2 show the result of all tokens deposited for leverage and non-leverage strategies. Column 3 and 4 show the result of the only stablecoin deposited, such as DAI, LUSD, RAI, sUSD, TUSD, USDC, and USDT, for both leverage and non-leverage strategies. Column 5 and 6 show the result of the only cryptocurrency deposited for both leverage and non-leverage strategies. The percentage of recent performance, size of the vaults, incentive reward, and market proxies are included in all columns. Value in parenthesis indicates standard errors. Stars represent statistically significant levels, with *, **, and *** denoting 10%, 5%, and 1%, respectively.

VARIABLES	**(1) Leverage**	**(2) Non-Lev**	**(3) Stable Lev**	**(4) Stable Non-Lev**	**(5) Crypto Lev**	**(6) Crypto Non-Lev**
%lagged ROI	1.60	3.64	14.2*	-0.627	1.32	-1.93
	(2.49)	(4.44)	(35.5)	(35.3)	(2.59)	(3.38)
lagged ln(TNA)	-0.914***	0.005	-3.03***	0.808	-0.798***	-0.189
	(0.265)	(0.560)	(0.380)	(0.514)	(0.258)	(1.37)
ln(YFI)	2.63	2.22	22.3	1.38	0.342	2.91
	(3.63)	(6.04)	(16.4)	(15.4)	(3.73)	(4.98)
ln(BTC)	1.19	1.47	-2.82	-2.53	1.81	9.09
	(5.15)	(7.50)	(16.2)	(13.9)	(6.04)	(8.85)
%BTC return	0.011	-0.085	-0.000	-0.075	0.018	-0.046
	(0.052)	(0.054)	(0.023)	(0.117)	(0.056)	(0.109)
%BTC volatility	0.228	0.687	-0.464	2.40	0.274	-0.131
	(0.357)	(0.754)	(1.35)	(2.10)	(0.388)	(0.256)
Constant	-63.3	-74.5	-178.5	-42.9	-49.1	-155.5
	(38.9)	(68.1)	(179.9)	(197.0)	(44.6)	(121.5)
Observations	964	194	89	71	875	123
R-squared	0.090	0.283	0.646	0.640	0.082	0.391
Number of Vaults	55	10	4	5	51	5
Week Dummy	YES	YES	YES	YES	YES	YES
Vault Dummy	YES	YES	YES	YES	YES	YES
Avg. of %lagged ROI	0.129	0.136	0.131	0.109	0.129	0.159

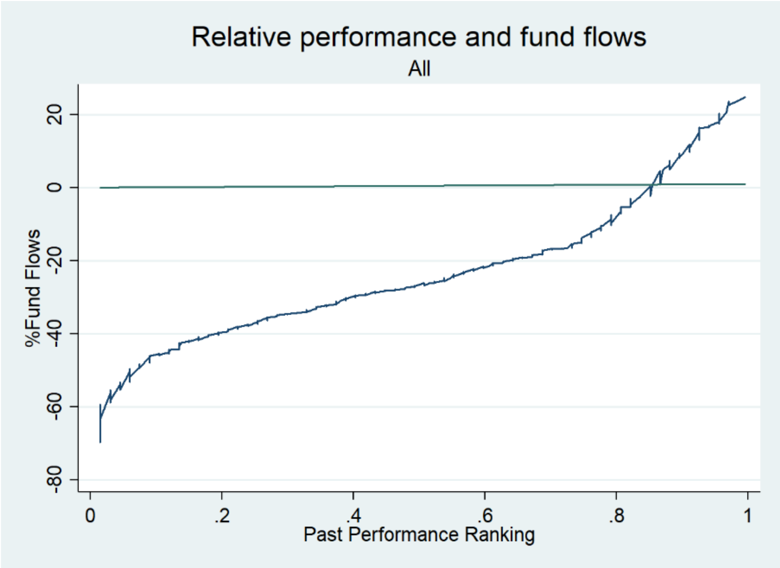
5.2.Empirical results for convexity in the flow-performance relationship

From the first hypothesis's empirical result, we know a relationship exists between fund flows and performance. In this section, we want to examine the shape of the relationship curve using a fixed-effect regression model (8), in other words, whether there is a linear relationship between fund flows and performance. If the relationship curve is linear, we expect the size of fund flows not to respond very differently for all ranking performers; to put it another way, the magnitude of the coefficient should not differ significantly across all rankings.

Panel A and B in Figure 5 illustrate the initial analysis of the fund flows and performance relationship; it is not linear but convexity. Next, we do a multivariate analysis. Column 1 and 2 of Table 8 report the result of continuous and discrete rankings sensitivity. There are no statistically significant regressors. However, the result of further investigation of each token type in Column 3 can confirm that we can reject the null hypothesis of the linear relationship. Because fund flows are sensitive to recent performance ranking, this is sensitive in the non-linear curve, mainly in the top performers using stablecoins deposited. The coefficient suggests that a 1% increase in recent performance is associated with a 44.4% increase in fund flows with a 5% significance level. The 44.4% increase in fund flows outperforms the weekly average of -30.2%. However, there is no relationship between a flow-performance relationship for the middle and poor performers. Hence, our initial analysis graph can support this statistic by returning to Panel A and B of Figure 5. Our result is consistent with Chevalier and Ellison (1997); Sirri and Tufano (1998), showing that the relationship between fund flows and recent performance is convex. On the other hand, Ippolito (1992) reports a positive linear relationship between fund flows and performance.

Figure 5: Relative performance and fund flows of each token deposited

Panel A: Relative performance and fund flows of all tokens deposited



Panel B: Relative performance and fund flows of only stablecoin deposited

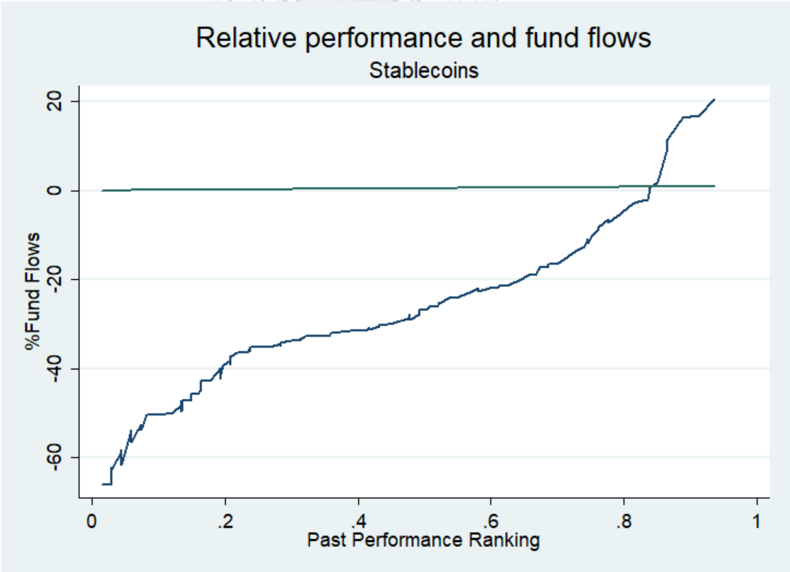


Table 8: Relative performance and fund flows by token type

This table reports the regression results of fund flows in percentage from January to December 2021 by ranking the recent performance. Column 1 shows the result of all tokens deposited for continuous. Column 2 shows the result of all tokens deposited for discrete. Column 3 to 5 show the result of the only stablecoin deposited, such as DAI, LUSD, RAI, sUSD, TUSD, USDC, and USDT, in the discrete for all strategies, leverage and non-leverage strategies. Column 6 and 8 show the result of the only cryptocurrency deposited in the discrete for all strategies, leverage and non-leverage strategies. The percentage of recent performance, size of the vaults, incentive reward, and market proxies are included in all columns. Value in parenthesis indicates standard errors. Stars represent statistically significant levels, with *, **, and *** denoting 10%, 5%, and 1%, respectively.

VARIABLES	(1) Continuous rank variable [continuous]	(2) Discrete categories [discrete]	(3) Stablecoins	(4) Stable Lev	(5) Stable Non-Lev	(6) Cryptos	(7) Crypto Lev	(8) Crypto Non-Lev
Rank	-2.97							
	(2.23)							
Top quartile		3.48	44.4**	64.2	40.6	-2.92	-4.38	-48.5
		(14.4)	(21.8)	(29.9)	(118.5)	(14.3)	(16.8)	(64.6)
Middle quartile		-5.67*	-7.58	-5.36	-18.7	-5.10	-5.49	-3.49
		(3.30)	(4.59)	(26.5)	(20.3)	(3.45)	(3.77)	(5.53)
Poor quartile		4.67	-22.5	-66.3	51.6	5.84	5.59	-48.1***
		(8.67)	(40.9)	(37.3)	(31.1)	(8.03)	(8.57)	(8.34)
lagged ln(TNA)	-0.665***	-0.656***	-0.365	-2.73**	0.642	-0.659**	-0.753***	-0.147
	(0.235)	(0.239)	(0.729)	(0.503)	(0.448)	(0.260)	(0.258)	(1.53)
ln(YFI price)	1.98	1.82	15.0	15.4	3.36	0.868	0.596	8.57
	(3.21)	(3.21)	(9.13)	(15.8)	(15.2)	(3.25)	(3.67)	(6.10)
ln(BTC Price)	1.25	1.63	-4.16	-7.65	-9.73	2.02	1.59	8.21
	(3.82)	(3.89)	(9.62)	(13.6)	(23.5)	(4.83)	(6.05)	(8.81)
%BTC return	-0.004	-0.006	-0.073	0.110	-0.122	0.010	0.029	-0.073
	(0.040)	(0.040)	(0.139)	(0.063)	(0.086)	(0.045)	(0.053)	(0.099)
%BTC volatility	0.407	0.407	0.090	-0.551	1.94	0.354	0.359	-0.728
	(0.332)	(0.334)	(1.20)	(1.51)	(2.93)	(0.353)	(0.391)	(0.707)
Constant	-60.4*	-64.0**	-132.2	-49.3	8.43	-59.2	-51.2	-187.0
	(31.8)	(31.6)	(102.4)	(200.4)	(255.5)	(36.0)	(45.9)	(142.9)
Observations	1,172	1,172	160	89	71	1,012	888	124
R-squared	0.066	0.067	0.367	0.659	0.655	0.069	0.084	0.433
Number of Vaults	65	65	9	4	5	56	51	5
Week Dummy	YES	YES	YES	YES	YES	YES	YES	YES
Vault Dummy	YES	YES	YES	YES	YES	YES	YES	YES

5.3.Empirical results for reaction to the publication

5.3.1 Internal event

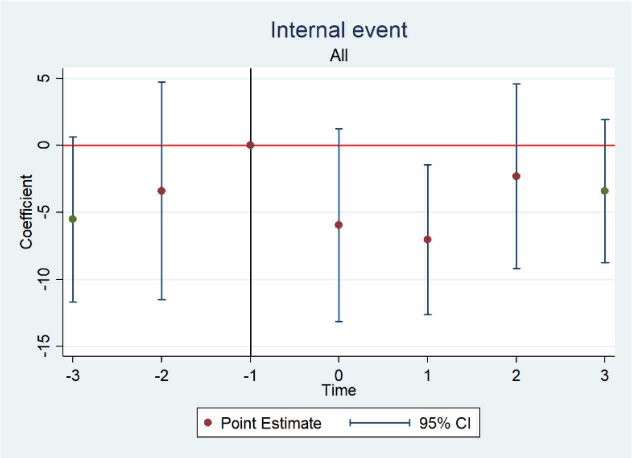
We already examine a flow-performance relationship from the above-hypothesis empirical results. In the third section, we want to explore the investor reaction to the internal event publication using the difference-in-difference model (9); whether there is evidence that investors do not immediately react to the publication of new strategies. If investors do not respond directly to the publication, we expect fund flows not to respond at the event date; the coefficient at the publication date should not differ significantly compared to a prior period of the publication. However, this effect should not occur before publication.

We do multivariate regression by using an event window in the range [-3,3] and a prior period of the event date (T-1) as a base point to see the effect of publication. Panel A in Figure 6 shows the result of the overall token deposited in the vaults that we fail to reject the null hypothesis because the regressor is not statistically significant at a 5% significance level at the event date. Therefore, we further investigate each token type. The results are shown in Panel B and C in Figure 6 for stablecoin and cryptocurrency, respectively. However, we still do not find a statistically significant regressor at the event date. Therefore, it can confirm that investors do not respond directly to the publication. The estimated results reported in Table 9.

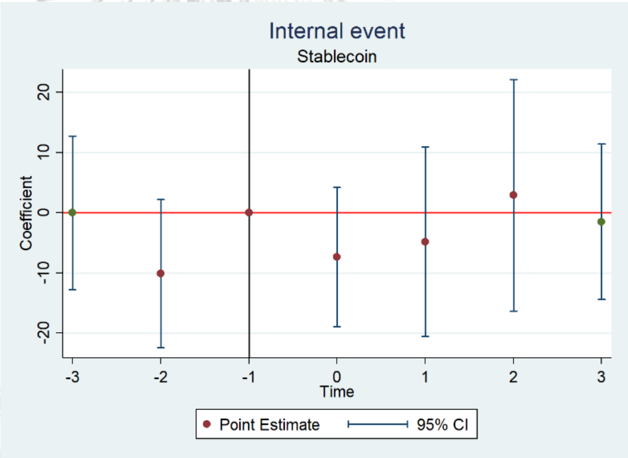
The lack of evidence to support the market's immediate reaction is due to the slow diffusion of information. According to Merton (1987), slow information diffusion is caused by paying the information costs of informed investors. In DeFi, all information is costless; hence, we cannot assert that information costs cause slow information diffusion. Nevertheless, not all investors can receive all-new information and make an immediate decision; hence, these can also influence slow information dissemination because investors may need to digest to recognize new investment opportunities before deciding to invest. Moreover, according to Hong and Stein (1999), new information gradually influences stock price response as it spreads in the group of interested investors; in the short run, momentum traders can make their own decisions and profit from the market.

Figure 6: The estimated coefficient of the binary variable for the internal event study decomposed by each token deposited

Panel A: The estimated coefficient of the binary variable for all tokens deposited



Panel B: The estimated coefficient of the binary variable for stablecoin deposited



Panel C: The estimated coefficient of the binary variable for cryptocurrency deposited

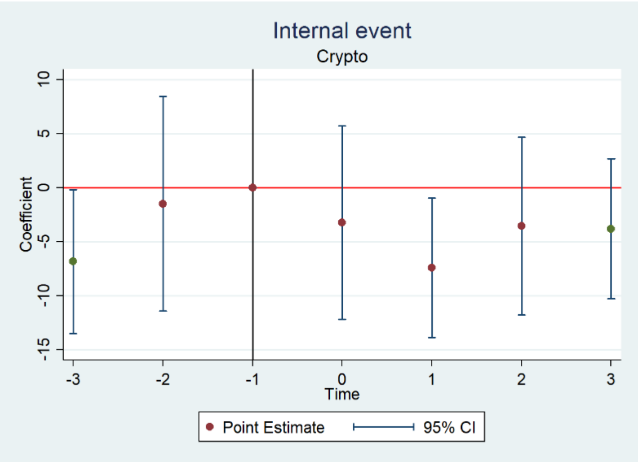


Table 9: Determinants of fund flows for the publication of internal event study

This table reports the regression results of fund flows in percentage from January to December 2021 for the publication of the internal event study with the event window in the range [-3,3]. Column 1 shows the result of all tokens deposited. Column 2 and 3 show the result of all tokens deposited for leverage and non-leverage strategies. Column 4 to 6 show the result of the only stablecoin deposited, such as DAI, LUSD, RAI, sUSD, TUSD, USDC, and USDT, for all strategies, leverage and non-leverage strategies. Column 7 to 9 show the result of the only cryptocurrency deposited for all strategies, leverage and non-leverage strategies. The percentage of recent performance, size of the vaults, incentive reward, and market proxies are included in all columns. Value in parenthesis indicates standard errors. Stars represent statistically significant levels, with *, **, and *** denoting 10%, 5%, and 1%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	**All**	**Leverage**	**Non-Leverage**	**Stablecoins**	**Stable Lev**	**Stable Non-Lev**	**Cryptos**	**Crypto Lev**	**Crypto Non-Lev**
%lagged ROI	1.33	1.95	3.61	16.4	19.8	27.2	1.29	1.58	1.30
	(2.04)	(2.39)	(5.94)	(9.22)	(29.6)	(31.0)	(2.09)	(2.46)	(3.27)
lagged ln(TNA)	-0.742***	-0.973***	-0.172	-0.651	-2.83**	-0.546	-0.769***	-0.862***	-0.481
	(0.234)	(0.266)	(0.573)	(0.527)	(0.521)	(1.58)	(0.255)	(0.260)	(1.35)
ln(YFI price)	2.63	4.04	0.017	16.2	23.7	7.74	1.53	1.32	0.318
	(3.17)	(3.56)	(8.10)	(9.19)	(13.5)	(18.0)	(3.25)	(3.65)	(5.10)
ln(BTC Price)	1.71	0.669	3.41	-1.48	-2.24	-3.37	1.68	1.22	11.9
	(3.91)	(5.19)	(8.24)	(6.99)	(15.2)	(22.8)	(4.88)	(6.07)	(10.5)
%BTC return	-0.011	0.020	-0.082	-0.125	0.095	0.017	0.008	0.026	-0.095
	(0.042)	(0.053)	(0.088)	(0.095)	(0.115)	(0.109)	(0.048)	(0.060)	(0.136)
%BTC volatility	0.280	0.124	0.866	0.427	0.633	2.38	0.141	0.113	-0.572
	(0.331)	(0.380)	(0.747)	(1.29)	(1.46)	(1.96)	(0.354)	(0.406)	(0.536)
T-3	-5.52*	-8.66**	-6.43	-0.019	-26.3	4.62	-6.83**	-7.43**	-15.1
	(3.08)	(3.48)	(16.4)	(5.53)	(21.2)	(26.4)	(3.32)	(3.65)	(12.6)
T-2	-3.40	-1.51	-13.8	-10.1*	-6.54	-26.3	-1.48	-0.450	-7.00
	(4.06)	(4.50)	(16.3)	(5.35)	(13.88)	(17.3)	(4.95)	(5.12)	(12.8)
T0	-5.95	-4.23	-13.3	-7.34	-9.92	-10.2	-3.21	-2.14	-26.8
	(3.60)	(3.53)	(17.8)	(5.02)	(7.54)	(38.7)	(4.46)	(4.34)	(18.9)
T+1	-7.02**	-7.17***	-4.48	-4.84	-8.31	-15.6	-7.39**	-6.36**	-22.5
	(2.80)	(2.46)	(17.9)	(6.84)	(13.59)	(34.6)	(3.22)	(2.89)	(13.6)
T+2	-2.30	-2.75	0.745	2.90	-6.28	17.7	-3.52	-2.15	-22.8
	(3.45)	(2.86)	(21.5)	(8.35)	(9.19)	(34.2)	(4.10)	(3.51)	(16.2)
T+3	-3.40	-2.91	-5.29	-1.49	0.120	-2.13	-3.80	-2.826	-14.5
	(2.68)	(2.35)	(16.7)	(5.60)	(6.85)	(29.6)	(3.22)	(2.73)	(11.0)
Constant	-66.8*	-66.6	-65.4	-175.5	-204.2	-95.4	-54.1	-47.4	-138.5
	(35.1)	(43.2)	(83.1)	(105.6)	(210.3)	(202.4)	(38.9)	(47.9)	(133.4)
Observations	1,171	977	194	160	89	71	1,011	888	123
R-squared	0.071	0.097	0.311	0.398	0.690	0.727	0.072	0.088	0.470
Number of Vaults	65	55	10	9	4	5	56	51	5
Week Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES
Vault Dummy	YES	YES	YES	YES	YES	YES	YES	YES	YES

5.3.2 External event

We employ the difference-in-difference model to examine the impact of external events that occur at a specific time by comparing the variation of fund flows around the event date to the reference point. We use a baseline point at a prior period of the event date (T-1) and event window in the range [-2,2]

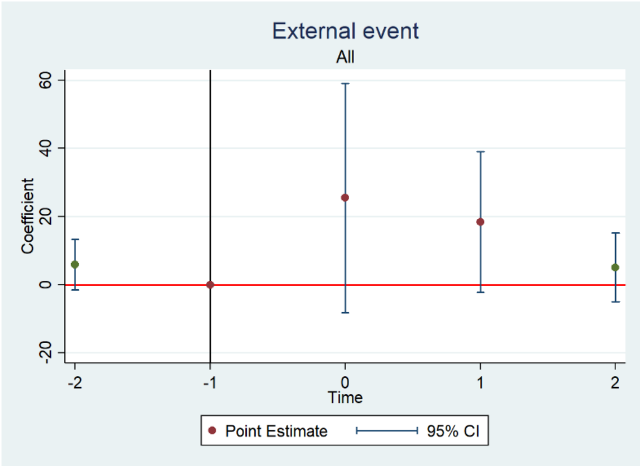
From the third hypothesis, we already investigate the internal event study. In the fourth section, we want to examine the investor reaction to the external event publication using the difference-in-difference model (10). Whether there is evidence that investors do not immediately react after protocol partners announce the investment policy to use Yearn finances as a backend for enhancing market efficiency. Therefore, if investors do not respond directly to the publication, we expect fund flows not to contribute to Yearn vaults at the event date; the coefficient at the announcement date should not differ significantly compared to a prior period of the announcement. However, this effect should not occur before publication.

We also do multivariate regression the same way as the third hypothesis but using an event window in the range [-2,2]. Panel A in Figure 7 shows the result of the overall token deposited in the vaults. We fail to reject the null hypothesis because the regressor is not statistically significant at a 5% significance level at the event date. Therefore, we further investigate each token type. For the stablecoin deposited, the results are shown in Panel B in Figure 7 that we can reject the hypothesis statement because the variation of fund flows of the stablecoins vault has immediately responded to tokens supplied by protocol partners. It can imply that the market reacted abnormally to the announcement on the event date. Table 10 reports that the coefficient suggests that the fund flows increase by 69.0%, which is more than the weekly average, at the event date after the partnership announcement with a 1% significance level because the external protocols collaborate with existing stablecoin vaults rather than deploying new vaults. Nonetheless, we cannot see the variation of fund flows in the regression for cryptocurrencies at the publication date because external protocols become partners immediately after launching new vaults; the result is in Panel C in Figure 7.

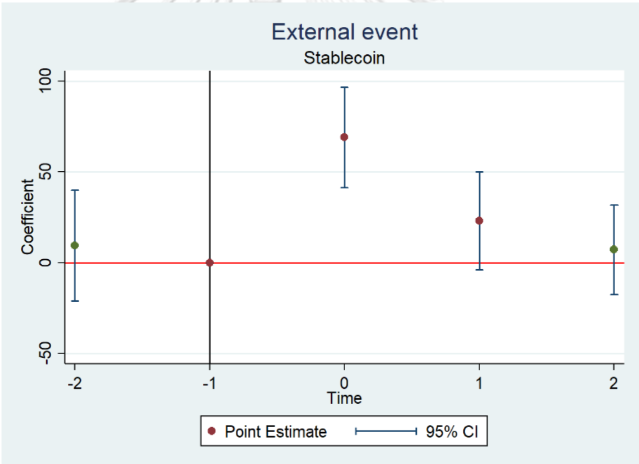
Lastly, Column 1 of Table 8 reports that the total number of vaults is 65. However, when we analyze each token type: stablecoin, and cryptocurrency, the number of vaults drops sharply to each of 5 because we only focus on the vaults that interact with partners. Furthermore, we cannot conduct a detailed analysis of leverage and non-leverage strategies for each token type. Because we can only collect the announcement date at the vault level and do not have enough information on which strategy they connect.

Figure 7: The estimated coefficient of the binary variable for the external event study decomposed by each token deposited

Panel A: The estimated coefficient of the binary variable for all tokens deposited



Panel B: The estimated coefficient of the binary variable for stablecoin deposited



Panel C: The estimated coefficient of the binary variable for cryptocurrency deposited

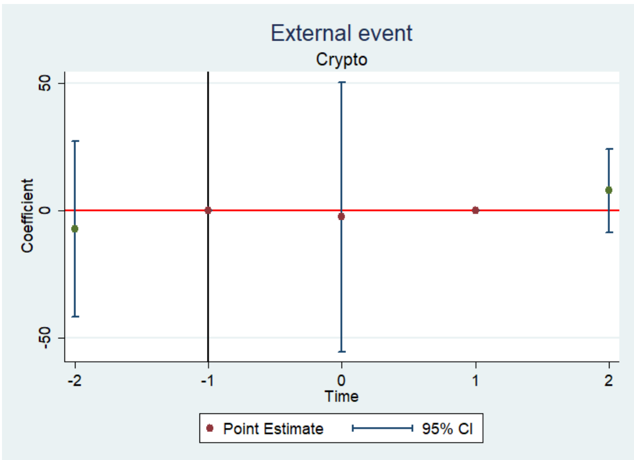


Table 10: Determinants of fund flows for the publication of external event study

This table reports the regression results of fund flows in percentage from January to December 2021 for the publication of the external event study with the event window in the range [-2,2]. Column 1 shows the result of all tokens deposited. Column 2 and 3 show the result of all tokens deposited for leverage and non-leverage strategies. Column 4 shows the result of the only stablecoin deposited, such as DAI, LUSD, RAI, sUSD, TUSD, USDC, and USDT, for all strategies. Column 5 shows the result of the only cryptocurrency deposited for all strategies. The percentage of recent performance, size of the vaults, incentive reward, and market proxies are included in all columns. Value in parenthesis indicates standard errors. Stars represent statistically significant levels, with *, **, and *** denoting 10%, 5%, and 1%, respectively.

VARIABLES	**(1) All**	**(2) Leverage**	**(3) Non-Leverage**	**(4) Stablecoins**	**(5) Cryptos**
%lagged ROI	1.04	1.68	1.06	22.0	-1.02
	(2.00)	(2.39)	(4.75)	(23.4)	(8.80)
lagged ln(TNA)	-0.693***	-0.918***	-0.188	-0.511	-2.62*
	(0.232)	(0.259)	(0.578)	(0.882)	(1.05)
ln(YFI price)	2.69	2.56	8.96*	15.2	1.81
	(3.04)	(3.57)	(4.25)	(14.9)	(6.43)
ln(BTC Price)	1.22	1.51	-1.58	-13.8	6.52
	(3.84)	(5.34)	(7.60)	(11.2)	(10.2)
%BTC return	-0.021	0.005	-0.124**	0.000	-0.097
	(0.041)	(0.051)	(0.054)	(0.069)	(0.079)
%BTC volatility	0.234	0.243	0.175	-0.150	0.516
	(0.332)	(0.371)	(0.775)	(1.33)	(1.45)
T-2	5.92	5.60	8.77	9.48	-7.26
	(3.70)	(4.10)	(8.00)	(11.0)	(12.4)
T0	25.5	-6.27	30.4*	69.0***	-2.63
	(16.8)	(5.16)	(13.7)	(9.98)	(19.1)
T+1	18.4*	32.5***	-4.42	23.1*	
	(10.3)	(3.26)	(8.49)	(9.73)	
T+2	5.07	7.75**	-11.5*	7.20	7.74
	(5.07)	(3.06)	(6.21)	(8.87)	(5.91)
Constant	-69.2**	-67.5*	-116.7*	-44.9	-102.9*
	(31.7)	(39.1)	(57.6)	(113.8)	(41.6)
Observations	1,171	977	194	113	165
R-squared	0.073	0.096	0.375	0.531	0.301
Number of Vaults	65	55	10	5	5
Week Dummy	YES	YES	YES	YES	YES
Vault Dummy	YES	YES	YES	YES	YES

CHAPTER 6
Conclusion

To see how fund flows respond to fund performances in DeFi yield aggregator, we use Yearn finance as a case study and examine the relationship at the transaction level to see if it is similar to traditional finance. Our observations are collected between January and December 2021 and regressed on a weekly basis.

On average, fund flows do not relate to market movements. Hence, we analyze each token type deposited: stablecoin and cryptocurrency. We find that the flow-performance relationship exists in the positive sign for only the stablecoin vault since it can reflect the actual wealth of investors. Moreover, we further examine the investor behaviours; which strategies they prefer. The result reports that the stablecoin holders would like to deposit their assets into the leverage strategy because of high returns; however, we do not find a significant statistical result for cryptocurrency. Furthermore, we find that investors prefer smaller vaults to larger vaults and do not find a relationship between incentive rewards and fund flows. Finally, we also test the shape of the relationship; it is a convexity curve for only the stablecoin vault.

We also investigate how investors react to changes, internal and external. We do not find the investors respond to internal changes for new strategies publication at the event date because of the slow information diffusion. In contrast, with the external changes for being a partnership with Yearn finance, there is evidence for investors' reaction at the event date for only the stablecoin vault because they become partners with the existing vaults. However, there is no evidence for the cryptocurrency vault since they directly become partners after deploying new vaults.

Lastly, our research's implication can apply to investors because all our findings point out that most rational investors in DeFi yield aggregator prefer to deposit stablecoin more than cryptocurrency. Moreover, stablecoin holders would like to invest in funds with good performance. Therefore, new or existing investors can adopt our empirical results to create a suitable investment strategy to satisfy their return on investment. However, our research might have a limitation because DeFi has many blockchains for deploying yield aggregators, but we only focus on the Ethereum blockchain due to time limitations for extracting the data from the individual blockchain and understanding the mechanism of each yield aggregator protocol. Therefore, other papers interested in this area might explore other protocols and blockchains to analyze and compare the study results.

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