On-chain Foreign Exchange and Cross-border Payments

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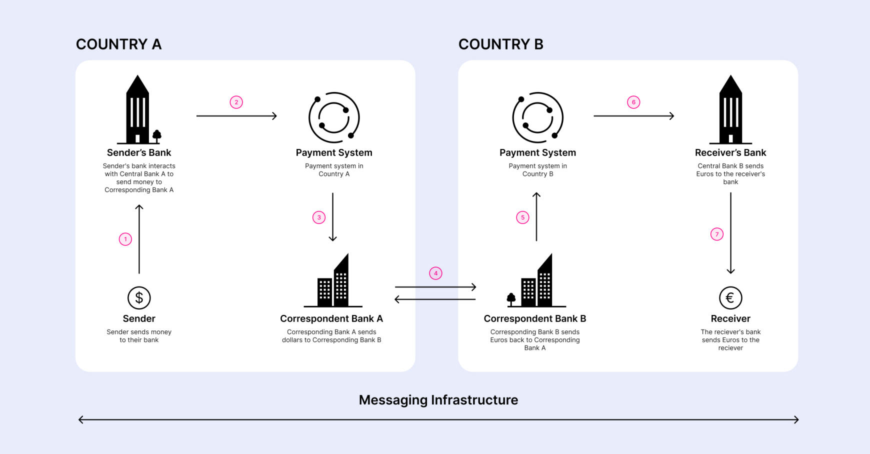
Motivation

1. FX Cross-border payments
   - Substantial FX settlement risks exists due to non-instantaneous corresponding bank settlements, estimated at $2.2 trillion a day of unprotected trade
   - Cost of remittance and small value transfers remains high, with around >6% average cost
2. Market making and exchanges
   - Market making on electronic exchanges has resulted in high-frequency arms race (Budish et al, 2015)
   - Distribution of gains on liquidity provision favors market makers
     - Retail traders are not compensated for providing liquidity (Barrot et al 2016)

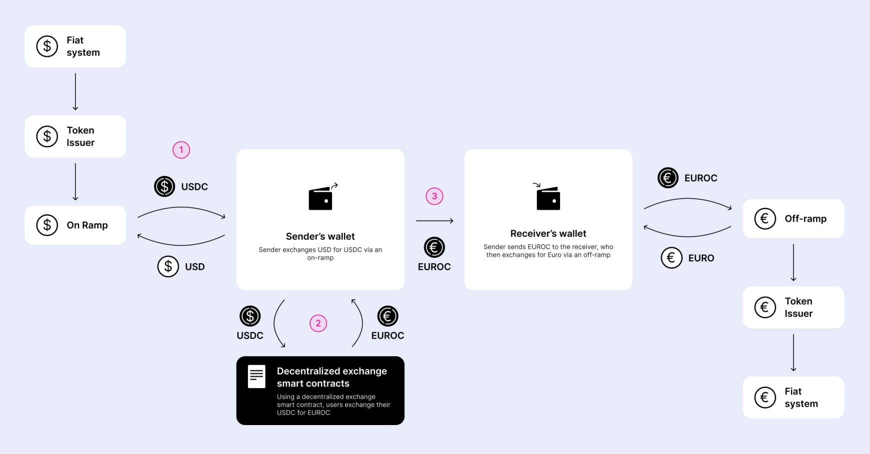
This paper investigates the use of automated market makers on distributed ledgers for the trading and settlement of foreign exchange

FX transaction with correspondent banking



FX transaction with decentralized finance (DeFi)

DeFi is the decentralization of balance sheets



Comparison of FX market features

Features	Traditional FX market	On-chain FX
Market hours	Nominal 24 hour market during weekdays; poor liquidity between NY close and Tokyo open; No trading and settlement on weekends	Always-on 24-7 trading liquidity through AMMs and near instantaneous settlement on blockchains
Settlement time	T+2 business days by convention and often greater than T+5 calendar days with holidays and weekends	Near instantaneous settlements in seconds; Occasional blockchain congestions that may result in high gas costs
Settlement risks (credit exposure and liquidity risk)	Around one-third of deliverable FX turnovers are subject to settlement risk exposure on any given day	Minimal settlement risks as on-chain transactions adhere to Payment vs Payment principles by design
Transparency and trade reporting	Limited trade reporting with non-harmonizing standards across jurisdictions; reporting predominantly on forwards and swaps	Privacy-preserving transactions recorded on public ledgers in real-time
Benchmark transparency	Key benchmark had issues of rigging with lack of transparency in the price discovery process	Transaction data visibility to the public allows for transparent benchmark construction and audits
Liquidity fragmentation	Increasing fragmentation in liquidity due to internalization of customer flows by banks	Composability of token standards enable direct liquidity aggregation from different AMM platforms
Liquidity providers	Principal trading firms supply liquidity on limit order books and dealers supply liquidity via bank platforms and voice	Any holders of tokenized cash in multiple currencies can supply liquidity via AMMs

Decentralized finance and automated market makers

- Decentralized finance (DeFi) removes the need of intermediaries in financial services
- Transactions occur on public blockchain, e.g. Ethereum, which serves as
  - a shared computing environment
  - a shared ledger for data storage
- Decentralized exchanges with automated market makers (AMMs) is one of the most used application of DeFi
  - Instead of matching buyers and sellers as in limit order books, AMMs provide liquidity using common pools based on set formula
  - Liquidity providers collect fees on "liquidity pool" from traders while being adversely selected

How do AMMs work?

- Liquidity suppliers deposit two assets into a “liquidity pool” that can be traded against by liquidity demanders (traders)
- Market making is formulaic based on pre-specified indifference curves.
- Constant product AMM (Uniswap v2):

$$\underbrace{x}_{\text{quantity of reserve } x} \times \underbrace{y}_{\text{quantity of reserve y}} = \underbrace{k}_{\textit{constant}}$$

- Purchase of asset $x$increase price of x and decreases the price of y but maintains the same k

$$(x_0 + \Delta x)\,(y_0 + \Delta y) = k$$

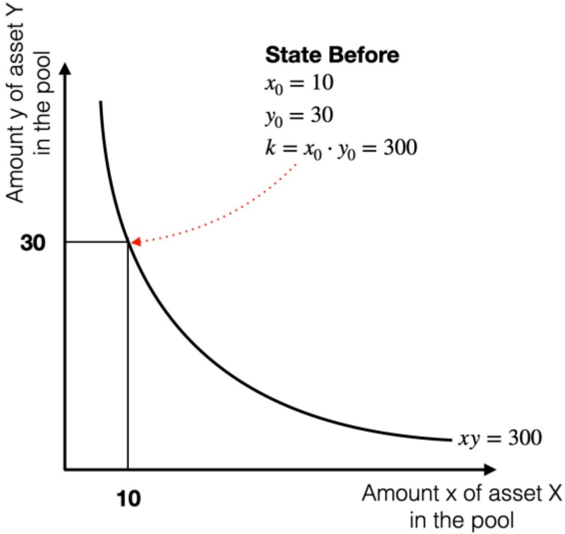
- Price of the assets are the marginal rate of substitution. E.g. price of x in units of y:

$$p = \frac{y}{x}$$

- Constant product AMM is equivalent to liquidity providers having a Cobb-Douglas utility function with $\alpha = 1/2$

Example of constant product AMM

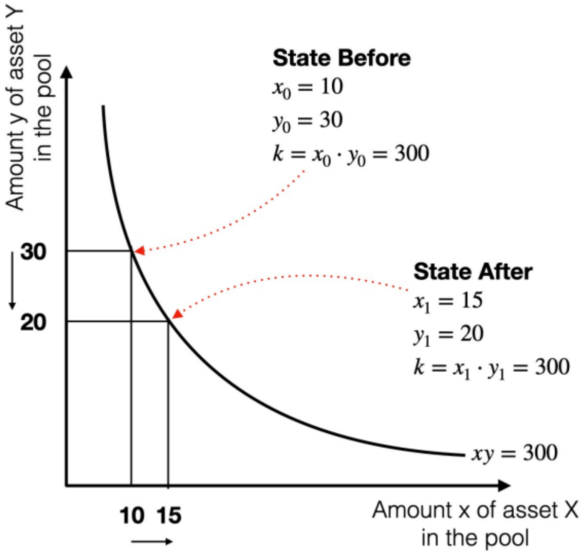
Liquidity pool starts out with 10 units of x and 30 units of y



Example of constant product AMM

Traders sends in 5 units of $x$in exchange for 10 units of y

Pool reserve of x and y changes accordingly; Execution price,$p = -\frac{\Delta y}{\Delta x} = -\frac{-10}{5}$



Adverse selection

- Price is updated when trade occurs
- Passive liquidity provider in the pool is left with "worse" of the two reserve assets
- When there are external references price (e.g. price from another exchange), price on the liquidity pool is updated via arbitrage
- Liquidity providers (passive holders of pool reserves) suffers from adverse selection by arbitrageurs
- To compensate for adverse selection, AMMs allocate fees to liquidity providers

$$(x_0 + \Delta x)\,(y_0 + (1-\phi)\,\Delta y) = k$$

$$\text{fee} = \phi \Delta y$$

Liquidity provider returns

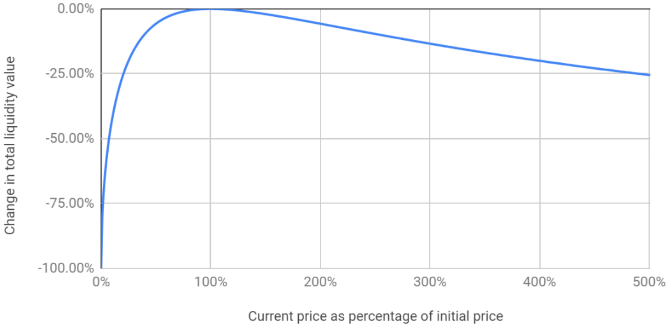
- Liquidity providers are compensated with (fixed) trading fees based on volume.
  - Fee-tiers can differ based on the pools (e.g. 1bps, 5 bps, 30 bps, 100 bps)
  - In equilibrium, for higher volatility pairs, liquidity provider and trader converges on higher fee-tiered pools
- Liquidity providers suffer from "divergence loss" by holding the worse of the two assets overtime
- Profit for liquidity provider with share s in the pool is

$$\pi = s\phi \sum_i |\Delta y_i| - \text{divergence loss}$$

for all trades i that occurs between $t = 0$ and $t = 1$.

Divergence loss on liquidity pools

$$\text{divergence loss} = \frac{2\sqrt{\frac{p_t}{p_0}}}{1+\frac{p_t}{p_0}} - 1$$



- Holding the same fees, higher the autocorrelation in returns, more loss for market makers and lower the equilibrium level of liquidity (same result as Grossman Miller 1988)

Customized and concentrated liquidity provision

- Constant product AMMs rely on a **fixed** indifference curve for market making
- Uniswap v3 allows customizability of indifference curves
- Capital deployed for market making is specified in a customized range $\in [a, b]$, thus concentrating liquidity.
- Un-concentrated (full-range) liquidity specified by general indifference equation:

$$\underbrace{x}_{\text{quantity of reserve } x} \times \underbrace{y}_{\text{quantity of reserve y}} = \underbrace{k}_{\textit{constant}}$$

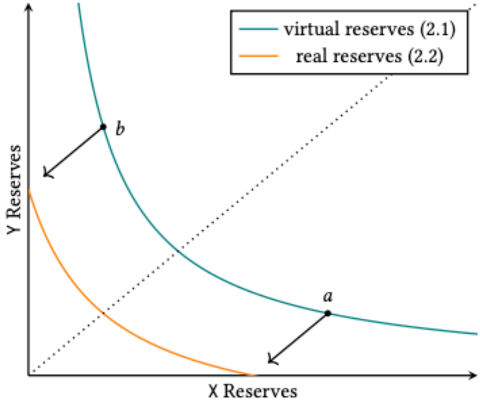
- Concentrated (range-bound) liquidity with in price range $[p_a, p_b]$

$$\underbrace{\left(x + \sqrt{\frac{k}{p_b}}\right)}_{\text{quantity of \textbf{virtual} reserve } x} \times \underbrace{\left(y + \sqrt{\frac{k}{p_a}}\right)}_{\text{quantity of \textbf{virtual} reserve } y} = k$$

where k represents the amount of liquidity contributed.

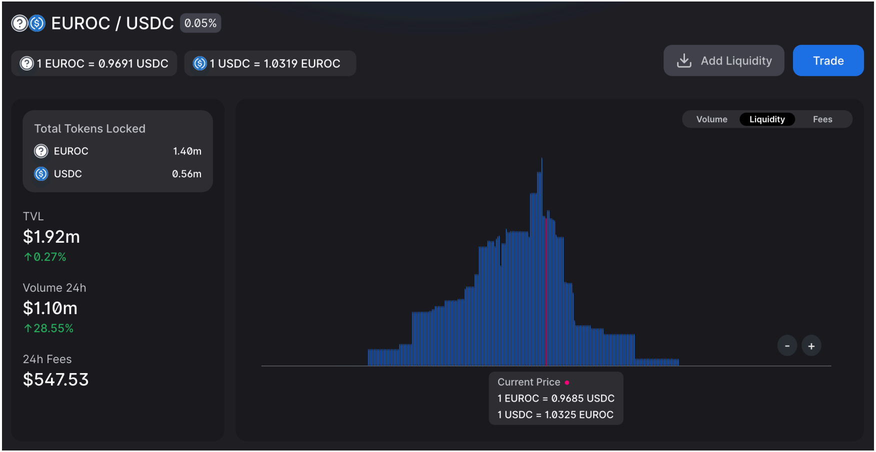
Customized and concentrated liquidity provisions

$$\underbrace{\left(x + \sqrt{\frac{k}{p_b}}\right)}_{\text{quantity of \textbf{virtual} reserve } x} \times \underbrace{\left(y + \sqrt{\frac{k}{p_a}}\right)}_{\text{quantity of \textbf{virtual} reserve } y} = k$$



Customized and concentrated liquidity positions

Example of actual liquidity distribution on EUROC/USDC pool



Liquidity providers are passive

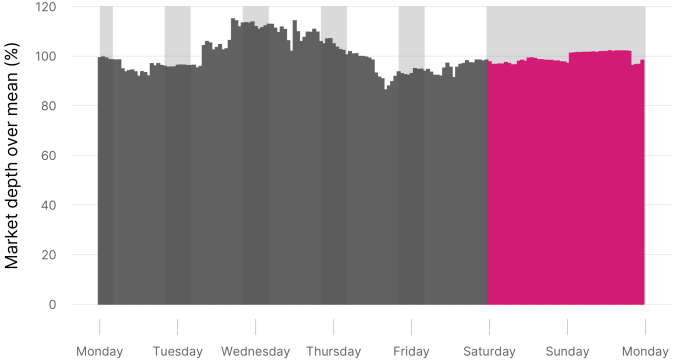
This leads to decentralization of risk-bearing capacity

- Relative to traditional limit order book market makers, AMMs are passive
- Lower technology and knowledge barriers increase capital allocation to market making
- Passive "market makers" on AMMs earn lower return on capital than traditional market makers

Position duration	Percent of LPs
$<$ 1 minute	3 %
$<$ 1 hour	12 %
$<$ 1 day	38 %
1 day +	68 %

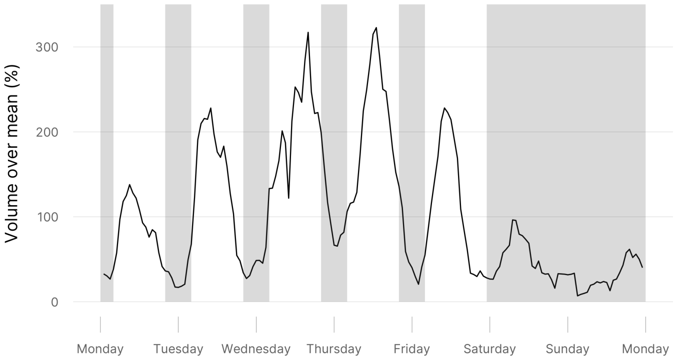
On-chain FX has always-on liquidity

Relative liquidity of dollar and euro on-chain exchange over the course of the week



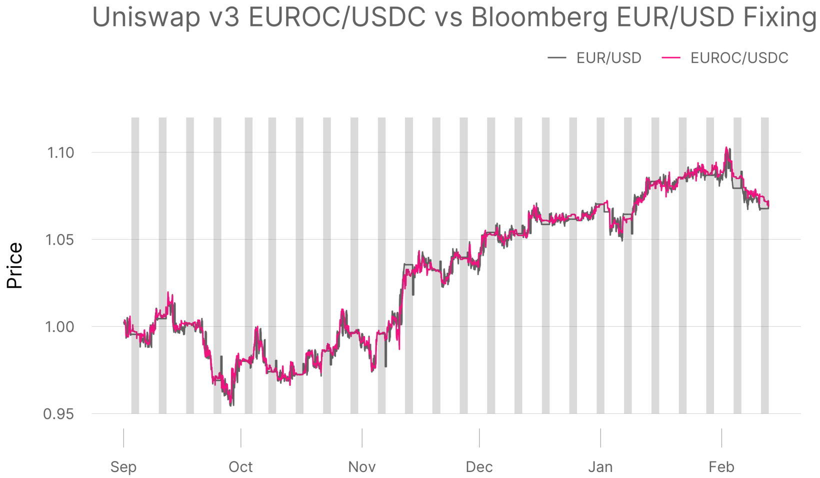
Weekend volume is around 20% of weekday average

Relative volume of the EUROC-USDC pair traded on Uniswap protocol over the course of the week

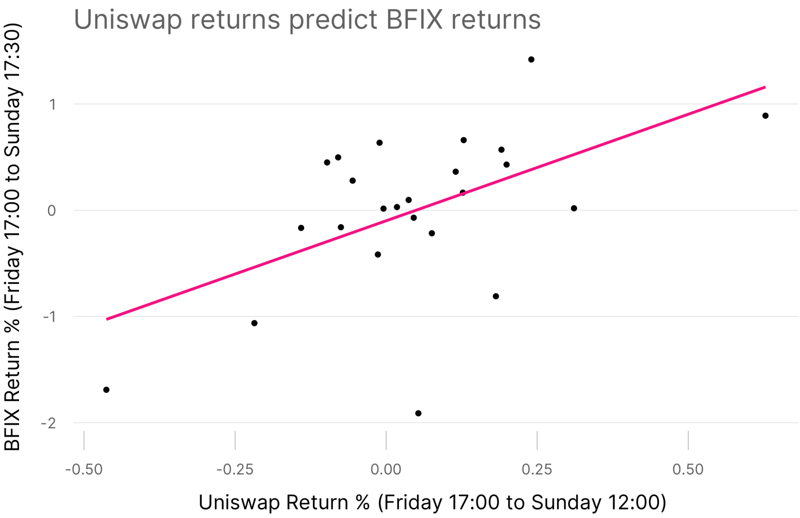


Prices are enforced by arbitrage during weekdays

Price comparison between on-chain and off-chain price



Weekend trading suggests independent AMM price discovery



Missing pieces

- Regulatory clarity on the application of DeFi
- On-chain decentralized identity solutions
- Safe custody service providers
- Forwards instruments
- Front-running risks in institutional use

Conclusion

- Distributed ledger technologies and DeFi can address challenges in traditional FX trading, liquidity, and settlement
- On-chain FX benefits: instantaneous transactions, lower cost of intermediation, enhanced liquidity, and stability
- Can enhance financial inclusion for remittance, SMEs, and corporate use cases
- Barriers to adoption: regulatory clarity, custody solutions, blockchain scaling
- Continued DeFi development and research needed for mainstream on-chain FX adoption