Are Automated Market Makers the Future of Foreign Exchange?

James Fennell

Bachelor of Business (Honours)
UTS Business School
November, 2024

Abstract

Automated Market Makers (AMMs) have risen to a multibillion-dollar industry in stable, high-volume cryptocurrency markets. I apply AMMs to foreign exchange (FX) using the volume and price history from exotic and G10 currency pairs to compare transaction costs. I show that AMMs struggle to compete with the scale of highly competitive centralized limit order books (CLOBs) in wholesale and retail FX trading. I simulate partial adoption of AMMs, showing that at low levels of turnover, the AMMs have an even greater cost disadvantage. I test each AMM with lower fee levels and optimize the fixed fee level to decrease the transaction, yet they remain significantly more costly than CLOBs. AMMs, however, can still provide an alternative to the slow and costly FX settlement process. My findings show that AMMs could be used for settlement in FX but are inefficient and more costly overall.

Keywords: FinTech, decentralized exchanges (DEX), Automated Market Makers (AMMs), Foreign Exchange (FX), Market Microstructure

Certificate of Original Authorship

I, James Fennell, certify that this thesis has not previously been submitted for a degree, nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text. I also certify that I have written the thesis. I acknowledge any help I have received in my research work and thesis preparation. In addition, I certify that I reference all information sources and literature in the thesis.

Signature of student: James Fennell[1]

Date: 10 August 2024

[1] I would like to thank my supervisors, Ester Felez Vinas, Talis Putnins, and Jonathan Karlsen. I also thank James Swerling and Lee Smales for expert industry interviews.

Contents

1 Introduction

Foreign exchange (FX) is the world's largest and most liquid market. This year, 1.875 quadrillion US dollars were traded through FX, 17.8 times larger than global GDP (Macrotrends and World Bank, 2024). However, the market remains fragmented and opaque, with unnecessary intermediation and inflated costs in some parts. Companies such as Russell Investments offer a transaction cost analysis (Russell Investments, 2024) charging to analyze the competitiveness of an FX trade. In a market where companies are charged to see if they are receiving an efficient trade, inefficiencies are at play. Large banks have also noticed these inefficiencies: "The cross-border payment process remains suboptimal from a cost, speed and transparency standpoint." (JPMorgan and OliverWyman, 2021).

, The rise of crypto markets, has seen Automated Market Makers (AMMs) become a popular trading method, with billions of dollars traded daily on exchanges such as Uniswap (Collective Shift, 2024). AMMs allow anyone to earn fees on trading by depositing assets into liquidity pools, challenging the traditional competition between market makers. AMMs attract the most liquidity to stable and high-volume markets from the high fee revenue and low adverse selection cost (ASC). The most popular trading pair, ETH/USDC, has a one-and-a-half billion dollar liquidity pool (UniswapLabs, 2024). If AMMs prove viable in volatile crypto markets, do they have potential in more stable and high-volume foreign exchange (FX) markets?

AMMs have a breakeven liquidity point where the adverse selection cost (ASC) equals the fee yield and opportunity cost of capital. I use the volume and price history of G10 and exotic currency pairs against the United States Dollar (USD) to calculate each market's cost and yield to liquidity providers (LPs). I find the breakeven liquidity point and simulate retail and wholesale trades, measuring the transaction cost. I compare the AMM transaction cost to the costs of centralized limit order books (CLOBs) wholesale and retail trades adapted from (Melvin et al., 2020). I then adjust the turnover to simulate the partial adoption of the AMM to view the fees of an only partially adopted AMM. I then vary the fixed fee level to 0.3% to test the cost impact of lower fixed fees and then optimize fixed fees to find the lowest possible transaction cost and compare it against the CLOB costs. Finally, I compare settlement costs in traditional FX markets with atomic settlement in AMMs. The analysis shows whether AMMs will be viable in FX and under what conditions.

I find that the AMMs have a higher transaction cost for all currencies in retail and wholesale trading. The larger, more efficient traditional markets are very efficient due to their access to major institutions as liquidity sources in the CLOBs. The larger and more stable currency pairs, such as USD/EUR, are close to current trading costs, but the difference is still significant at 30 BPS in retail trading. Less traded and more volatile currencies like the Norweigan Krone are more expensive in the AMM, with wholesale trading at over 200 BPS over the CLOB. The more volatile currencies have a greater portion of the cost coming from the price impact costs. The low fee revenue from trading and the ASC from volatility make them less attractive to LPs, reducing the liquidity in these markets. The resulting price impact from the low liquidity makes them significantly more expensive than traditional CLOBs.

The partial adoption results show that the AMMs at low levels of turnover face even higher transaction costs. The partial turnover generates less fee revenue, attracting fewer LPs. The smaller liquidity in the market inflates the price impact fee, passing on a greater transaction cost. The adoption curves all present as exponential graphs flattening as adoption gets closer to 100% of the current turnover. However, as they flatten, they remain at least 30 BPS greater than CLOBs transaction costs. The results show that when AMMs are only partially adopted, the transaction costs will be substantially larger.

I have calibrated the AMMs to a lower fixed fee of 0.3 BPS than the assumed Uniswap fee of 30 BPS. My results show that the substantially increased price impact outweighs the reduced fixed fee savings. The AMM becomes more costly for all currency pairs at 0.3 BPS. I then find the optimal fixed that balances the price impact cost and a fixed fee for the smallest possible transaction cost. I find the optimal fixed fee for all G10 currencies and compare the retail transaction cost to CLOBs. Even at the optimal fixed fee, the CLOB is still cheaper, but all currencies see a major reduction in transaction costs compared to other fee levels. The USD/EUR pair decreases by 15 BPS using the optimal fixed fee, creating a more efficient and cheaper AMM and highlighting the power of fee optimization.

I then investigated FX settlement and found that most institutions use continuous linked services (CLS) to settle their trades. CLS is a costly service to avoid settlement risk, while unsophisticated traders choose between long settlement times and high-risk networks. I have estimated this choice is equivalent to 20BPS for unsophisticated traders. The AMM gives participants atomic settlement, which is instantaneous trading, offering 20BPS in savings to those traders. The settlement of physical cash is not needed in the AMM, removing the need for margin checks, pre-funding and cash transportation costs. With the savings in the settlement, in some cases, the AMM may be beneficial for its settlement uses. Some unsophisticated traders may decide that they are willing to pay a premium to attain these features. However, with partial adoption, the AMM becomes very costly.

My findings show that AMMs have some use cases in providing cheaper and faster settlement but, as a whole, create increased transaction costs in FX. AMMs can be run more efficiently by calculating and applying the optimised fixed fee to each market. The optimal fixed will significantly reduce the cost to traders but not enough to make them competitive with CLOB in FX. (Jones, 2024) has unveiled that Australia is releasing a wholesale CBDC to remove inefficiencies in financial markets. The wholesale CBDC could be used with AMMs to receive the gains in settlement in FX. The widescale use of AMMs for trading foreign exchange is not feasible due to the high cost compared to very efficient CLOB markets.

I have added to the literature applying AMMs to physical asset classes. I build on the work of (Foley, S. and O'Neill, M. and Putnins, T., 2023) by calculating benefits on a granular currency pair level and demonstrating the effect of different adoption rates. I have also demonstrated a new optimized fixed fee approach and the cost savings it can create within an AMM. I have also used expert industry interviews to quantify settlement costs and offer the AMM to solve longstanding FX settlement issues.

I have also contributed to the market microstructure theory within FX, demonstrating how the efficient CLOB outperforms AMMs building on the work of (Zohar and Kuenzi, 2021). I demonstrate how the AMM adjusts to market characteristics similarly to traditional centralized market makers. However, the AMMs lack CLOB's scale and liquidity, making them more costly and inefficient.

1.1 background on AMMs

The FX market is one of the largest markets in the world, trading at 6.6 trillion USD daily. As a whole, the market remains strongly intermediated, fragmented and opaque. The FX market operates through CLOBs, the most popular exchange trading method. CLOBs use centralized market makers who set and modify quote prices and act as third parties to transactions, removing counterparty risk. Because they act as third parties, market makers own the underlying asset for short periods, holding increased quantities when facilitating unbalanced order flow. The ownership exposes market makers to adverse selection cost (ASC), as informed traders buy or sell from market makers to push prices to their intrinsic value. For example, if informed traders know that the price will rise, they will purchase assets from the market maker to sell them back to them at a higher price, creating ASC. Market makers can recoup this loss by charging a spread between buying and selling. The uninformed traders in a market will make round trades, paying the spread. The market makers dynamically adjust the spread to balance ASC and acquire market share from competing exchanges.

In 1994, Nick Szabo first conceptualized agreements written into the code of digital transactions called Smart Contracts (Szabo, 1996). The contracts are used to create atomic swapping, the instantaneous trading and settlement of an asset, removing counterparty risk. The first commercial AMM Uniswap was released in 2018 on the Ethereum blockchain and currently trades over 180 billion USD monthly (Block, 2024). AMMs allow traders to swap with pooled assets to determine price discovery through a hard-coded function. The liquidity Providers (LPs) stake assets within the AMM pool in exchange for transaction fees. The pricing function in an AMM can be set as a range of coded functions, but most commonly, it is a constant product formula, as in equation Equation 1 below.

$$\text{Quantity of A} \times \text{Quantity of Asset B} = K \tag{1}$$

The value of K is held constant, creating a pricing curve that increases proportionally to the amount traded, as seen in Figure 1. Since the pricing process is automated through trading, liquidity provision has minimal barriers to entry. Uniswap allows anyone with a digital wallet to be a liquidity provider by depositing an equal amount of each asset into a pool (Uniswap, 2024).

However, one issue LPs face in AMMs is the inability to react to price-sensitive information. Centralized market makers can 'step' out of the way of bad trades by modifying and setting quotes in response to new information. However, LPs in AMMs are forced to trade at inefficient prices from the hardcoded pricing function. Informed traders see a difference between the AMM and the intrinsic value of an asset and swap assets with the pool until they share the same price. This process decreases the pool value as traders withdraw the appreciating asset and leave the less valuable one, creating ASC. Centralized market makers have less ASC exposure from their active price setting but have higher overhead costs.

AMMs have a set transaction fee that is charged on each trade that provides a yield to LPs. High-volume markets are more attractive to LPs as the total fee yield increases. Liquidity pool depth also affects the yield as fees are split between each LP. LPs withdraw or join pools based on the balance of ASC and market volume, seeking markets with greater yield than ASC. LPs stake assets in profitable liquidity pools, reducing the shared yield until the total fee yield matches the ASC and the opportunity cost of capital. The point at which this occurs is the breakeven liquidity point. This occurs because the efficient market hypothesis states that no one can generate abnormal returns in the long run.

AMMs, although passive, have been found to adjust liquidity provisions to deal with informed traders dynamically. The breakeven liquidity level is where the fee yield matches

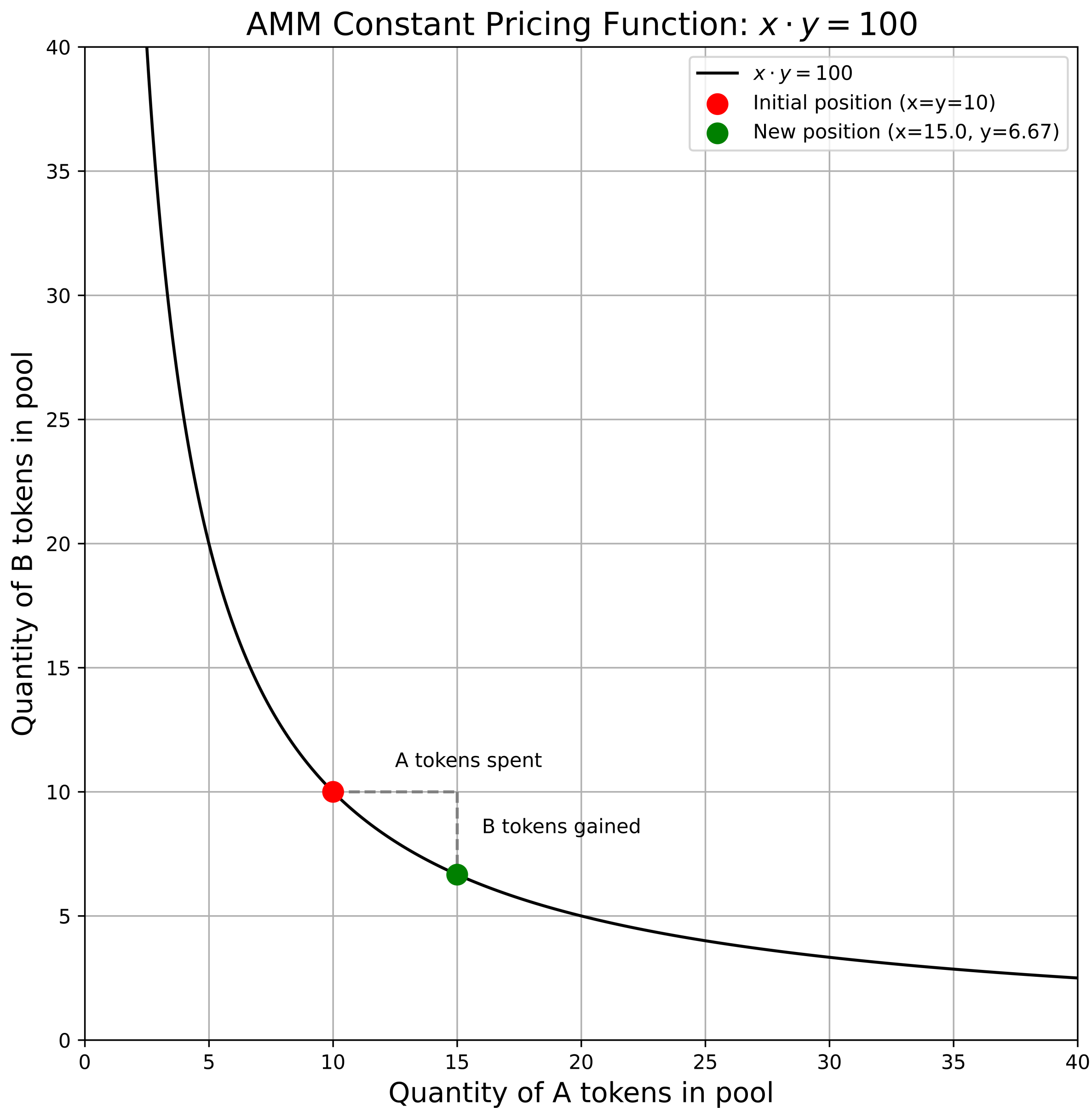

Figure 1: An example of a constant pricing function with ten units of asset A and ten units of asset B such that k=100. An example transaction of five units is demonstrated.

the ASC. With a greater level of informed traders, LPs face a loss as ASC outweighs fee yield. LPs withdraw from the pool as staking their assets is no longer profitable, driving down the size of the liquidity pool. The smaller pool gives LPs increased fee yield, stabilizing it, and informed traders receive increased price impact for each trade, making trades more costly and reducing the possible arbitrage. I explore how the volume and ASC in exotic and G10 currency pairs affect breakeven liquidity provisions. I then explore if these levels of liquidity make transacting in AMMs more efficient than current CLOB markets.

The greatest yield to LPs is available in low-volatility and high-volume markets. These markets have low ASC and high yield, attracting the most LPs and creating a high breakeven liquidity point. Some of the highest trading pools on Uniswap AMMs include fiat currencies. If digital fiat currencies already create successful AMM exchanges, would FX also benefit from using AMMs?

FX will be very applicable to AMMs through the development of central bank digital currencies (CBDCs). Of the G20 nations, 19 are in the advanced stage of CBDC development (Atlantic Council, 2024). (Goodell, G. and Al-Nakib, H. D. and Aste, T., 2024) find that the ideal structures of CBDCs allow transactions to be processed in a distributed manner. When CBDCs are released, will they be traded through CLOB only? Or will they be partially or fully traded through AMMs like current cryptocurrencies? Which currencies would benefit from trading through AMMs? I seek to answer these questions.

AMMs also have the potential to utilize assets such as currency reserves that sit idle in CLOB markets. These idle assets offer a low opportunity cost for being staked and could generate a greater return for the asset holders. They are unlocking even liquidity through the use of an AMM. Trading FX through an AMM could also disproportionately benefit developing nations by avoiding corrupt intermediaries. The corruption in traditional FX trading in developing countries has long hindered companies or governments looking to transact efficiently. An AMM using CBDCs removes corrupt intermediaries, giving developing nations access to more international funding. Countries like Nigeria and the Bahamas have been some of the first nations to issue CBDCs because of these challenges. This study provides evidence for improving their payment systems with the technology from CBDCs. With more countries issuing CBDCs, the AMM could solve significant global inefficiencies in payment systems.

2 Literature Review

Market Microstructure theory explains how LPs derive their cost and yields to facilitate an exchange. The CLOB markets are exposed to ASC and overheads in active price-setting. Centralized market makers need to revert inventory quickly to minimize their ASC. Empirically, it has been found that market makers put price pressure of 0.98% in the opposite direction to previous trades to mean-revert inventory (Hendershott, T. J. and Menkveld, A. J., 2014). For example, after a sale in the market, the market maker decreases prices to encourage other participants to purchase their inventory, limiting ASC. The market makers in CLOB also try to reduce their exposure to ASC by learning from the direction and size of trades and modifying their quoted spreads by identifying informed trading from unbalanced orders. Market makers try to predict the valuation of informed traders, moving quotes to the new prices that limit ASC, bringing prices closer to fundamental value (Glosten, L. R. and Milgrom, P. R., 1985). The market makers are active in doing so, and their skill in learning from trades determines how much ASC they receive.

LPs in AMMs only receive ASC and do not incur overheads due to their passive nature. The exchange facilitating the AMM can charge a protocol fee as a percentage of the fixed fee (Uniswap, 2021). Uniswap has not used the protocol fee in most instances, such as Uniswap V2, and when it does, it is a small percentage of the fixed cost, so it is not significant. LPs have a defensive mechanism similar to centralized market makers in minimizing their exposure to ASC. The constant pricing function in AMMs increases exponentially with one-way trading, as shown in Figure 1. Price slippage is a component of the transaction cost within AMMs, creating high costs for large trades in one direction. This discourages informed traders from profiting from ASC because it becomes too costly to trade large trade sizes. The exponential pricing nature also ensures that the inventory of each asset is not exhausted. Removing the entire supply of one asset from the pool is impossible as it becomes infinitely more expensive as the quantity of an investment in the pool approaches zero, as shown in Equation 2

$$\lim_{q \to 0} \text{Cost}(q) = \infty \tag{2}$$

The prior market-making theories also show that competition minimizes the bid-ask spread within a CLOB market to cover only ASC and inventory holding costs. Market makers that do not minimize their bid-ask spread will be undercut by competition and forced to leave the market. A similar competition occurs in AMM, with LPs searching for profitable markets to supply liquidity and making an economic loss if they oversupply. Studies such as (Glosten, L. R. and Milgrom, P. R., 1985) show that ASC and inventory holdings costs within a market are a product of price volatility and the number of informed traders. Recent literature by (Foley, S. and O'Neill, M. and Putnins, T., 2023) shows that the same cross-asset variations in liquidity occur in AMMs. However, as fees in AMMs are fixed, the mechanism for dealing with more informed traders is pool size rather than spread. The pool size increases transaction costs through price slippage on trades. (Gupta et al., 2021) studied the AMM liquidity pools and found the equilibrium pool size in AMMs varies with price volatility and volume levels. Still, if a market is viable, the equilibrium pool size always reaches a breakeven liquidity point where the fee yield matches ASC and the opportunity cost of capital.

In non-viable AMM markets, a process occurs where a breakeven liquidity provision may never be reached. The liquidity pool reduces when the LPs leave the market from an unbalanced ASC. The traders then incur more price slippage, equating to higher transaction costs. If the traders in the market are reactive to the rise in transaction costs, they withdraw, reducing fee yield and creating another mismatch. The cycle of LPs and liquidity demanders withdrawing from the market occurs, and the pool decreases without a breakeven liquidity provision ever being reached.

The movement of LPs towards only viable AMM markets is supported by work such as (Lehar, A. and Parlour, C. A. and Zoican, M., 2024). Lehar et al. find that high fee pools attract 58% of liquidity provision but only execute 21% of the volume. The study concludes that investors prefer AMMs over traditional CLOBs for many markets in which they are viable. (Capponi, Agostino and Jia, Ruizhe, 2023) investigate which cryptocurrency pairs are feasible in an AMM market structure. They find that AMMs are only adopted in currency pairs with high personal use or a high correlation of price movements supporting high volume, low volatility assets. They also find that pricing functions with increased curvature reduce arbitrage and investors' surplus, showing the possibility of a cyclical market withdrawal process identified by (Foley, S. and O'Neill, M. and Putnins, T., 2023)

The literature on applying AMMs in traditional asset classes has not been explored until recently. (Foley, S. and O'Neill, M. and Putnins, T., 2023) applied AMMs to various physical asset classes, finding that the most viable markets had relatively low volatility and high volume. Among the asset classes with the most potential were Exotic and G10 FX, which had a 50% reduction in trading fees from CLOB. (Malinova and Park, 2023) tailor AMMs to volume and volatility characteristic of individual shares in the stock market. They use similar derivations of breakeven liquidity requirements but in cash and underlying shares for LPs. They empirically show that AMMs provide utility for liquidity demanders and LPs in most small-cap equities and some large-cap equities. The paper advocates for AMMs as an alternative market structure that is potentially superior to

CLOB for most individual equities.

The FX market uses an intermediated cross-border payment process primarily from a CLOB. (Melvin et al., 2020) measure wholesale FX transaction costs using the order book for G10 and exotic currencies. They use a sample trade size and the order book to calculate the total transaction cost. Melvin can accurately measure the transaction costs in CLOBs by including half spreads and the price impact of each trade. Melvin's CLOBs costs are used in this study comparatively against the same order size in an AMM Figure 6.

The (BIS Innovation Hub, 2023), in conjunction with the central banks from Singapore, Switzerland and France, have also investigated using CBDCs in AMMs for wholesale FX transactions in Project Marina. They used Sepolia Testnet to trial AMMs on the Ethereum blockchain, testing a multi-asset pool with three types of currencies, shown in Figure 4. They created a hybrid model where financial institutions can trade CBDCs with each other and the AMM pool. They also highlight that AMMs improve the accessibility to FX markets by having the possibility of running seven days a week.
(Zohar and Kuenzi, 2021) examines the challenges AMMs face when applied to high-volume markets, such as FX. The paper explores critical limitations, including slippage, which occurs when the expected price of a trade is different from the actual executed price; price impact, where large trades move the market price; and liquidity constraints, which affect the efficiency of AMMs in large-scale markets. These factors make it difficult for AMMs to match the performance of traditional centralized exchanges in high-frequency or large-value markets like FX.

3 Adverse Selection Cost

ASC is the process of informed traders using their informational advantage to make trades that depreciate the assets of LPs. Figure 1 provides an example of ASC. In the example, the tokens are initially valued one-to-one, but an informed trader realizes token A will appreciate double token B's value in the future. The informed trader purchases five units of token A by depositing ten units of token B into the pool. The remaining pooled assets are twenty units of token B and five units of token A, so K remains 100. The ASC LPs receive equals the depreciation in pool value shown in Equation 3.

$$\text{ASC} = 1 - \frac{10 \times 1 + 10 \times 1 - (20 \times 0.5 + 5 \times 1)}{20} = -0.25 \tag{3}$$

The LPs lost 25% of the pool value as ASC from informed traders. ASC can also be a function of market returns as shown in Equation 4.

$$\mathrm{ASC}_T = \sqrt{R_T} - \frac{1}{2}(1 + R_T) \tag{4}$$

The above function increases with volatility, showing that LPs face more ASC in markets with increased price movements. As prices move, the less valuable asset is deposited into the pool, and the appreciating asset is removed, creating the ASC.

$$\frac{d\,ASC}{d\,\sigma} > 0 \tag{5}$$

ASC against cumulative returns is graphed in Figure 2 and transformed to returns in Figure 3. These graphs show that the total ASC cannot be greater than 50%, as it is impossible to remove one asset from the pool completely.

I use Refinitiv to download pricing data for G10 and six exotic currencies against USD from 2018 to 2024. (Foley, S. and O'Neill, M. and Putnins, T., 2023) find that the average stake time for an LP in AMMs is 35 days. I calculate the daily ASC using Equation 4 and take a rolling average over 35 days to match the average stake time. I then take the average of the rolling windows over the whole period to get the average ASC an LP receives over the 6 years. See the appendix for the table of ASC values for G10 in Table 7 and Exotics in Table 8. The tables show that in more volatile markets, such as the Turkish Lira to USD, the ASC is approximately ten times larger than that of a stable currency pair, such as the Euro to USD.

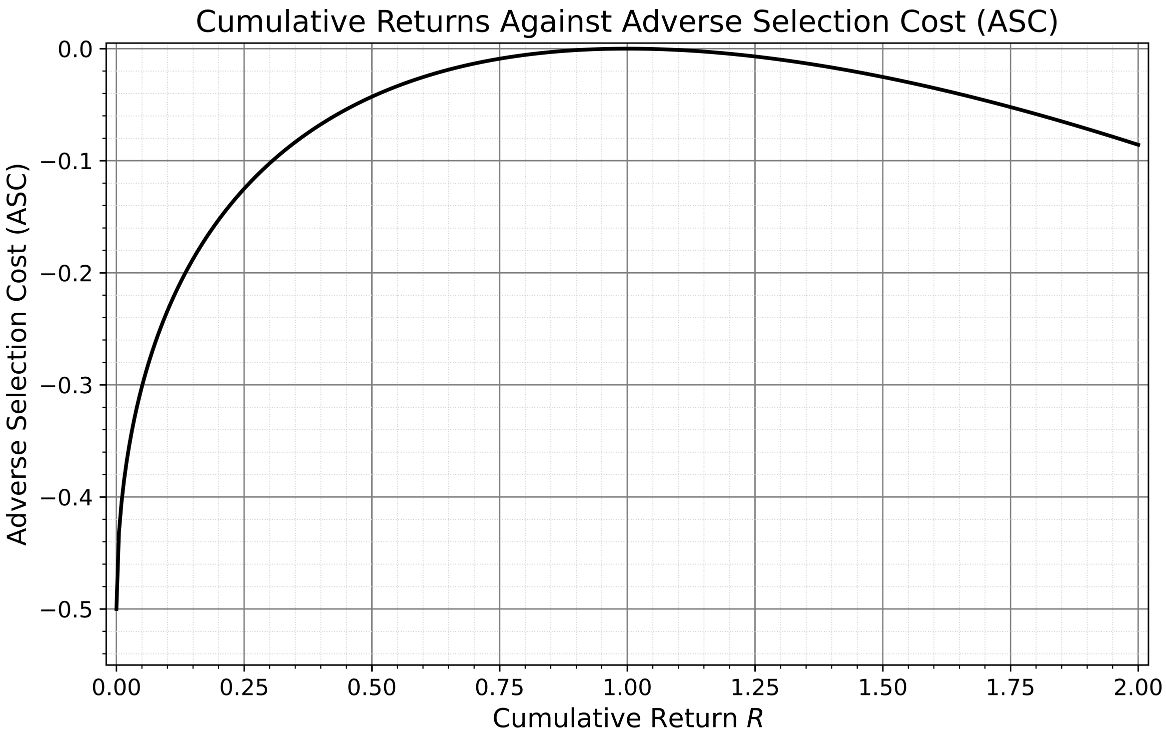

Figure 2: The level of ASC as a function of cumulative returns

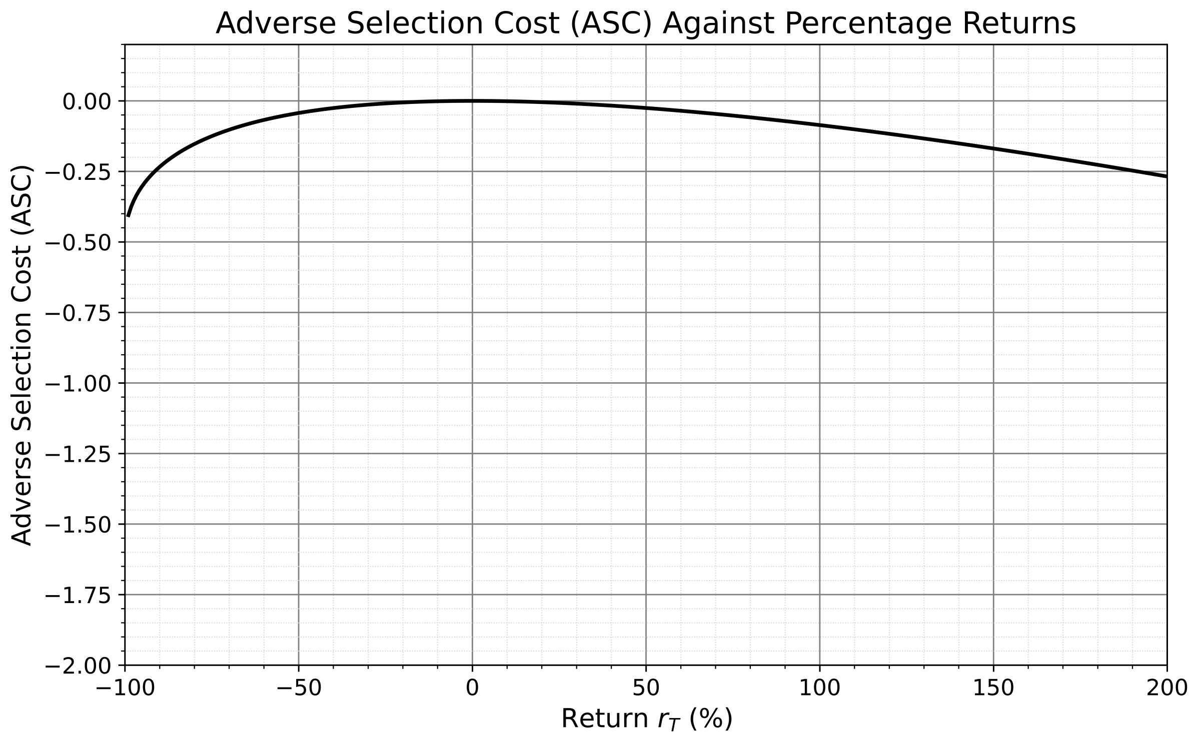

Figure 3: ASC as a function of returns (%).

4 Breakeven liquidity

Breakeven liquidity is the amount of pooled assets that balances the costs and yields to LPs. The breakeven point is where there is no economic profit for staking additional assets. I derive the costs to LPs with their yield to find this point. The LP fee yield is given by Equation 6.

$$\mathrm{f} = 0.003 \times \frac{Q_t}{V_0} \tag{6}$$

The assumed fee level used in the AMM is 0.3%, matching Uniswap as the most popular AMM exchange and has a 0.3% fixed fee. The quantity traded in the AMM is Q, showing that LPs receive 0.3% of the amount traded in fee yield. The ASC gives the cost LPs face in a market, but there is also an opportunity cost of capital. I use the long-term average of the ten-year US treasury rate of 4.08% (US Department of Treasury, 2024). I divide the risk-free rate by the trading days in the year to get the daily opportunity cost. When the fee yield minus the ASC equals the opportunity cost of capital, the breakeven liquidity provision point is reached. This point is shown below in Equation 7.

$$0.003 \times \frac{Q_T}{V_0} - ASC(\sigma) = 0.000162 \tag{7}$$

QT is the daily quantity traded for each currency pair from the BIS triennial survey (BIS Innovation Hub, 2022). The equation can be rearranged to find the breakeven liquidity point V0 shown below in Equation 8

$$V_0 = 0.003 \times \frac{Q_T(V_0)}{0.000162 + ASC(\sigma)} \tag{8}$$

The calculated breakeven liquidity points, daily turnovers, and ASC can be found in Table 7 and Table 8. I have also graphed the breakeven liquidity provisions in millions of dollars in Figure 4 for G10 and Figure 5 for Exotics. The graphs show that EUR/USD has the most extensive breakeven liquidity provision of any currency in this study. The stable nature of the Euro gives it a low level of ASC, and the high volume produces a substantial fee yield. Many LPs are attracted to the high yield and low ASC market and join the liquidity pool until there is no more economic profit. The resulting pool reaches this breakeven liquidity point at over 23 Billion dollars. This result is consistent with Uniswap, where the USDC/ETH pool has attracted the most considerable breakeven liquidity despite being the most stable and high volume. Looking at the lowest breakeven point, the Turkish Lira is the most volatile and has the lowest turnover of all the currencies, creating the highest level of ASC with the lowest total fee yield. This pool only attracts a small amount of LPs to split the total yield, creating a low breakeven point of 303 million. These results are consistent with the literature and current AMMs that break liquidity balances to levels of volatility and volume of the underlying market. The graphs show the dynamic nature of LPs in AMM-seeking markets that provide the highest yield until the economic profit is removed.

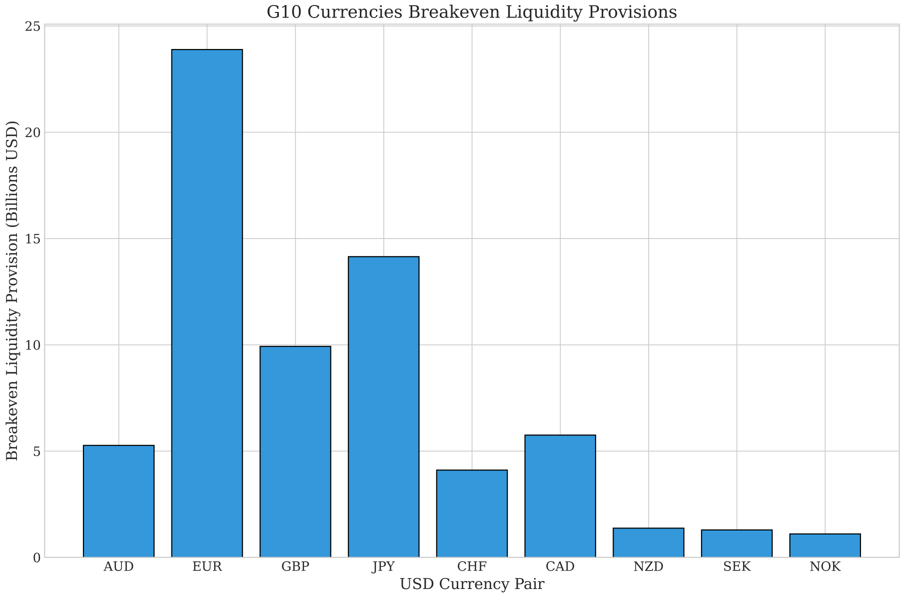

Figure 4: The Breakeven Liquidity levels of G10 Currencies

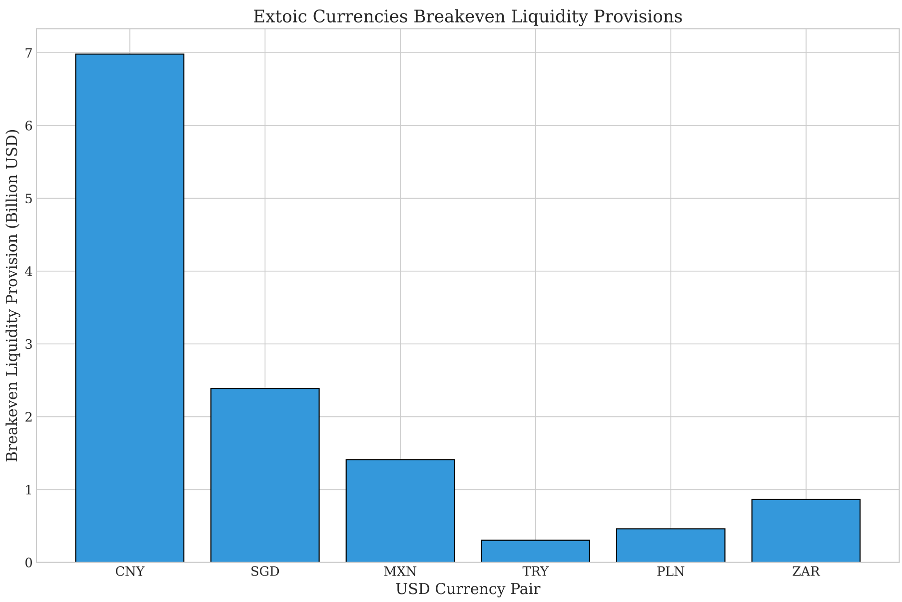

Figure 5: The Breakeven Liquidity Levels of Exotic Currencies

5 AMM vs Traditional FX Transaction Cost

The transaction cost of an AMM comprises two parts: the fixed fee and the price impact as shown in Equation 9.

$$\text{Transaction Cost} = \text{Price Impact} + \text{Fixed Fee} \tag{9}$$

The fixed fee is shown below in Equation 10 using the uniswap fee level of 0.3%.

$$\text{Fixed Fee (BPS)} = 0.003 \times 10,000 = 30 \tag{10}$$

The price impact is the amount charged so that the constant product K remains equal pre and post-transaction. I take the ratio of the change in liquidity and convert it into BPS. This gives the price impact costs in BPS for the constant product to remain equal, as shown in Equation 11.

$$\text{Price Impact (BPS)} = \frac{K_0}{K_T} - 1 \times 10,000 \tag{11}$$

I then use the breakeven liquidity provision V0 and T the trade size to calculate the constant products and insert them into the equation shown in Equation 12

$$\text{Price Impact (BPS)} = \frac{(V_0/2)^2}{(V_0/2 - T) \times (V_0/2)} - 1 \times 10,000 \tag{12}$$

I then add the fixed fee cost from Equation 10 to calculate the transaction cost as shown in ??.

$$\text{Transaction Cost (BPS)} = \left(\left(\frac{(V_0/2)^2}{\left(\frac{V_0}{2} - T\right) \times \frac{V_0}{2}} - 1\right) \times 10,000 \right) + 30 \tag{13}$$

The AMM transaction cost is in BPS to be compared to the traditional FX costs derived by (Melvin et al., 2020). The transaction costs Melvin derived are shown below in Figure 6. Melvin calculates the transaction cost of traditional FX trading in basis points (BPS) for trades of \$1 million, \$10 million, and \$25 million. I assume that 1 million dollar trades are retail trades and 25 million dollar trades are wholesale trades. Melvin measured the transaction costs by the half spreads on electronic platforms like the EBS or Reuters FX, using "sweep to fill" aggregation down the order book. Melvin gives a more accurate cost for traditional FX, including the price impact on the order book for larger trades. The comparison between the conventional FX costs and the calculated AMM cost will show which currency pairs will have a cost-benefit in retail or wholesale markets.

Table 1

Annualized volatility and transaction costs of g10 currencies. Transaction costs are measured by half spreads in basis points for trades of $1 million, $10 million, and $25 million from spot prices on the EBS or Reuters FX electronic brokerages by "sweep to fill" aggregation down the order book. Values for volatility and spreads are sample averages. Volume data are billions of USD from the BIS Triennial Survey, and include spot and forward dated transactions against the USD. Spreads are in basis points.

Currency	EUR	JPY	GBP	CAD	CHF	AUD	NZD	SEK	NOK
Volatility	8.60%	10.20%	*9.40%*	*7.90%*	10.50%	10.00%	11.10%	*6.20%*	8.40%
Volume	$1,172b	$901b	$470b	$218b	$180b	$262 b	$78b	$66b	$48b
1mn	0.47	0.53	0.9	0.96	1.07	1.09	1.62	2.14	2.81
10mn	0.8	0.98	1.49	1.76	2.2	1.99	3.41	4.32	6
25mn	1.29	1.68	2.51	3.1	4.24	3.52	6.41	8.53	12.31
25/1	2.7	3.2	2.8	3.2	4.0	3.2	4.0	4.0	4.4
WMR	1.15	1.46	1.55	1.40	2.88	2.15	3.01	2.78	3.54
WMR/1	2.45	2.75	1.72	1.46	2.69	1.97	1.86	1.30	1.26
WMR/25	0.89	0.87	0.62	0.45	0.68	0.61	0.47	0.33	0.29

Table 2

Annualized volatility and transaction costs of emerging market currencies. Transaction costs are measured by half spreads in basis points for trades of $1, 10, and 25 million from spot prices on the EBS or Reuters FX electronic brokerages by "sweep to fill" aggregation down the order book. Values for volatility and spreads are sample averages. Volume data are billions of USD from the BIS Triennial Survey, and include spot and forward dated transactions against the USD. Volume data for HUF and CZK are against EUR. Volume data for CNH and CZK are from the respective central bank sources, as their volumes are not reported separately in the BIS Triennial Survey. Spreads are in basis points.

Currency	CNH	SGD	MXN	CZK	TRY	PLN	HUF	ZAR	ILS
Volatility	3.6%	5.4%	11.6%	3.6%	11.4%	5.8%	6.2%	15.7%	6.6%
Volume	$67b	$81 b	$90 b	$18 b	$64b	$19b	$5b	$40b	$7b
lmn	0.43	0.99	2.30	2.50	3.14	3.80	4.29	4.92	6.02
lOmn	0.95	2.22	5.20	5.19	6.90	7.32	7.90	10.38	12.85
25mn	1.94	4.58	10.53	10.26	14.22	13.96	14.80	21.55	26.66
25/1	4.5	4.6	4.6	4.1	4.5	3.7	3.5	4.4	4.4
WMR	1.17	2.39	1.17	6.48	1.81	3.57	5.88	3.99	2.52
WMR/1	2.71	2.42	0.51	2.59	0.58	0.94	1.37	0.81	0.42
WMR/25	0.60	0.52	0.11	0.63	0.13	0.26	0.40	0.19	0.09

Figure 6: Adapted from (Melvin et al., 2020)

5.1 G10 Transaction Costs

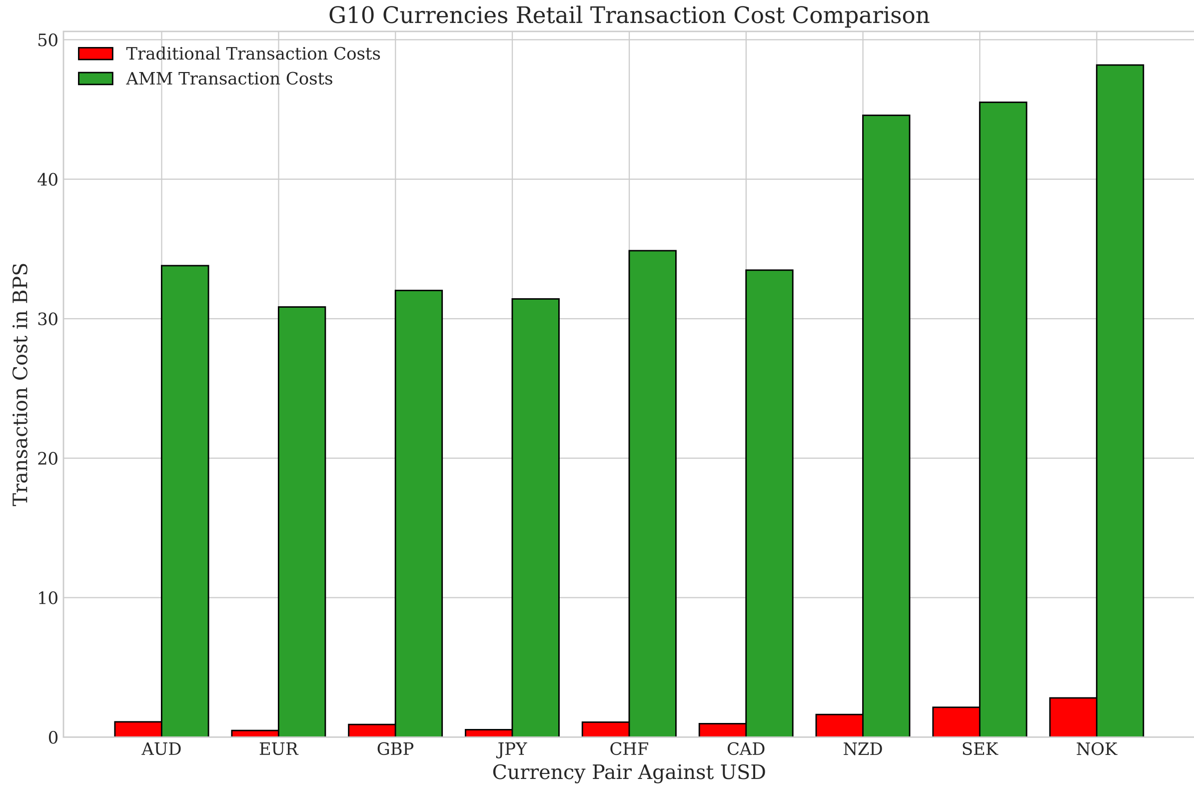

Figure 7: The AMM Retail Transaction Cost vs Traditional FX Markets for G10 Currencies.

The retail costs for G10 currencies are shown in Figure 7 and Table 1. The traditional FX markets strictly dominate the AMMs, offering an advantage of 30-50 BPS in transaction costs. AMMs have a fixed transaction cost to attract liquidity suppliers of 30BPS. The fixed AMM fee is too large in FX markets where traditional markets trade is already under 5 BPS. Even in the market with the lowest price impact, the Euro, the price impact fee of 0.837 BPS is larger than the CLOB total fee of 0.470 BPS.

The transaction cost in the CLOB is approximately 30 times smaller than AMMs. The reason comes down to liquidity from large banks and institutions, they provide to the order book while they compete to capture trading volume. The more volatile currencies, such as the Swedish Krona, Norweigan Krone and New Zealand Dollar, have the most significant difference in transaction cost of 40 BPS. These currencies have a 30 BPS fixed fee and a significant price impact cost of 10 BPS. The three currencies have the least turnover of the G10 currencies and relatively high ASC shown in Table 7. The high ASC low fee yield makes the market unattractive for LPs, reducing the breakeven liquidity and passing on a more significant price impact cost. The lack of liquidity attracted to the AMM and the high fixed fee to do so is why the CLOB is cheaper.

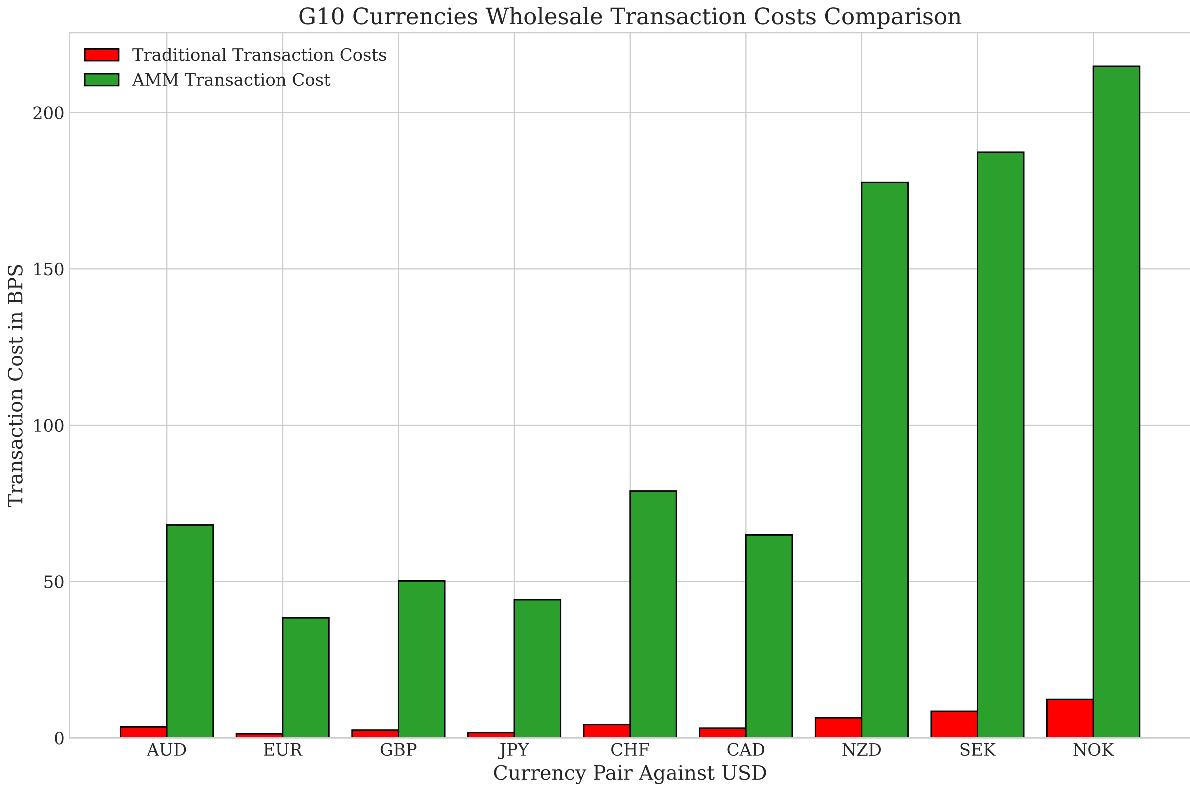

Figure 8: The AMM Wholesale Transaction Cost vs Traditional FX Markets for G10 Currencies.

The wholesale transaction costs for G10 currencies are shown in Figure 8. Traditional CLOBs have an even greater advantage over AMMs regarding wholesale costs. The 25 million wholesale trade size incurs a significant price impact fee in the AMM as the liquidity of the AMM is far less than the CLOB. In Norweigan Krone, the currency with the smallest turnover and most volatile price, the price impact fee is 184 BPS. The AMM incurs a 154 BPS price impact fee compared to the total cost for the CLOB, which is 12.310 BPS lower than even the fixed AMM fee of 30 BPS. The results show that AMMs in G10 currency markets do not outperform highly competitive FX markets such as EBS or Reuters. They cannot attract the same level of liquidity at a lower cost than the CLOB.

Table 1: Retail and Wholesale Trading Costs Within CLOB vs AMM

Currency Pair	CLOB Retail	CLOB Wholesale	AMM Retail	AMM Wholesale
USD/AUD	1.090	3.520	33.797	68.103
USD/EUR	0.470	1.290	30.837	38.379
USD/GBP	0.900	2.510	32.016	50.196
USD/JPY	0.530	1.680	31.414	44.160
USD/CHF	1.070	4.240	34.875	78.962
USD/CAD	0.960	3.100	33.479	64.900
USD/NZD	1.620	6.410	34.574	177.678
USD/SEK	2.140	8.530	45.513	187.324
USD/NOK	2.810	12.310	48.179	214.812

5.2 Exotic Transaction Costs

Figure 9: The AMM Retail Transaction Cost vs Traditional FX Markets for Exotic Currencies.

The retail transaction costs for exotic currencies show the AMM underperforming traditional CLOBs as shown in Figure 9 and Table 2. The relationship observed in G10 currencies of the more volatile and low volume currencies have considerably higher AMM transaction costs, which is seen here but to a greater extent. For example, exotic currencies such as the Turkish Lira are 93 BPS more expensive than the CLOB, with 63 BPS in price impact cost. The high ASC and low volume of the Turkish Lira generate a low total yield in the AMM, attracting a small number of LPs. The small breakeven liquidity point then creates a significant price impact cost. The relationship shows, as expected that more exotic currencies are prone to price volatility and lower turnover. The findings suggest that exotic currencies struggle to provide competitive costs to CLOB as they cannot attract sufficient liquidity. The currencies with the closest cost to traditional markets are stable and high-volume currencies that attract the most liquidity providers, such as the Chinese Yen.

The wholesale transaction costs for exotic currencies are shown in Figure 10 and Table 2. The results show that the AMM has a significantly more expensive wholesale transaction cost in exotic currencies. The AMM is more costly in wholesale trading by up to 700 BPS or 7%, which is a significant cost disadvantage. The wholesale transactions have

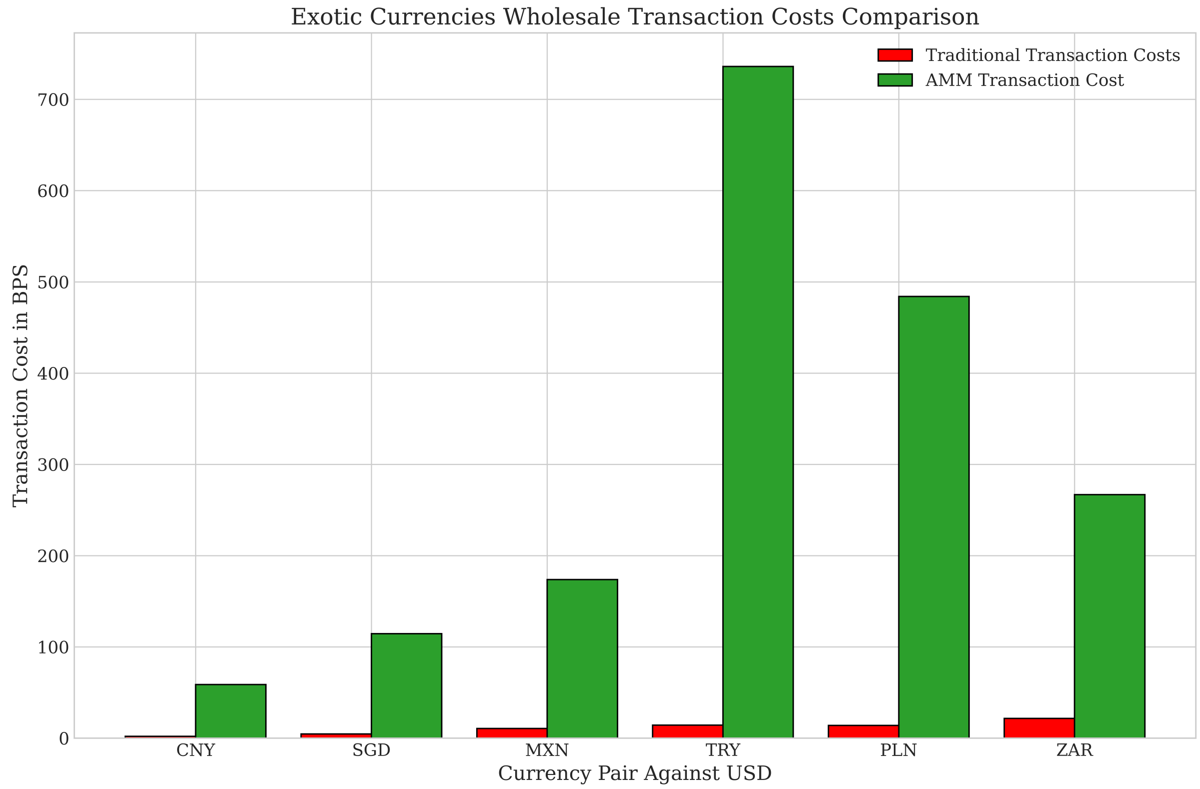

Figure 10: The AMM Wholesale Transaction Cost vs Traditional FX Markets for Exotic Currencies.

higher costs for the TRY and the PLN in the AMM. The Polish currency does not have a significantly high level of ASC comparatively; however, it does have a shallow level of turnover at 33 million. The reduced yield is unattractive to LPs, resulting in a small 460 million-dollar pool. This pool faces a significant price impact from a 25 million dollar wholesale trade, equating to a 454 BPS or 4.54% price impact cost. The price impact cost truly becomes important as it is unlikely any wholesale trader will pay anywhere upwards of a 4% premium to trade in the AMM. The wholesale markets are far too costly, showing that AMMs can only reasonably be used for retail trading in exotic currencies.

Table 2: Current Retail and Wholesale Trading Costs for Exotic Currencies

Currency Pair	**CLOB Retail Costs**	**CLOB Wholesale Costs**	**AMM Retail Cost**	**AMM Wholesale Cost**
USD/CNY	0.430	1.940	32.866	58.738
USD/SGD	0.990	4.580	38.379	114.418
USD/MXN	2.300	10.530	44.196	173.799
USD/TRY	3.140	14.220	96.382	736.003
USD/PLN	3.800	13.960	73.621	484.036
USD/ZAR	4.920	21.550	53.187	266.806

6 Partial AMM Adoption

AMMs are a new technology introduced in 2018 by Uniswap. Since then, they have slowly acquired more market share. In some of the largest markets on the Uniswap platform, such as Weth/USDC, the AMM has acquired a significant market share, with one-third of all trades occurring (Uniswap, 2024). However, with any new market structure, it is not practical to assume that the entire turnover of a market will switch rapidly. Partial adoption is a much more realistic assumption and is the case for all current AMMs, where some of the trading occurs outside of centralized exchanges. I use this section to investigate the cost comparison between AMMs and CLOBs at partial levels of turnover. The results show a more realistic cost that an AMM would have soon after release when only partially adopted.

To simulate partial adoption, I varied the daily turnover rate from five to 100 per cent within each G10 and exotic currency. The breakeven liquidity provision is then recalculated based on the partial turnover, and cost comparisons are made by calculating the transaction cost at the new level of breakeven liquidity.

6.1 G10 Patrial Adoption

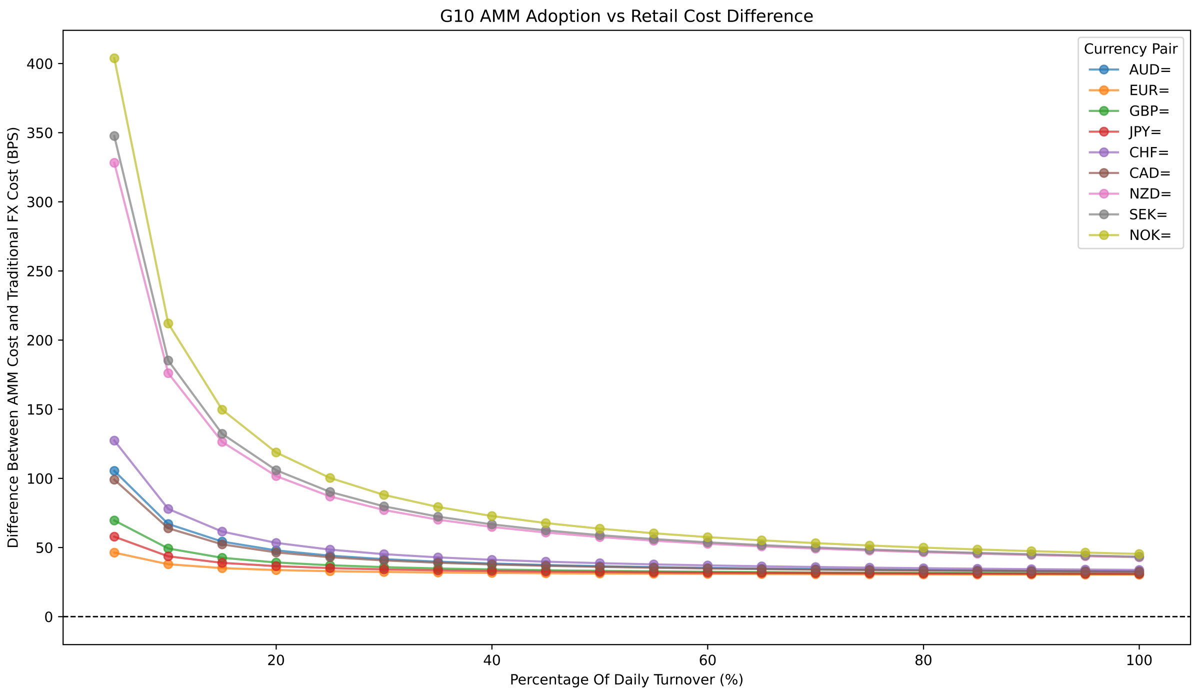

Figure 11: Retail Transaction Cost Difference with Partial Adoption Rates for AMMs in G10 Currencies

I graph the cost comparison against the adoption percentage for retail trades in G10 currencies in Figure 11. the results show that the more volatile currency, such as the New Zealand dollar or the Norweigan Krone, has a steeper adoption curve. The adoption curve initially decreases quickly and then plateaus at around a 60% adoption level. The high turnover and more stable currencies, such as the Euro, have a less steep curve as the total amount of turnover is large enough that the breakeven liquidity will be significant even at marginal adoption rates. Large turnover currencies have adoption curves that are less steep depending on the initial level of turnover. For example, The Euro plateaus at only 15%, showing that the price impact is minimal even at 15%.

The effect of G10 adoption on wholesale costs is shown in Figure 12. The adoption curve is similar to the retail adoption curve as the adoption level adjusts the breakeven liquidity, affecting retail and wholesale markets through price impact. However, the difference between the AMM and CLOB is greater in the wholesale markets due to the larger trade size. The costs will be based on comparing retail and wholesale trading Table 1.

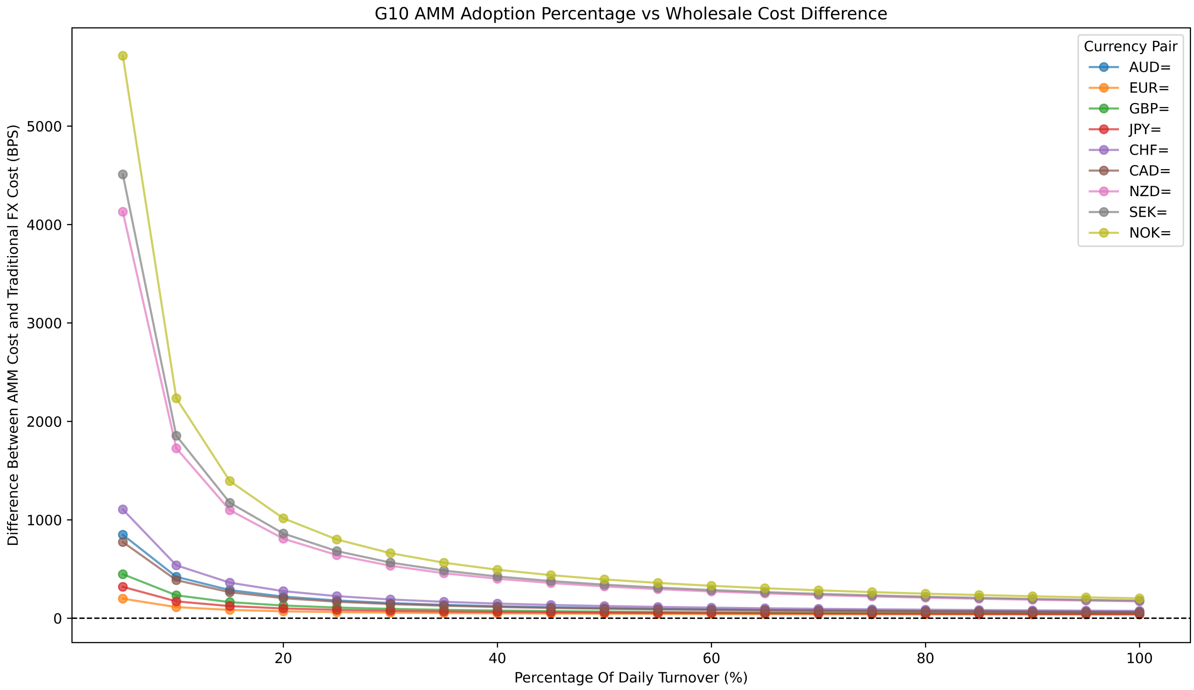

Figure 12: Wholesale Transaction Cost Difference with Partial Adoption Rates for AMMs in G10 Currencies

6.2 Exotic Patrial Adoption

The partial adoption of exotic currency retail costs is shown in Figure 13. The exotic currencies are far less competitive than the G10 nations with lower levels of adoption. It is only when 80% of the current market moves to the AMM that it becomes cheaper to trade the majority of currencies. As previously mentioned, some currencies, such as the Turkish Lira, do not have any adoption rate where the AMM creates a cost advantage. TRY has the greatest ASC at -0.002% and the lowest daily turnover at 23 million USD. The market is not very attractive for LPs due to its high cost and low revenue, creating a small liquidity pool. By reducing the revenue further by assuming partial adoption, the pool reduces to the point where the price impact from trade creates a greater transaction cost than in traditional markets.

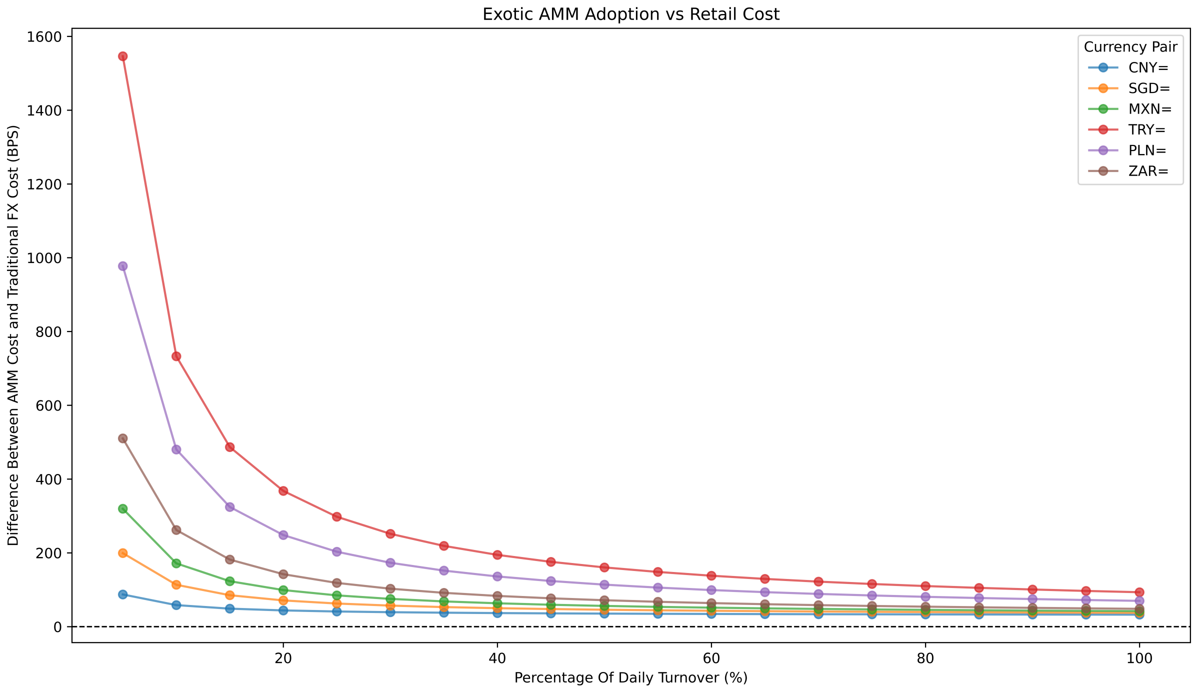

Figure 13: Retail Transaction Cost Difference With Partial Adoption Rates of AMMs in Exotic Currencies

I have also graphed the wholesale costs for different levels of adoptions Figure 14. The wholesale cost differences are substantially larger than the retail costs because of the greater price impact. The more exotic currencies show the greatest price impact and, at the lowest levels of adoption, have a fee difference of over 20%. The wholesale transaction costs show the same exponential style curve. With substantially higher transaction costs at low levels of adoption and then plateauing past 50%. I have started this graph at 30% because there are some currencies that, at partial adoption, the wholesale trade size is larger than the breakeven liquidity. This results in a negative cost, which is impossible, but I have included it in the appendix at Figure 21 to show the shape of initial adoption.

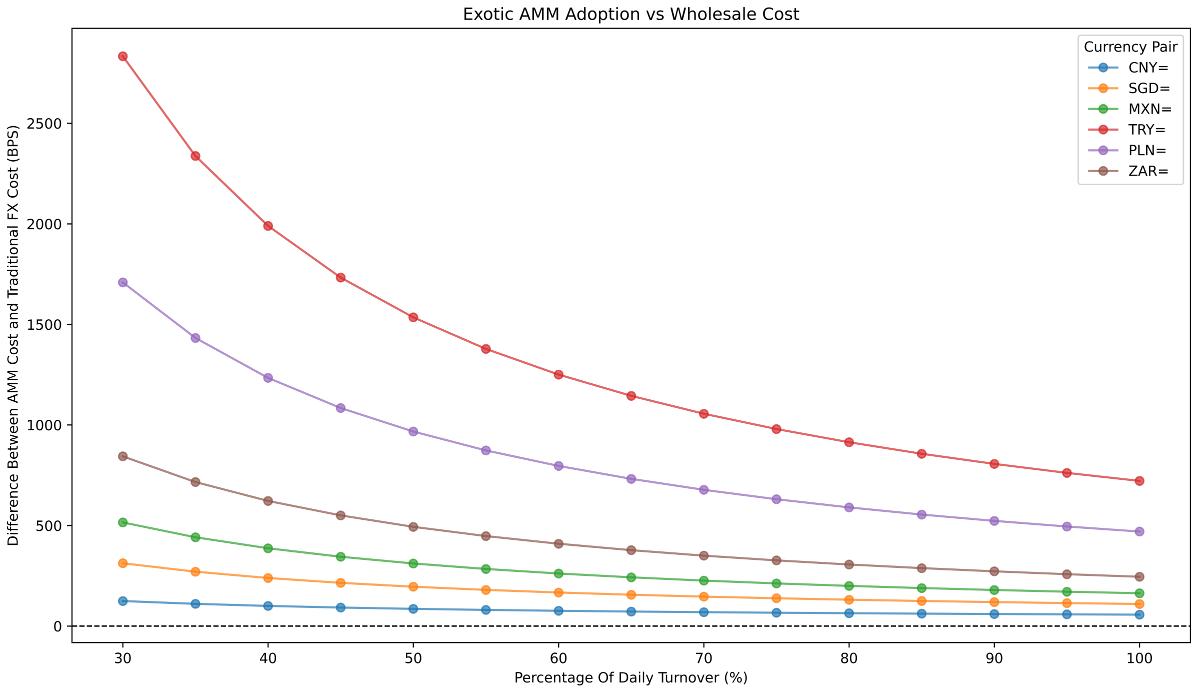

Figure 14: Wholesale Transaction Cost Difference With Partial Adoption Rates of AMMs in Exotic Currencies

The adoption curves show a plateau because of the fixed cost component of the AMM, as none of the currencies can move below 30 BPS. They can only approach it. Given enough turnover, it can be said that all currency pairs could attract enough liquidity providers to make the price impact so small that it is barely noticeable. Therefore, for the price of the AMM to be less than the CLOB, the fixed fee must first be lowered.

7 AMM Fee Optimisation

The AMM faces an issue: the fixed cost of 30BPS is higher than any of the costs found in Figure 6. The AMM fixed fee means no matter how deep the liquidity pool is, the transaction cost will always result in the AMM being more expensive. The 30 BPS fee is based on current market fees on the Uniswap platform, but what if the fixed fee was lower? I have altered the fixed fee assumption to test the effect of different fee levels and find under what conditions the AMM provides a cost advantage in FX.

7.1 0.3 BPS Fixed Fee Calibration

I have assumed a fixed fee of only 0.3 BPS to allow the AMM to compete with even the most competitive USD/EUR market. I then recalculate the breakeven liquidity based on the new fee level they are graphed below in Figure 16 and Figure 15.

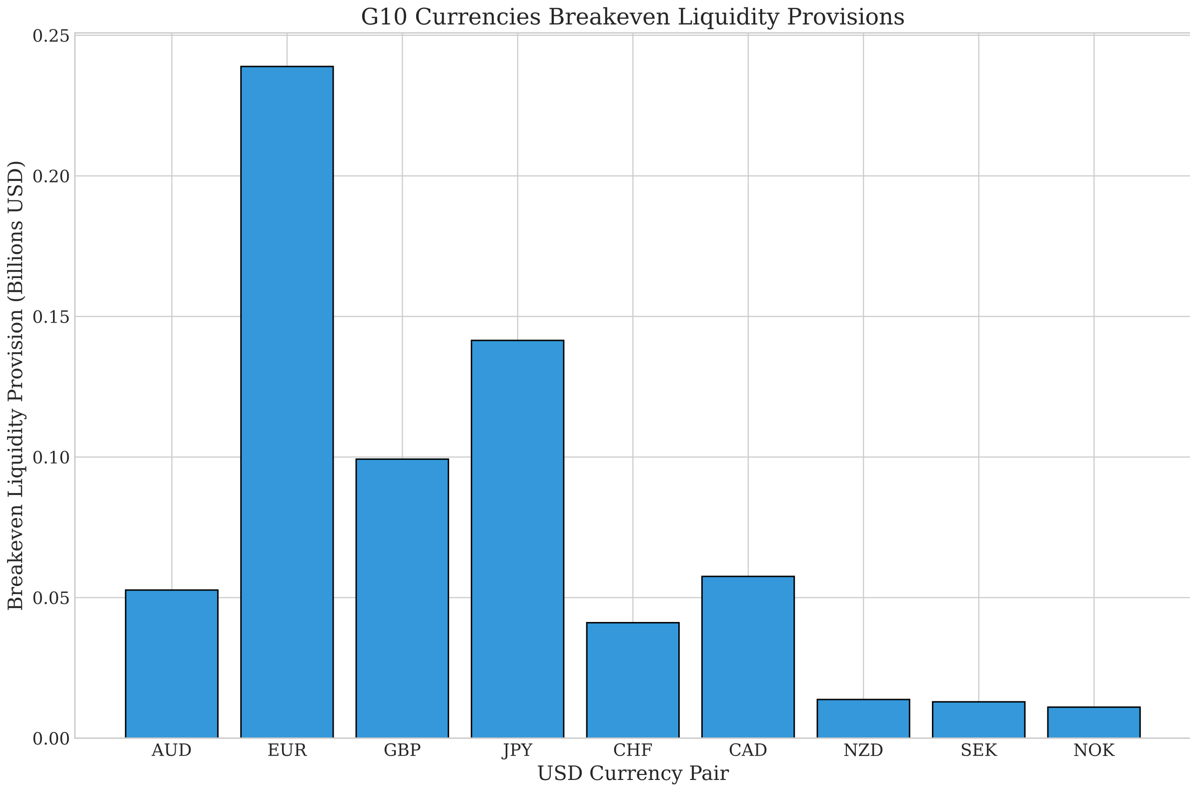

Figure 15: 0.3 BPS Fixed Cost G10 breakeven Liquidity.

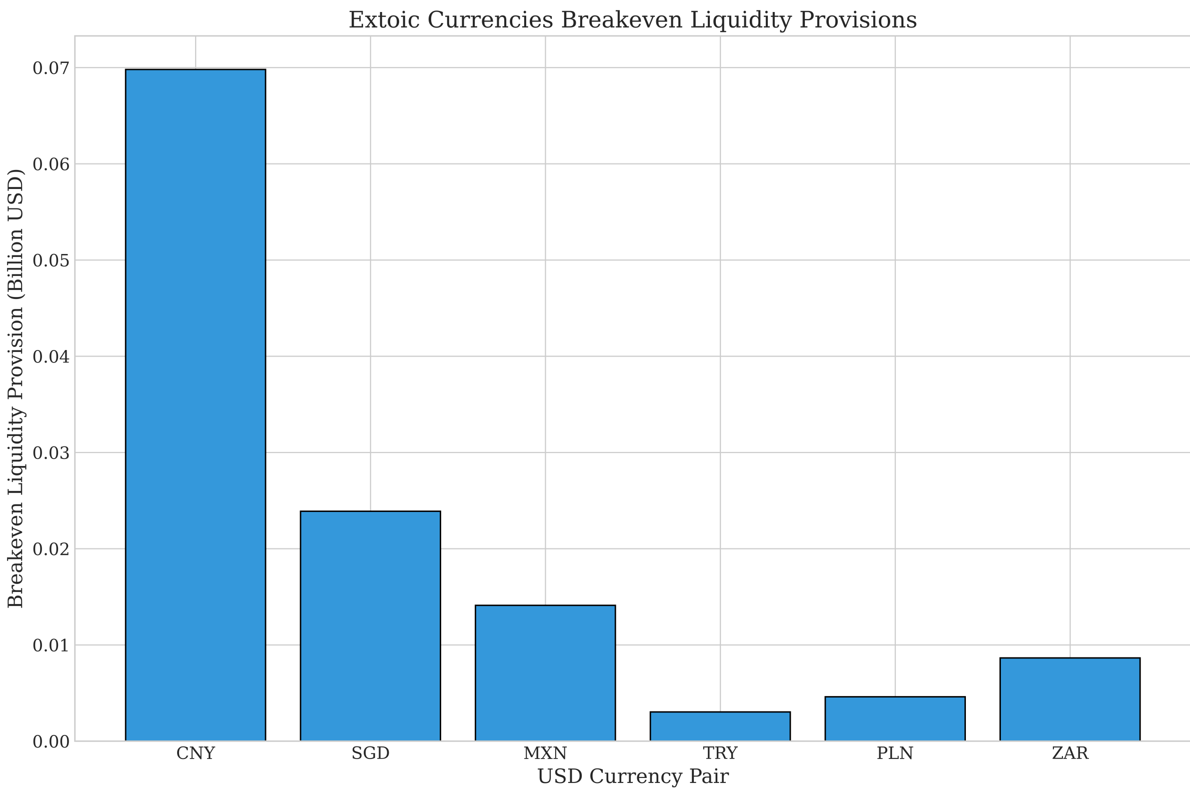

Figure 16: 0.3 BPS Fixed Cost Exotic breakeven Liquidity.

The breakeven liquidity provision shows that when the fixed cost is reduced, the liquidity provision reduces by the same factor. The fee level was divided by 100 from 30 BPS to 0.3 BPS, and the resulting effect on breakeven liquidity shows the same reduction. The USD/AUD liquidity pool went from five billion to 50 million when the fee change was implemented. The effect on transaction costs is shown below in Figure 17 and Figure 18 and input into Table 3 and Table 4.

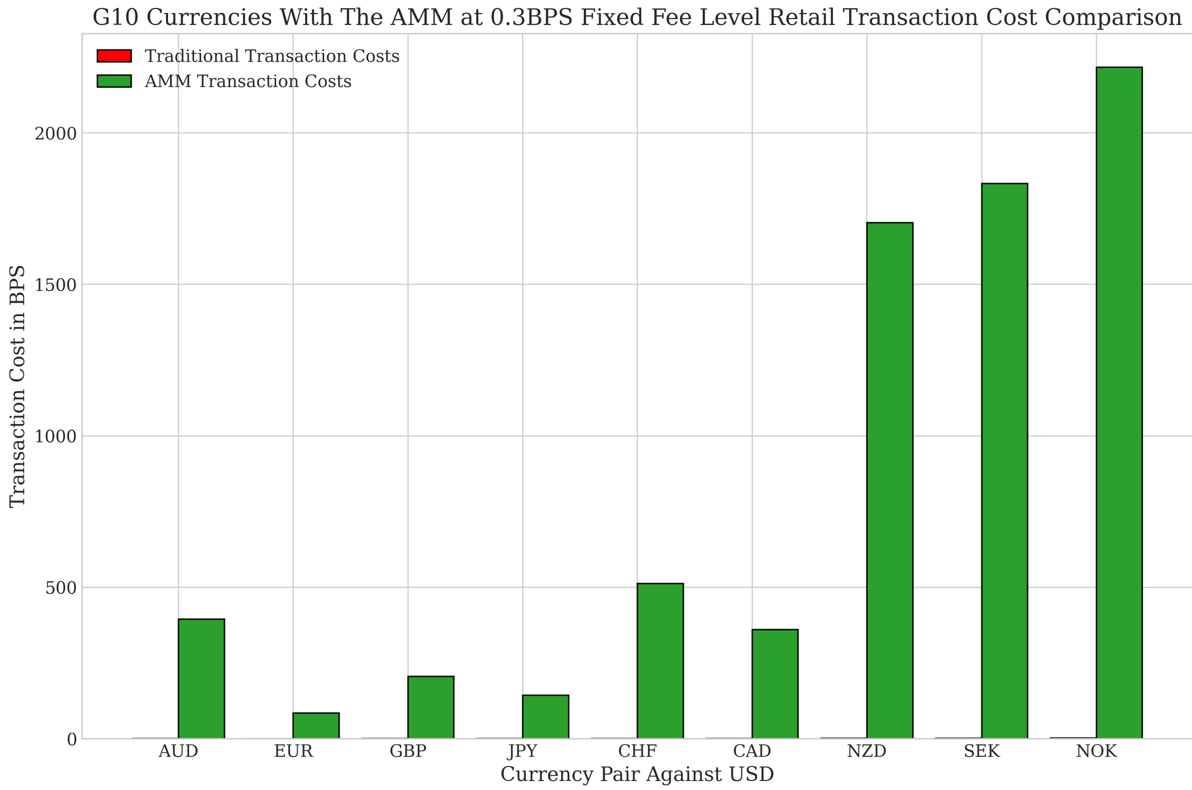

Figure 17: G10 Retail Transaction Costs When the AMM has a 0.3 BPS Fixed Fee Level

Table 3: 0.3 BPS Fixed Fee AMM Retail Costs Compared to CLOB for Exotic Currencies

Currency Pair	**CLOB Retail**	**AMM Retail**
USD/AUD	1.090	394.865
USD/EUR	0.470	84.731
USD/GBP	0.900	206.002
USD/JPY	0.530	143.726
USD/CHF	1.070	512.485
USD/CAD	0.960	360.624
USD/NZD	1.620	1703.452
USD/SEK	2.140	1833.052
USD/NOK	2.810	2217.145

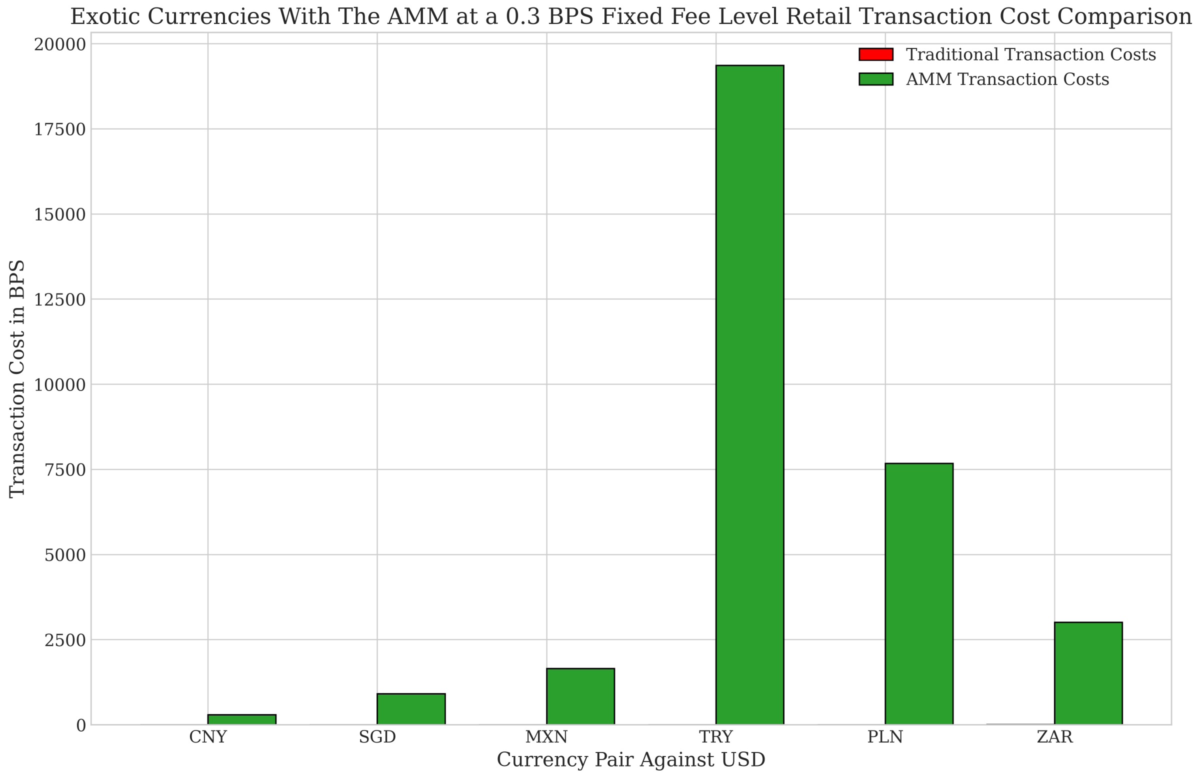

Figure 18: Exotic Retail Transaction Costs When the AMM has a 0.3 BPS Fixed Fee Level

Table 4: 0.3 BPS Fixed Fee AMM Retail Costs Compared to CLOB for Exotic Currencies

Currency Pair	CLOB Retail Costs	AMM Retail Cost
USD/CNY	0.430	295.305
USD/SGD	0.990	913.896
USD/MXN	2.300	1652.0589
USD/TRY	3.140	19364.200
USD/PLN	3.800	7678.008
USD/ZAR	4.920	3009.744

The wholesale transaction costs are not analyzed because, for most currencies, the 25 million transaction size is larger than the breakeven liquidity. The constant product pricing equation makes trades larger than the liquidity pool impossible, trades become infinitely more expensive as the transaction size approaches the liquidity pool size

The results show that decreasing the fixed fee to 0.3 BPS increases the total transaction cost by multiples of the previous transaction cost. The large increase in price impact caused by the smaller liquidity pool outweighs the small decrease in fixed costs for traders. The price impact increases significantly because the reduced fixed fee decreases the total yield to LPs, attracting less liquidity. The smaller liquidity pool incurs greater price impact costs, which outweigh the reduced fixed fees for traders. However, even in the Euro, which has the largest breakeven liquidity, the total fee increased by 53.894 BPS, with 53.594 coming from the price impact cost. The smaller fixed fee shows that even when the fixed fee is competitive compared to CLOB, all markets remain more expensive due to increased price impact costs.

7.2 Fixed Fee Optimisation

But what if the fixed fee level was optimized to minimize the transaction cost? Would any of the AMMs be cheaper at the optimized transaction cost? I have found the fixed fee level that minimizes transaction costs for each currency. I have graphed them in Figure 19 and put them in Table 5.

Table 5: Retail Trading Costs at Optimal Fixed Fee Compared to CLOB for Exotic Currencies

Currency Pair	CLOB Retail	Optimal Fixed Fee (BPS)	Retail Trading Cost at Optimal Fixed Fee (BPS)
USD/AUD	1.090	19.768	39.497
USD/EUR	0.470	7.513	15.021
USD/GBP	0.900	13.328	26.639
USD/JPY	0.530	10.484	20.956
USD/CHF	1.070	17.857	35.683
USD/CAD	0.960	14.912	29.802
USD/NZD	1.620	38.110	76.076
USD/SEK	2.140	40.309	80.457
USD/NOK	2.810	50.449	100.647

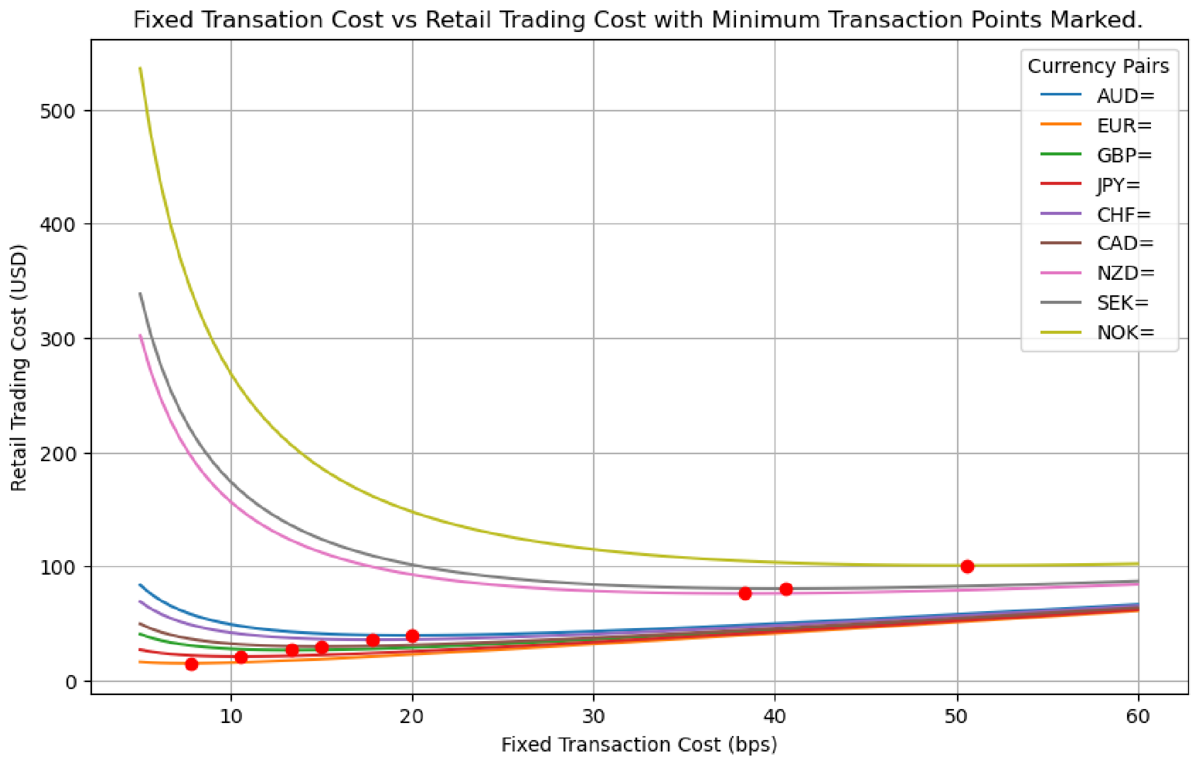

Figure 19: Fixed Fees Against Transaction Costs with Optimal Fixed Fee Marked.

The optimal fixed costs result in retail trading that is as close as possible to the CLOB retail costs. However, the AMM is still significantly more expensive than the CLOB in all markets. The markets with the highest and most stable volume are the closest to the CLOB costs, such as USD/EUR. The optimal costs present an intuitive new way of running AMMs where the optimal fixed cost is calculated and applied to the AMM. The fixed cost within an AMM is usually set arbitrarily, but there could be cost savings when using the optimal fixed cost. LPs still receive the same revenue as the breakeven liquidity balances to the new fixed fee level, yet the consumer receives the lowest possible transaction cost.

The optimal fixed fee does reduce the transaction cost of the AMM, but it still is multiples of the CLOB transaction cost. Given that the level of ASC cannot reasonably be changed and the fee level is optimized, the only other factor could be the market turnover. AMMs could possibly operate at a lower cost than CLOB but require an enormous amount of extra turnover to achieve it. The required turnover is multiples of the current turnover before the AMM is close to being at the same transaction cost as the CLOB.

8 Quantifiying The Cost of Settelement

One avenue that an AMM that has a distinct advantage over CLOB is the atomic settlement through the coded transactions that removes counterparty risk. The settlement of FX has long been an issue without a simple solution. Companies have a multitude of options when it comes to settlement in the FX industry. The preferred option depends on a trade-off between risk, cost and speed. The Table 6 shows the most popular methods for settlement and their associated risk, cost, speed and usage.

Table 6: Comparison of FX Settlement Methods

Method	**Risk**	**Cost**	**Speed**	**Usage**
CLS	Low (PvP)	Medium-High	T+2 or same day	High-volume institutional trades
Bilateral Settlement	High	Low	T+2 or T+3	Non-CLS trades, smaller participants
Prime Brokerage	Medium	Medium	T+1 to T+3	Institutional and retail aggregators
Local Payment Systems	Medium	Low	T+0 to T+2	Domestic and regional trades
CCPs	Very Low	Medium-High	T+1 to T+2	FX derivatives
Correspondent Banking	Medium-High	Low-Medium	T+1 to T+3	Smaller players or exotic currencies

The FX market has large amounts of capital flowing through it and multiple time zones, making it challenging for two parties to come together to transact. The risk of one party failing a transaction was a major problem within the industry.

8.1 Herstatt Risk

Herstatt risk, or settlement risk, occurs when one party in an FX transaction fulfils its obligation to deliver currency, but the counterparty fails, leading to potential financial loss. The risk is named after the German bank Herstatt, which was closed by regulators in 1974 due to insolvency. The bank had already received Deutsche Marks from counterparties in the European time zone but had not yet delivered the corresponding USD. The US market was closed then, and the counterparties lost their money. The Hersatt failure caused a severe loss of trust in the FX market, highlighting the systemic risks of cross-border settlement and the time-zone mismatch.

The Hersatt failure created a move towards payment-vs-payment (PVP) settlement. PVP ensures that both legs of a transaction are settled simultaneously, and if one party fails, the other payments are not released. This removes the Herstatt risk and only creates an opportunity cost if the transaction fails. CLS, formed in 2002 to create this service, is the most prominent institution in wholesale FX settlement.

8.2 The Cost of FX Settlement

CLS is the preferred method of wholesale FX trading for large institutions. CLSSettlement is the most commonly used option with a standard settlement of T+2 days, CLSNow has same-day settlement for more urgent trades(CLS Group, 2024). The CLSNow settlement costs additional fees to receive a faster settlement. This is an example of the trade-off market participants face between settlement time and transaction cost. Even with CLSnow, participants must pre-fund their accounts with sufficient liquidity for settlement, which can delay the transaction by a few hours to a full day.

A study by Russell Investments demonstrates this issue, as shown in Figure 20 there is, on average, a ten BPS difference between indirect trading and using a manager to trade FX. Furthermore, once an agent is used, the difference becomes 20 BPS. From this analysis, it can be derived that traders are willing to forgo 20 BPS to achieve faster settlement by not using an agent. The premium for faster settlement was also confirmed in an expert interview with James Swerling from Ebury: "This cost to make payments is all about perception. An unsophisticated business/individual making irregular payments will happily pay an A$25 fee for a fast payment by Real Time Gross Settlement (RTGS) to ensure it goes instantly. But a larger institutional or sophisticated entity will expect this from their payment provider/bank as standard and for free."

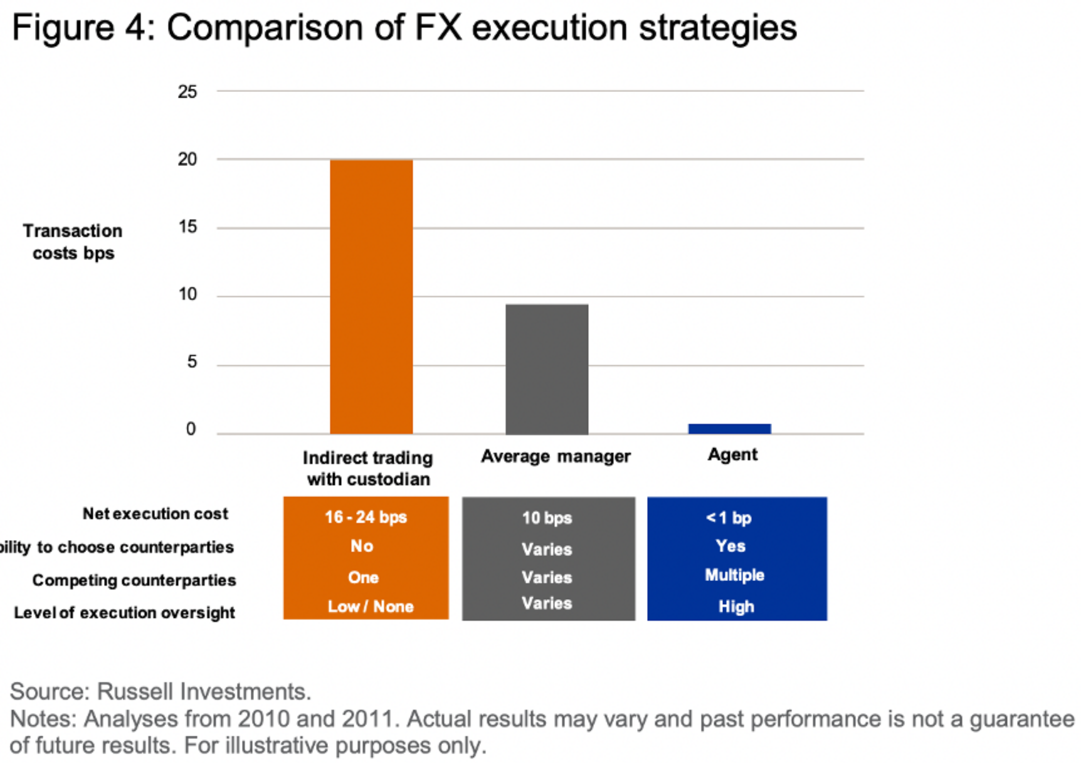

Figure 20: FX execution strategies investigation by Russell Investments

AMMs have the ability to negate settlement risk at a lower cost than CLSSettlment for most investors. CLS settlement is the most expensive, and it is only available to large, high-volume institutions. The cost of the service is not feasible for other businesses, so they are left deciding between high risk or low speed, both of which are costly. To these traders, in particular, using an AMM to settle an FX trade could be very useful and cost-saving. Businesses that want risk-free, fast settlement will be happy to bear a reasonably inflated transaction cost using the AMM.

CLS also needs pre-funding to initiate the settlement, leaving capital tied up between hours and a full day before settling the trade. AMMs allow the trader to interact directly with the liquidity pool, removing the need for funding and the associated costs. Delays in settlement significantly drag on a business's liquidity and costs. A conservative estimate is that traders will forgo a 20BPS premium for a fast, safe settlement. The AMM can save this cost, allowing some individuals to decide whether the AMM is more beneficial due to its settlement benefits.

9 Counclusion

AMMs have the ability to pool liquidity by offering anyone to deposit assets in return for fixed fees. This ability to attract LPs can create deep pools with large amounts of liquidity, which has the potential to lead to decreased transaction costs. The AMMs in crypto markets have acquired a third of all market share in some trading pairs. However, when AMMs are applied to FX, sophisticated traders with access to electronic brokerage or other FX networks can access highly efficient CLOBs with low transaction costs. The current FX trades on CLOB have very low fixed fees, and the price impact is minimal due to the large amount of liquidity in the order book. The transaction costs in all the CLOBs are lower than even the fixed fee used on most AMMs, which is 30 BPS.

I applied the AMMs to G10 and exotic USD currency pairs, assuming the Uniswap fixed fee of 30BPS. I showed that the AMM underperformed the CLOBs in terms of costs in all markets. I then showed that at partial adoption rates, the transaction cost inflates further. I then assumed a lower fixed fee of 0.3 BPS to be competitive with CLOBs, but the AMMs incurred much larger price impact costs at that point, again making them not competitive. I optimize the fixed fee based on market characteristics of ASC, turnover, and the average transaction amount, which can improve the AMM. With the optimized fixed fee, traders receive the lowest possible AMM transaction cost. However, this AMM transaction cost is still not close to being competitive with the CLOB. There are some use cases for the AMM in FX, but it may still be attractive for unsophisticated traders who pay inflated costs. The atomic settlement of AMMs is a useful tool for receiving a risk-free, fast settlement, alleviating high costs for traders without access to CLSSettlement. Even for some traders, using the AMM at a higher transaction cost may be cheaper than using a service such as CLS. However, at a low level of adoption, with only part of the market using the AMM, the transaction costs are even higher, making it unlikely.

Although AMM might not be the cheapest option to trade FX, they have proven to provide attractive features in crypto markets that make them preferred among some users. The decentralized nature is popular among crypto, specifically due to the bypassing of centralized institutions. The AMM also has the possibility to include otherwise idle assets, such as currency reserves, in the liquidity pools. Yet, the turnover needed to attract the liquidity providers to give them an advantage cost is many multiples of the current AMM turnover, which is not a realistic assumption.

The AMM could also benefit from being a more transparent and less fragmented market. In more exotic currencies, the AMM centralized marketplace can reduce the costs associated with corruption and unnecessary intermediation. The coded nature of the AMM cannot be misused to a country's benefit. Countries such as the Bahamas or Nigeria have already moved to CBDCs because of the high costs of their traditional payment system. The applicability of an AMM to these CBDCs is already possible. When the rest of the world issues CBDCs, AMMs offer an efficient solution to transact with countries with high corruption, bypassing the intermediation that is the cause of the inefficiencies.

I have added to the literature of applying AMMs to physical assets classes. My findings show that the CLOBs used in FX are too efficient in accessing large amounts of liquidity for the AMM to compete on a cost basis. Although there are some use cases in settlement and corrupt payment systems that would find the AMM attractive. The issuance of CBDCs could include AMMs and attract the same users who prefer a decentralized body to handle the transaction. The major benefit would be offering a solution to struggling payment systems in developing nations. I have demonstrated a fixed-cost optimization method for AMMs, which can be used as a better way for institutions that run AMMs to calibrate them. By optimizing the fixed cost the transaction cost can be significantly reduced creating greater efficiency and cost savings. I have focused on the larger trade size in this paper as FX lends itself to being the largest exchange in the world. However, at smaller transaction sizes, the price impact may be small enough that the AMM is cheaper than CLOBs in some markets. Future studies could investigate that, as well as more sophisticated fee systems, such as the tiered system Uniswap V3 currently uses.

AMMs are specifically applicable to CBDCs due to the decentralized nature of the currencies. A marketplace such as Uniswap could easily be applied when released on a large scale. When this does occur, it is not obvious whether the CLOB liquidity that is currently in FX will be transferred quickly. I believe the majority of trades will still occur through a CLOB, but there will be some of the market that will prefer the benefits of trading through an AMM.

References

Atlantic Council (2024). Central bank digital currency tracker. Retrieved from https://www.atlanticcouncil.org/cbdctracker/#:~:text=134%20countries%20&%20currency%20unions,%20representing%20advanced%20stages%20of%20CBDC%20development.

BIS Innovation Hub (2022). Otc foreign exchange turnover in april 2022. Retrieved from https://www.bis.org/statistics/rpfx22_fx.htm.

BIS Innovation Hub (2023). Project mariana: Cross-border exchange of wholesale cbdcs using automated market-makers. Retrieved from https://www.bis.org/publ/othp75.htm.

Block, T. (2024). The block co. retrieved from dex to cex spot trading volume. Retrieved from https://www.theblock.co/data/decentralized-finance/dex-non-custodial/dex-to-cex-spot-trade-volume.

Capponi, Agostino and Jia, Ruizhe (2023). Liquidity provision on blockchain-based decentralized exchanges. *SSRN Electronic Journal*.

CLS Group (2024). Cls settlement and clsnow pricing. Retrieved from https://www.cls-group.com/products/settlement/clssettlement/pricing/.

Collective Shift (2024). Guide to Automated Market Makers (AMMs). Retrieved from https://collectiveshift.io/defi/amm-guide/.

Foley, S. and O'Neill, M. and Putnins, T. (2023). A better market design? applying automated market makers to traditional financial markets. Retrieved from https://ssrn.com/abstract=4459924.

Glosten, L. R. and Milgrom, P. R. (1985). Bid, ask, and transaction prices in a specialist market with heterogeneously informed traders. *Journal of Financial Economics*, 14(1):71–100.

Goodell, G. and Al-Nakib, H. D. and Aste, T. (2024). Retail central bank digital currency: Motivations, opportunities, and mistakes. Retrieved from https://arxiv.org/abs/2403.07070.

Gupta, R., Gupta, M., and Gupta, D. (2021). Role of liquidity pool in stabilizing value of token. *Journal of Blockchain Research*. Retrieved from https://orcid.org/0009-0002-0626-7614,https://orcid.org/0009-0005-3542-1408,https://orcid.org/0009-0006-6750-8433.

Hendershott, T. J. and Menkveld, A. J. (2014). Price pressures. *Journal of Financial Economics*, 114:405–423. Retrieved from https://ssrn.com/abstract=1411943.

Jones, B. (2024). Financial innovation and the future of cbdc in australia. Speech at the Intersekt Conference, Melbourne. Retrieved from https://www.rba.gov.au/speeches/2024/sp-ag-2024-09-18.html.

JPMorgan and OliverWyman (2021). Unlocking $120 billion value in cross-border payments. Retrieved from https://www.jpmorgan.com/onyx/documents/mCBDCs-Unlocking-120-billion-value-in-cross-border-payments.pdf.

Lehar, A. and Parlour, C. A. and Zoican, M. (2024). Fragmentation and optimal liquidity supply on decentralized exchanges. Retrieved from https://ssrn.com/abstract=4267429.

Macrotrends and World Bank (2024). Comparison of annual fx trading volume and global gdp (2023). Retrieved from https://www.macrotrends.net/global-metrics/countries/WLD/world/gdp-gross-domestic-product.

Malinova, K. and Park, A. (2023). Learning from defi: Would automated market makers improve equity trading? Retrieved from https://ssrn.com/abstract=4531670.

Melvin, M., Pan, W., and Wikstrom, P. (2020). Retaining alpha: The effect of trade size and rebalancing frequency on fx strategy returns. *Journal of Financial Markets*.

Russell Investments (2024). Implementation solutions: Transaction cost analysis. Retrieved from https://russellinvestments.com/au/institutional-investors/solutions-and-services/customised-portfolio-solutions/currency-management/transaction-cost-analysis.

Szabo, N. (1996). Smart contracts: Building blocks for digital markets. *EXTROPY: The Journal of Transhumanist Thought*, 18(2):16. Issue 16.

Uniswap (2021). Introducing uniswap v3. Retrieved from https://blog.uniswap.org/uniswap-v3.

Uniswap (2024). How uniswap works. Retrieved from https://docs.uniswap.org/contracts/v2/concepts/protocol-overview/how-uniswap-works.

UniswapLabs (2024). Eth/usdc pool on uniswap - largest pool in november 2024. Retrieved from https://app.uniswap.org/pools.

US Department of Treasury (2024). Daily treasury yield curve rates - october 2024. Retrieved from https://home.treasury.gov/resource-center/data-chart-center/

interest-rates/TextView?type=daily_treasury_yield_curve&field_tdr_date_value_month=202410.

Zohar, J. and Kuenzi, D. (2021). Challenges in applying amms to large markets. *Journal of DeFi Studies*.

Appendix

Table 7: ASC, Turnover and Breakeven Liquidity Provisions for G10 Currencies

Currency Pair	ASC %	Daily Turnover (USD Millions)	Breakeven Liquidity Provision (USD Millions)
USD/AUD	−0.000 530	381	5269
USD/EUR	−0.000 269	1705	23 888
USD/GBP	−0.000 421	714	9923
USD/JPY	−0.000 344	1013	14 144
USD/CHF	−0.000 254	293	4105
USD/CAD	−0.000 243	410	5751
USD/NZD	−0.000 502	99	1374
USD/SEK	−0.000 538	93	1291
USD/NOK	−0.000 809	81	1102

Table 8: ASC, Turnover and Breakeven Liquidity Provisions for Exotic Currencies

Currency Pair	ASC%	Daily Turnover (USD Millions)	Breakeven Liquidity Provision (USD Millions)
USD/CNY	−0.000 101	494	6980
USD/SGD	−0.000 091	169	2389
USD/MXN	−0.000 773	103	1410
USD/TRY	−0.002 236	23	303
USD/PLN	−0.000 567	33	460
USD/ZAR	−0.001 143	64	864

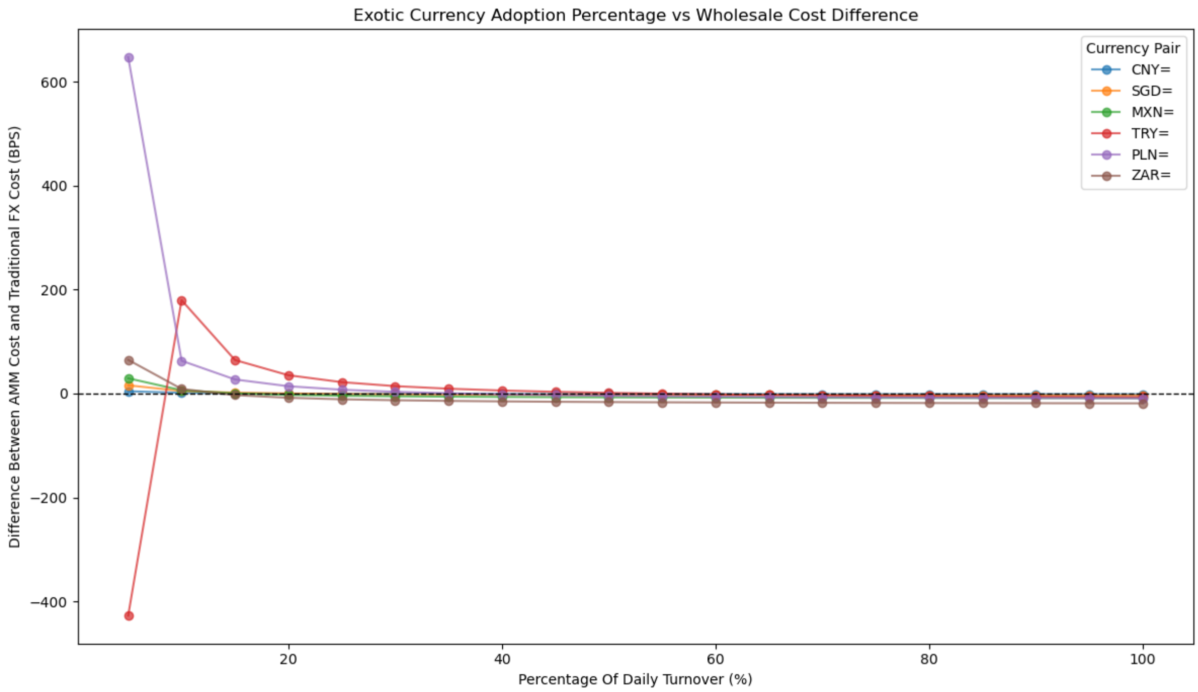

Figure 21: The Exotic Currency Adoption Percentage vs Wholesale Cost Difference. Note that the first negative value for the Turkish Lira is due to the wholesale trade amount being larger than the breakeven liquidity.