IJIE
International Journal of Innovation and Entrepreneurship

International Currency Circulation and Monetary Policy

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Submitted: 5 February 2024, accepted: 20 February 2024, published: 23 February 2024

Abstract: This paper explores the challenges in the internationalization of local currencies and the establishment of a robust International Currency Circulation (ICC) mechanism. Employing an innovative Agent-Based Model (ABM) grounded in Behavioral Finance, our research examines the interdependence between currency circulation and inter-bank treasury bond market. Through simulations, we analyze the impacts of monetary policies, increased overseas holdings, and investor sentiments on treasury bond prices and market activities. Our findings underscore the pivotal role of a robust monetary policy, the strategic optimization of market structures through overseas institutions, and the non-linear relationship between investor sentiment and treasury bond prices. This study contributes valuable insights for policymakers, investors, and academics, emphasizing measures to enhance market efficiency and stability in the realm of international currency circulation.

Keywords: international currency circulation; agent-based model; monetary policy

How to cite: Zhang, H.; Guo, D. International Currency Circulation and Monetary Policy. *Int. J. Innov. Entrep.*, 2024, 3(1): 1; doi:10.56502/IJIE3010001.

1. Introduction

In the contemporary landscape of global finance, the internationalization of local currencies stands as a pivotal yet intricate challenge for monetary policymakers. Amidst this pursuit, the establishment of an efficient international currency circulation (ICC) mechanism is of paramount importance to address liquidity risks inherent in the internationalization process. As scholars and policymakers grapple with the complexities of currency circulation, a central problem emerges: how can an effective ICC mechanism be established to navigate the risks associated with the internationalization of local currencies in the inter-bank treasury bond market?

To contextualize this question, it is crucial to review the existing literature that has laid the foundation for understanding ICC. Existing scholarly works have primarily concentrated on two critical aspects: the crises arising from currency internationalization and the selection of safe assets for ICC. Scholars have meticulously examined the mechanisms driving currency crises within the international monetary system. Simultaneously, a substantial body of literature, pioneered by Kindleberger and Krugman, emphasizes the geopolitical and economic dimensions influencing the choice of financial vehicles for ICC. Notably, the prominence of US treasury bonds in this role, as highlighted by Krishnamurthy and Milbradt, underscores the interconnectedness of economic power, trade dynamics, and the selection of safe assets.

Against the backdrop of this existing literature, this article contributes a novel perspective by employing an Agent-Based Model (ABM) to construct a computational framework for analyzing the impact of risk in the inter-bank treasury bond market. ABM, historically underutilized in financial analysis, provides a unique avenue to simulate the actions and interactions of autonomous agents, thereby offering a nuanced understanding of complex economic phenomena. Grounded in the insights from Behavioral Finance, our research aims to address the research question by exploring the dynamics of ICC and the implications on the stability of the treasury bond market. This simulation-based research seeks to enhance the understanding of policymakers, investors, and academics in implementing monetary policy in the form of treasury bonds.

2. Literature Review

Establishing an ICC mechanism can effectively address liquidity risks arising from the internationalization of local currencies, thereby fostering the comprehensive development of local currency internationalization (Guo and Zhou, 2021). Existing literature on ICC primarily centers on two key aspects: causes of currency crises and identification of safe assets.

The first body of literature concentrates on crises stemming from currency internationalization. Scholars such as Filardo et al. (2016) examine the mechanisms of currency crises within the international monetary system. They highlight the liquidity issues in the international monetary system, as evidenced by historical events like the conflict between the British pound and the US dollar, leading to the collapse of the gold standard and the Bretton Woods system. Additionally, Bernanke and Eichengreen argue that the internal tensions within the dollar double-linked system contribute to the "Triffin's dilemma" within the Bretton Woods framework (Bernanke, 2005; Eichengreen and Mathieson, 2000; Eichengreen and Kawai, 2014; Eichengreen and Lombardi, 2017). This dilemma arises as the US, through trade imbalances, provides liquidity and foreign exchange reserves to the world, ultimately resulting in the breakdown of the monetary system.

The second strand of literature focuses on the selection of safe assets for ICC. Currency circulation can involve goods, technology, services, or financial assets, as discussed by Feng et al. (2023). Among these, a substantial body of literature analyzes financial vehicles based on international reserve assets. Scholars like Kindleberger and Krugman argue that the choice of financial vehicles for ICC is not merely a financial matter but is intricately linked with economic and trade power, as well as military and diplomatic hegemony, considering the functions of money, war, and financial crises. He et al. (2016) contend that US treasury bonds serve as the world's safe assets, supporting the USD international recycling mechanism and facilitating US expansionary economic policies.

When comparing the internationalization efforts of the USD and the JPY, along with the opening of the treasury bond markets in the US and Japan, a notable distinction emerges. The US actively promotes both the internationalization of the USD and the opening of its treasury bond market, whereas Japan's government did not actively champion the internationalization of the yen and the establishment of the currency circulation system. In terms of the choice of the circulation vehicles, the USD opted for the onshore treasury bond market, while the JPY commenced with the construction of an offshore market.

To elaborate on the internationalization policy of the JPY, it underwent phases of negative, passive, and active policies (Zhang et al., 2016). In the evolution from a "trade yen" to an "investment yen," Japan's bond market, particularly the treasury bond market, lags behind in terms of internationalization (Guo and Zhou, 2021). Therefore, it holds greater significance for China to take the US treasury bond market as the benchmark. Additionally, the dollar crisis in 1970s resulted from poor ICC, triggering the collapse of the Bretton Woods system. To overcome this crisis and promote the opening of the treasury bond market, the US balanced the ICC by holding overseas US treasury bonds. This approach not only solidified its world currency status but also serves as a reference point for other countries.

Due to data availability, research on ICC beyond USD is constrained. Existing literature predominantly explores the impact of overseas holdings of US treasury bonds on macro variables (Beltran et al., 2013), the micro-mechanisms of foreign investors' participation in primary and secondary markets (Fabozzi and Jones, 2019), motivations for other countries to invest in US treasury bonds, and the support of overseas holdings of the USD. Moreover, Guo (2019), based on information from the US government's website, identifies the gradual non-market opening-up process of the US treasury bond market through political, military, and diplomatic means. Based on existing literature, the timeline, approach, and nature of the US treasury bond market's opening can be summarized in Table 1.

This paper takes a novel approach to address the aforementioned question by employing Agent-based Modeling (ABM). ABM serves as a computational model designed to simulate the actions and interactions of autonomous agents. ABM is not the dominant analytical method. The mainstream approaches are still VAR and DSGE models. However, ABM has significant advantages in analyzing complex economic issues, as it can flexibly incorporate behavioral finance insights into economic models, especially agent heterogeneities and herding behaviors. These rich features are important to financial markets but difficult to be modelled in traditional models.

Table 1: The gradual opening process of the US treasury bond market.

Market Types	**Illiquid Treasury Bond Market**			**Treasury Bond Market**		**Medium- and Long-Term Treasury Bond Market**		
foreign subjects	foreign currencies denominated		USD denominated	official	private	petroleum country	private	official
	official	bank	official					
opening times	1961–1979	1978–1983	1963–2012	1970-present	1982-present	1974-present	1984-present	1990s-present
main events	Lisa bond	Carter bond	industrial countries + three Latin American countries	the eve of the collapse of the Bretton Woods system	oil crisis	oil crisis	oil crisis	global imbalance of payment + financial crisis
main mechanism	directed sale			money market fund + the Eurodollar market		foreign official additional issuance + full opening		
opening types	government-driven			external demand pulled		government-driven + external demand pulled		

3. Agent-Based Model

To conduct an economic simulation of transactions in the treasury bond market, we have developed a heterogeneous investor model within the Netlogo system. The research framework is illustrated in Figure 1, which outlines our approach to analyzing investor heterogeneity.

3.1. Rules and Mechanisms Settings in the Inter-bank Market

Treasury bonds and policy financial bonds serve as benchmark products for interest rates in the inter-bank market and exhibit a high correlation. For simplicity, we assume that treasury bond transactions occur exclusively between banks, considering their significant trading volumes. We establish both transaction price and volume mechanisms, alongside a transaction monitoring mechanism.

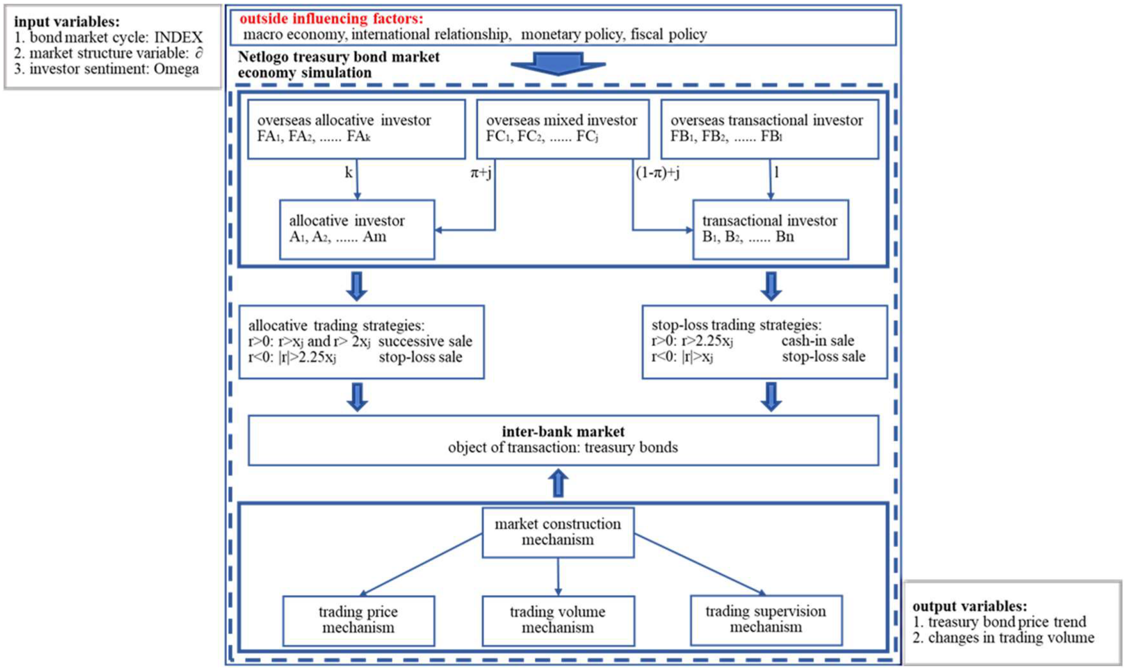

Figure 1: The research framework for analyzing investor heterogeneity.

3.1.1. Transaction Price Mechanism

We assume a single transaction type for the treasury bonds. The net price, initialized at 100, is chosen as the treasury bond market price based on market supply and demand principles. The current treasury bond price (P_t) is determined by the demand for treasury bonds, represented by the formula: $P_t = \alpha P_{t-1}$. Here, α is the lag coefficient, influenced by the difference (ΔQ_t) between the current supply (Q_t^s) and demand for treasury bonds (Q_t^d). When $\Delta Q_t > 0$, $\alpha > 1$ leading to a rise in treasury bond prices. Conversely, when $\Delta Q_t < 0$, $\alpha < 1$, resulting in a decrease in treasury bond prices. If $\Delta Q_t = 0$, $\alpha = 1$, and the treasury bond price remains constant.

3.1.2. Transaction Volume Mechanism

Market participants are categorized into three groups based on the trading strategy: long-selling, short-selling, and holding. The difference between supply and demand (ΔQ_t) is determined by the formula:

$$\Delta Q_t = \frac{Q_t^{long} - Q_t^{short}}{Q_t^{long} + Q_t^{short} + Q_t^{hold}}$$

Here, Q_t^{long}, Q_t^{short}, and Q_t^{hold} represent the numbers of long traders, short sellers, and holders, respectively. Depending on the relationship between Q_t^{long} and Q_t^{short}, the market position is either buying long, selling short, or at a stalemate.

While market activity is typically analyzed based on absolute and relative transaction volumes, the inter-bank market experiences less frequent transactions compared to the stock market. Therefore, we opt for analyzing the decisive volume of trading volume to measure market activity. The formula for current trading volume is given by:

$$Q_t^{trade} \equiv Q_t^{long} + Q_t^{short}$$

3.1.3. Transaction Monitoring Mechanism

We introduce a regulatory intervention into the research framework, wherein a circuit breaker is triggered to halt trading if bond prices rise or fall excessively. This aligns with real-world scenarios where governments intervene during abnormal market fluctuations or severe attacks, resorting to measures such as market closure. The circuit breaker mechanism is represented by:

- Circuit breaker of bull market: $P_t > \overline{P}$, stop trading at $t+1$.
- Circuit breaker of bear market: $P_t < \underline{P}$, stop trading at $t+1$.

3.2. Settings of Heterogeneous Investors and Trading Strategies

In line with the literature convention, we categorize investors in the inter-bank market into two types: disposition effect type investors (Agent_DEI) and stop-loss effect type speculators (Agent_STP). These correspond to allocation-oriented investors and transaction-oriented investors in actual transactions. Additionally, our simulation considers domestic and foreign investors, extending the framework to an open economy context, where the ICC mechanism involves foreign investors increasing their holdings of treasury bonds.

To capture investor heterogeneity based on preferences for net income from treasury bond transactions, we introduce different net income rates in the ABM. The net income rate (r_t) is calculated as the natural logarithm of the current price (P_t) minus the natural logarithm of the previous period's price (P_{t-1}).

Furthermore, we assume different institutions possess varied expected returns (X_i), where $i = 1, 2, 3, \ldots, N$ and N represents the number of all participants in the inter-bank market. We set $X_i > 0$, designate X_{max} as the maximum expected rate with a normal distribution. When simulating actual trader behavior, the probability distribution for buying and selling behaviors aligns with Silvar's approach.

Allocative Investors

Allocative investors, in contrast to transactional investors, exhibit a stronger inclination towards long-term bond investments and a robust willingness to hold them. Their trading habits reflect disposition effects, meaning they tend to cash in returns when the portfolio has a positive return and exhibit a low risk tolerance. Conversely, in the face of losses, allocative investors are more likely to compensate by extending the waiting period for positions, indicating a higher risk tolerance for losses.

Some banks in the inter-bank market have lower profit targets. They cash in profits but do not implement stop-loss measures promptly in case of losses. This is because the cost of their trading account is based on historical cost rather than adjusting to timely market prices. Based on performance appraisal, unsold bonds do not result in actual losses, leading to a strategy of waiting for a price rebound over time to compensate for losses, even if the loss-making bonds are transferred to longer-term holding accounts.

Thus, we define r_{it}^{DEI} as the return of allocative investor i at period t, assuming all allocative investors share the same trading strategy:

1. If there is a positive return, sell part of the bonds when $r_{it}^{DEI} > X_i$, or sell all bonds when $r_{it}^{DEI} > 2X_i$.
2. If there is a negative return, allocative investors hold onto bonds when $\left|r_{it}^{DEI}\right| < 2.25X_i$; otherwise, they sell all bonds.

Additionally, the trading behavior of allocative investors is characterized by a "herding effect." They are influenced by their local environment and tend to adopt the same trading behavior as other traders. We simulate this "herding effect" based on Netlogo's framework, where each trader corresponds to a patch, and adjacent patches influence each other's transaction activities. Specifically, the buying probability of an allocative investor is directly proportional to the number of surrounding investors choosing to buy.

3.3. Estimations of Input Variables and System Parameters

In our simulations, we have three key systematic input variables: the bond market cycle variable (Σ), market structure variable (Θ), and investor sentiment variable (Ω). These variables are adjusted to perform multi-scenario analyses, aiming to understand how these factors influence treasury bond prices and market activity. The estimation approaches for these variables are explained below.

1. **Bond Market Cycle Variable (Σ):** This variable represents the impact of external information on the market, simulating both bull and bear bond markets. Notable events like 9/11 are considered major negative influences, leading to a value within the range $[-\infty, -1]$. To simulate the impact of the current monetary policy on the inter-bank treasury bond market, we opt for a relatively mild range of $[-1, 1]$, capturing scenarios of neutral, stable, and loose monetary policy.
2. **Market Structure Variable (Θ):** This variable indicates the proportion of trading investors to total traders. Assume an initial wealth of 100 for each trader and consistent numbers of investors and the proportion of their bond holdings at the beginning. Commercial banks, city commercial banks, insurance institutions, and similar entities are categorized as allocative investors. On the other hand, brokers and funds fall under the transactional investor category. While the actual proportion of allocative investors in bond custodian institutions is around 10%, the proportion of bond trader institutions is closer to 20%.
3. **Investor Sentiment Variable (Ω):** We use the parameter to measure investor overconfidence, reflecting market sentiment. A higher Ω value implies more active participation and frequent transactions in the market. We set the desirable range of Ω as $(0, 10]$, where 0 signifies minimal market activity, and values exceeding 10 suggest extremely active investor participation.

Additional parameter settings include: $\overline{P} = 200$ and $\underline{P} = 50$ in the circuit breaker mechanism, $\delta \sim Uniform\,(0, 0.2)$, the maximum expected return $X_{max} = 20$ and $X_i \sim Uniform\,(0, 0.2)$. The upper limit of the total number of simulated periods is set to 1500 ticks, where a tick is the time unit in Netlogo, differing from actual trading time.

With these settings, snapshots of the inter-bank national debt market at time points 500 ticks, 1000 ticks, and 1500 ticks are presented under the initial state ($\Sigma = 0$, $\Theta = 0.1$, $\Omega = 1$) in Figure 2. Blue patches denote long trading, red patches represent short trading, and white patches signify a holding state.

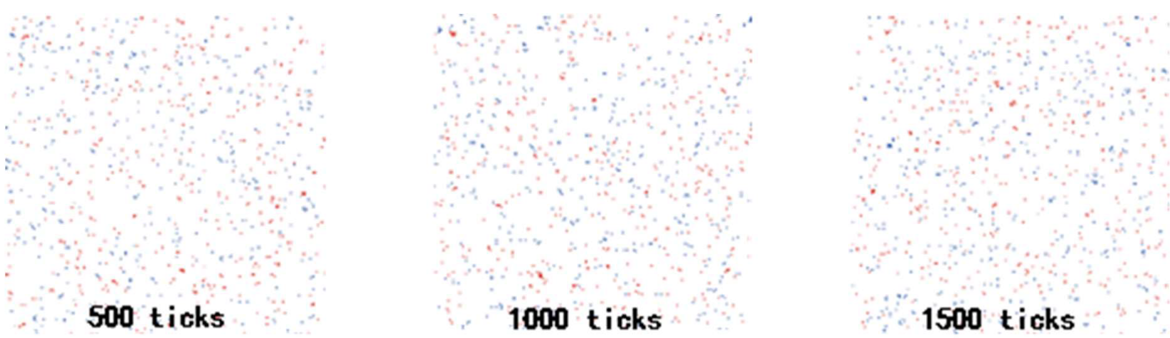

Figure 2: The overall view of treasury bond market observations.

4. Results

4.1. Simulation of Monetary Policy Effect

Currently, the primary driver of fluctuations in treasury bond prices within the inter-bank market is the liquidity tightness in the money market. Guo (2019) underscores the strong correlation between monetary policy and the treasury bond market, emphasizing the market's weak efficient state. In our ABM, we introduce the adjustable bond market cycle variable (Σ). $\Sigma = 0$ signifies neutral monetary policy. $\Sigma = -1$ represents a contractionary monetary policy, with the central bank reducing money supply or increasing policy interest rates. $\Sigma = 1$ indicates expansionary monetary policy, with the central bank injecting money or lowering policy interest rates. $\Sigma = 0.02$ reflects a prudent monetary policy, showcasing a central bank adopting a cautious monetary policy with an appropriate and loose policy orientation. Importantly, we deviate from traditional volume-price policies and adopt more structural monetary policies and forward-looking guidelines.

As shown in Figure 3, in the case of neutrality ($\Sigma = 0$), the treasury bond price exhibits a mean-reverting trend, hovering in a small range above 100. The frequency of fluctuations is low. The market tends to be stable, with the price determined by market supply and demand.

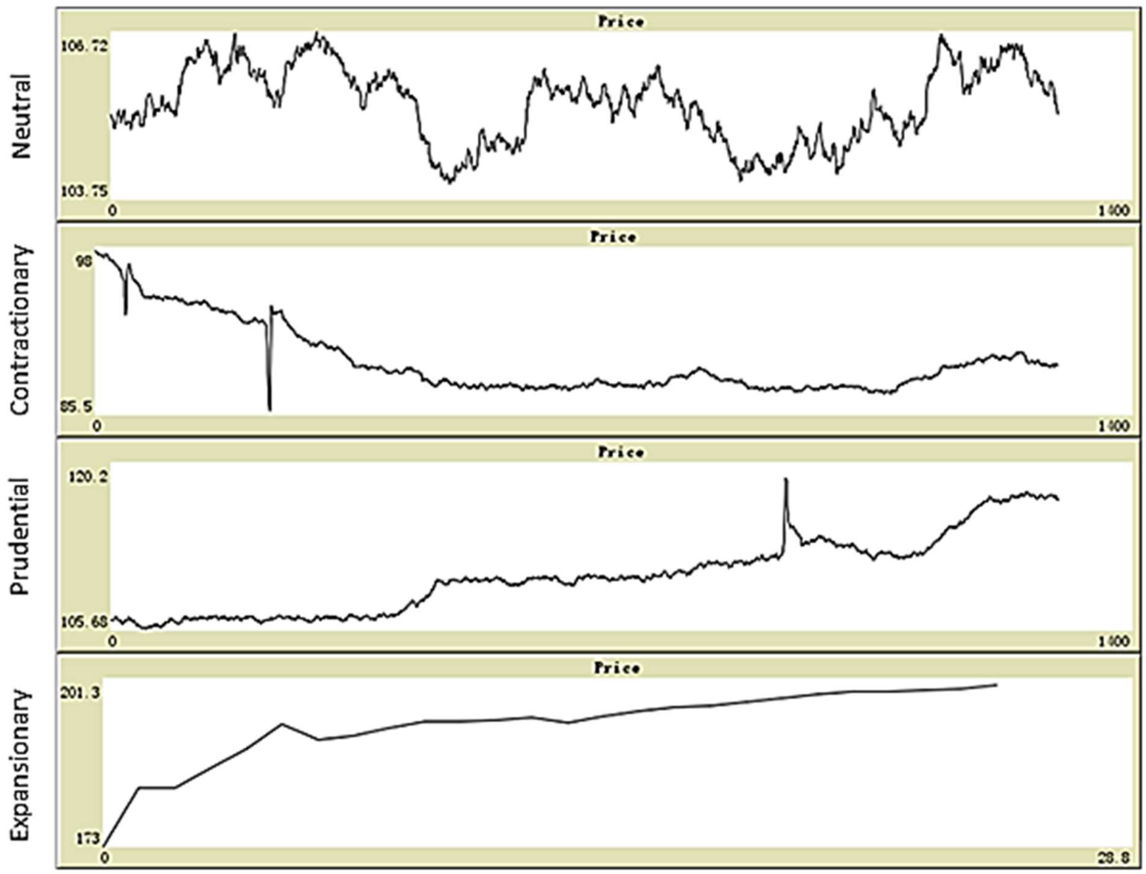

Figure 3: Impacts of Monetary Policies on Treasury Bond Price.

In the case of monetary tightening ($\Sigma = -1$), the treasury bond price experiences a downward trend, aligning with the market rule under tight monetary policy where yield to maturity rises, causing bond prices to fall. The closing price at the end of the simulation is 89.2, with a maximum decrease of 14.2% (85.8). Time-varying features are evident, showing significant declines in the early period, with two distinct price jumps. The second jump indicates substantial stop-loss activity by transactional investors, followed by a subsequent price rebound as allocative investors hold low-priced bonds to reduce position costs. The impact of the tight monetary policy persists for an extended period due to the rigidity of treasury bonds' bottom price. The herding effect influences allocative investors' holding reduction, affecting bond trading activity.

In the case of quantitative easing ($\Sigma = 1$), the bond price rises to over 170 by the end of the simulation period. A ceiling is set at 200 as the upper limit price, triggering a halt in trading once reached. Trading volume significantly increases in the initial observation period, reaching 16,500, but experiences a sharp decline after hitting the upper limit price. Asymmetric effects are observed, with tightening policies having decreasing convergence and easing policies displaying divergent characteristics with greater lag effects. Adjusting Σ to 0.02 results in a treasury bond price fluctuating between 105 and 118, similar to $\Sigma = -1$ but with distinct time-varying characteristics in the price trend. During the early period (400 ticks), the policy's price effect is not significant. The first price jump occurs after 450 periods (110). After the first jump, the market enters a new price range, witnessing large trade volumes and a significant jump shock near 920 ticks. Allocative investors achieve their profit targets, selling bonds for income realization. The price recovers quickly after allocative investors' sales, with speculative investors pushing the price to the third jump at 1200 ticks.

4.2. Simulation of Overseas Holdings Effect

In the context of RMB internationalization, the surge in RMB is anticipated to boost the holding ratio of foreign investment institutions. In alignment with the categorization of domestic investment institutions, we classify overseas holders into allocative investors and transactional investors. Examining the impact of increased overseas holdings on the treasury bond investor structure, we distinguish three distinct scenarios:

- Conservative Change: Overseas holdings alter the proportion of institutional investors, accounting for 10% of the total market structure.
- Moderate Change: Overseas holdings include a higher percentage of transactional investors, constituting 15% of the trading type.
- Aggressive Change: Transactional investors in overseas holdings gradually increase, reaching a substantial 40%.

Conservative Market Structure. The simulation in Figure 4 primarily focuses on the impact of increased overseas holdings during a bear market, which is crucial for risk prevention. Setting $\Sigma = -1$ as the initial state of the bear market aligns with recent practical experiences, where the bull-bear market in the inter-bank sector is driven by monetary policy. Despite the change in foreign investor structure, the increased overseas holdings do not alter the price trend of the original market, maintaining similarity to the monetary tightening scenario in Figure 3.

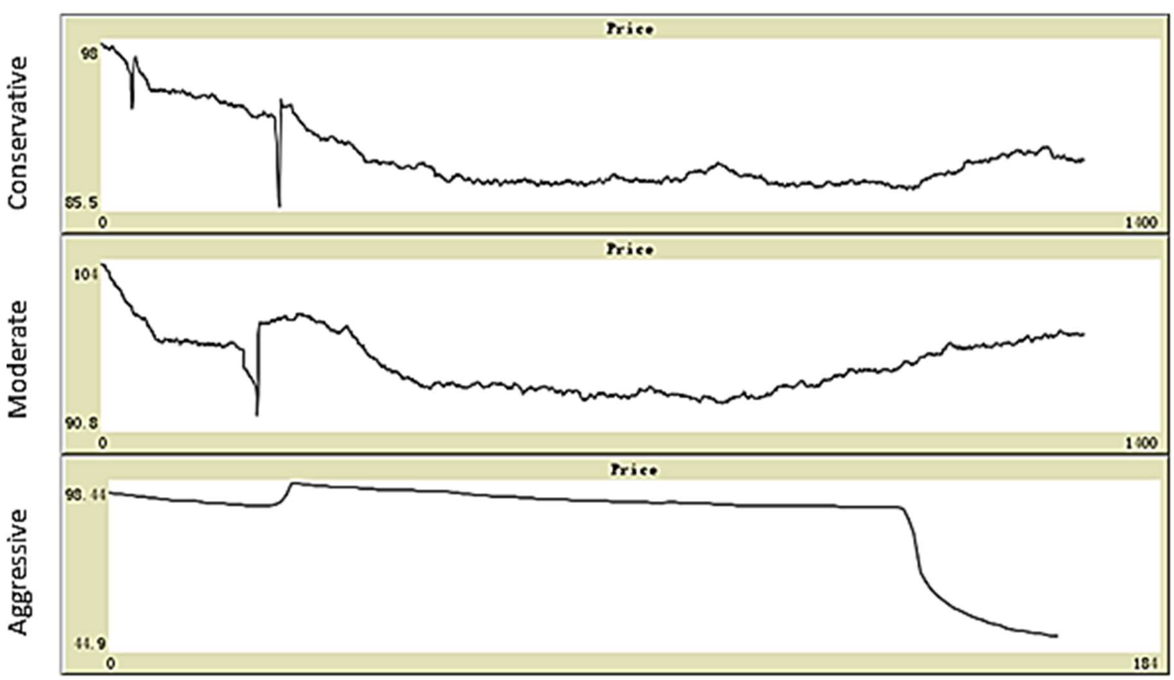

Figure 4: Impacts of Increased Overseas Holdings on Treasury Bond Price.

Moderate Market Structure. Due to the rise in overseas holdings, the investor structure shifts, assuming a 15% increase in the proportion of transactional investors. This leads to enhanced price stability. The closing price at the end of this period is 98.3, higher than the conservative scenario's 12.5, with the most significant drop of 8% nearly 5% lower than the conservative market. The price curve experiences a relatively smooth decline in the early stage, transforming the original two price jumps into a "slow decline and rapid rebound" pattern. This shift can be attributed to the increased proportion of overseas transactional investors, improving the market structure and boosting treasury bond market price stability.

Aggressive Market Structure. Assuming increased overseas holdings result in an aggressive change in market structure, setting the transaction to stop when the price falls to 50. The treasury bond price exhibits a gradual decline at the beginning of the bear market, differing from the previous two situations. Following the drop, there is no direct rapid decline jump; instead, a price recovery occurs at the observation period of 35 ticks, followed by a stable period lasting more than 100 ticks. A cliff-like drop emerges in the observation period of 140 ticks, corresponding to a sharp increase in transaction volume to 13,000. Subsequently, the lower limit is reached during the observation period of 184 ticks, resulting in the stagnation of repeat transactions. This scenario mirrors the reality in emerging markets, where foreign capital influxes during the boom of emerging markets contribute to transactional investment, providing stability for a certain period. However, a swift exit of funds leads to a rapid collapse in market prices.

4.3. Simulation of Investor Sentiment Effect

In our simulation, the parameter Ω serves as a measure of changes in investor sentiments regarding treasury bonds. A higher Ω value indicates stronger sensitivity to market information. Specifically, Ω set at 0 suggests investors' emotional numbness, reflecting insensitivity to market information. As Ω increases beyond 0, investor sentiments become more influential, leading to price fluctuations.

The simulation in Figure 5 analyzes four scenarios based on different Ω values:

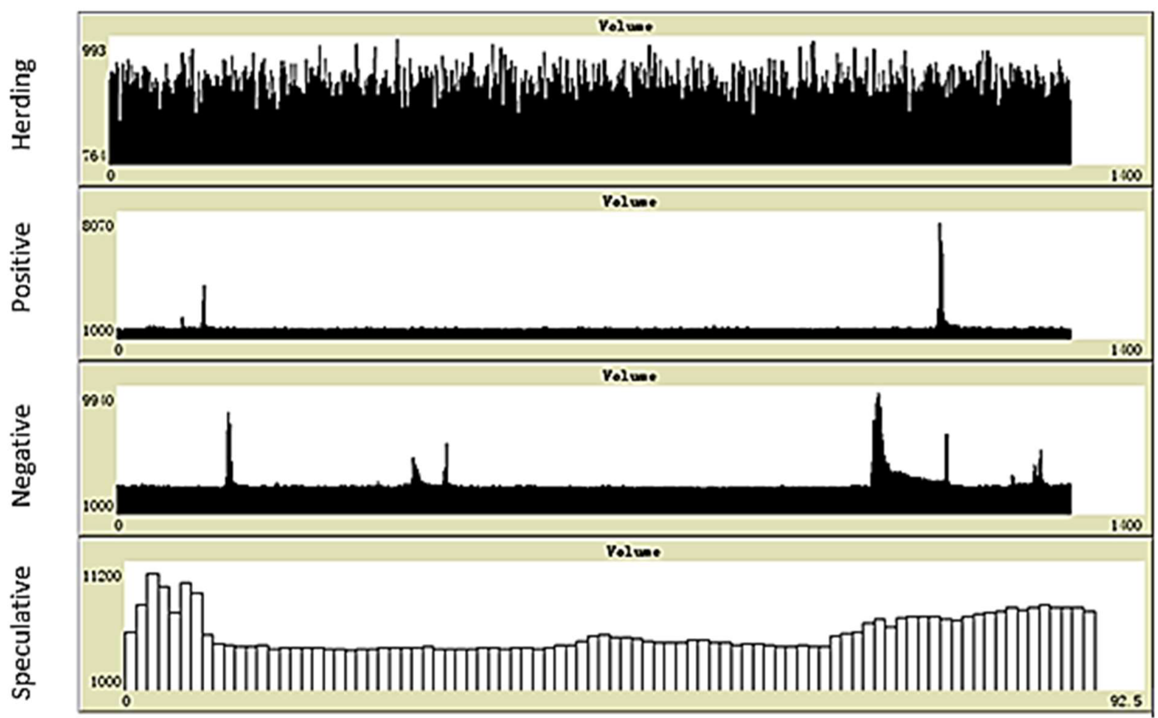

Figure 5: Impacts of investors' sentiment on treasury bond trading volume.

Hearding Emotions ($\Omega = 1$). Investors follow rational economic assumptions, making expectations based on macroeconomic and monetary policy changes. This reflects a stable market period where investors' expectations align, minimizing drastic fluctuations due to overly pessimistic or optimistic emotions. Tight monetary policy signals a bear market, but investors navigate the short-term policies without panic.

Positive Expectations ($\Omega = 2$). Investor sentiment sensitivity is slightly higher than following emotions, leading to increased trading adjustments. Despite heightened sensitivity, the downward price trend slows, and the early-stage price jumps decrease. The overall treasury bond price curve shifts upward, especially during ticks 500–800, exceeding 100 at its highest point, reflecting investors' optimistic expectations. Volatility induced by positive expectations benefits transactional investors in band operations, supporting market activity during the bear market.

Negative Expectations ($\Omega = 5$). With a significant increase in sentiment sensitivity, the price curve shows a distinct trend. In the early bear market stage, bond prices exhibit a gentle, continuous decline, with two small fluctuations before tick 1024. A sudden "crash" occurs at tick 1025, reaching the lower limit of suspension (50), indicating the destructive impact of investor pessimism. The slow downward trend in the early stage resembles the aggregation process of negative expectations, and the abrupt crash has a devastating effect on the market. The simulation results affirm the nonlinear relationship between investor sentiment and treasury bond prices. This nonlinearity complicates the monitoring and prevention of risk factors in treasury bond prices. Despite less sensitivity in price fluctuation than investors with a low Ω, a slow decline in negative expectations can lead to a disastrous impact in the later stages, highlighting the complexity of assessing and mitigating risk in treasury bond prices.

Speculative Sentiment ($\Omega = 10$). This scenario represents an extreme state where investor sentiments act as amplifiers of market information, with significant impacts on prices. Without setting a lower limit, the treasury bond price could converge to 0, emphasizing the extreme nature of speculative sentiment. A lower limit of 50 halts transactions at tick 87, depicting a rapid price decline and significantly higher trading volume compared to other scenarios. The simulation mirrors the phenomenon of overseas holdings rapidly withdrawing when expecting treasury bond depreciation, demonstrating theoretical significance. While the speculative sentiment scenario holds theoretical significance, the practical relevance lies in negative expectations for studying overseas holdings' fleeing during a treasury bond market downturn. The simulation outcomes provide valuable insights into the intricate dynamics of investor sentiments and their consequential effects on market behavior.

5. Conclusions

Our ABM simulations offer insights into various factors influencing the treasury bond market and the transmission effects of potential risks in the ICC. Three key conclusions emerge. First, monetary policy serves as a pivotal tool for stabilizing the treasury bond market. Counter-cyclical regulations have asymmetric effects in the weak efficient inter-bank bond market. Maintaining market stability requires a neutral monetary policy. Tight policies exhibit convergent characteristics, while expansionary policies show a lagged amplification effect. Second, introducing overseas institutions for ICC optimizes the onshore market structure. Overseas holdings contribute to market stability, offering investment proceeds. Simulations reveal that transactional investors can enhance market liquidity and treasury bond price stability, but an excessive level can lead to increased price fluctuations, especially with the presence of speculative investors. Third, the link between investor sentiment and treasury bond prices is non-linear. Investor sentiment, often seen as a price signal amplifier, exhibits a nuanced relationship. Moderate sentiment intensity offsets negative information impact, promoting price stability. However, elevated sentiment intensity poses a risk of price collapse after accumulation, emphasizing the non-linear nature of this relationship.

Building on these findings, we have the following policy implications. Robust monetary poli-cy is crucial, with a focus on mitigating hidden risks associated with the lag effect of quantitative easing. Moreover, gradual opening of the bond market requires safety measures and a risk monitoring system. Utilizing treasury bonds for ICC enhances market efficiency and stability. Establishing an effective risk monitoring system with safety parameters is essential to prevent external risks from speculative attacks. Therefore, it is advisable to strengthen information disclosure systems and regulate intermediary services to curb market manipulation. Given the influences of market sentiments, measures should be taken to improve rational judgment, foster transaction activity, and instil market confidence.

Author Contributions: Conceptualization, H.Z. and D.G.; methodology, D.G.; software, D.G.; validation, H.Z. and D.G.; formal analysis, H.Z. and D.G.; investigation, H.Z. and D.G.; resources, H.Z. and D.G.; data curation, H.Z. and D.G.; writing—original draft preparation, H.Z. and D.G.; writing—review and editing, H.Z. and D.G.; visualization, H.Z. and D.G.; supervision, H.Z. and D.G.; project administration, H.Z. and D.G.; funding acquisition, H.Z. and D.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by The National Social Science Fund of China, grant number 21BGJ074.

Conflicts of Interest: The authors declare no conflict of interest.

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