Losing grip?
The Quantity Theory of Money under Currency Competition*

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Abstract

This study examines currency competition between a centrally managed currency, the Dollar, and a rigid-supply alternative, Bitcoin, focusing on the role of monetary policy. Using theoretical modeling and laboratory experiments, we show that proportional transfers, modeled as interest on Dollar balances, increase Dollar trade shares (Dollar dominance) and reduce Dollar velocities, thereby weakening the pass-through of monetary policy to prices. These dynamics are self-fulfilling: low inflation expectations drive trade shifts and slower spending, which in turn suppress Dollar prices. In the lab, we observe how evolving expectations shape trade, velocity, and inflation. Dollar policy induces inflation spillovers into Bitcoin by crowding out trade, despite Bitcoin's lack of a monetary authority, revealing the limits of central bank influence in an increasingly pluralistic monetary system.

Key words: currency competition, cryptocurrencies, dominant currency, Quantity Theory of Money, exchange rates, currency crowding out, Gresham's law, Thier's law
JEL codes: E5, E4, C92

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1 Introduction

The rise of digital currencies, such as Bitcoin, stablecoins, and foreign central bank digital currencies (CBDCs), is increasingly challenging the dominance of traditional national currencies in the realm of trade (Duffie, 2019; Huberman, Leshno, and Moallemi, 2021; Prat and Walter, 2021; Makarov and Schoar, 2021; Saleh, 2021; Jermann, 2021; Andolfatto and Martin, 2022; Auer, Frost, Gambacorta, Monnet, Rice, and Shin, 2022; Biais, Bisiere, Bouvard, Casamatta, and Menkveld, 2023; Chiu, Davoodalhosseini, Jiang, and Zhu, 2023; Sockin and Xiong, 2023; Von Luckner, Reinhart, and Rogoff, 2023; Brunnermeier and Landau, 2023; John, Kogan, and Saleh, 2023; Brunnermeier, Limodio, and Spadavecchia, 2023; Jermann, 2023). As of May 2025, Bitcoin's market capitalization exceeded $1.66 trillion, surpassing the Canadian Dollar M1 and reaching nearly half the size of the UK's M1 money supply (see Figure 1). This trend highlights the growing relevance of decentralized currencies and intensifying currency competition at the national level.

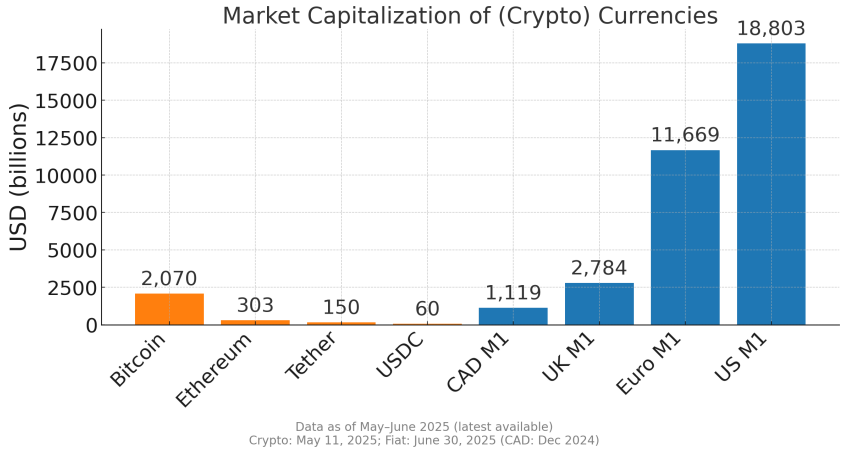


Figure 1: National currencies (M1), cryptocurrencies and stablecoins by market capitalization

As agents gain the option to transact in alternative currencies, the effectiveness of monetary policy, i.e. its transmission into Dollar inflation, becomes uncertain. Using both theoretical modeling and controlled laboratory experiments, this paper explores how interactions between monetary policy and currency competition unfold, and assesses the conditions under which currency competition undermines or coexists with effective monetary policy. While previous theoretical studies have examined currency competition and its impact on exchange rates (Kareken and Wallace, 1981; Manuelli and Peck, 1990; Arifovic, 2001; Garratt and Wallace, 2018), currency competition under transaction costs (Camera, Craig, and Waller, 2004; Schilling and Uhlig, 2019b) or competition among privately issued monies (Marimon, Nicolini, and Teles, 2003, 2012; Fernández-Villaverde and Sanches, 2019; Rahman, 2018; Zhu and Hendry, 2018), few have investigated how it challenges central banks by possibly undermining the effectiveness of monetary policy transmission to prices, or, in extreme cases, by threatening to crowd out the domestic currency entirely.

In this context, Girton and Roper (1981) study currency substitutability but with exogenous drivers, Schilling and Uhlig (2019a) analyze how monetary policy interacts with currency competition, currency pricing, and policy pass-through, demonstrating that expansionary monetary policy may not only affect domestic (Dollar) prices but can also spill over into the price of competing currencies such as Bitcoin. Benigno, Schilling, and Uhlig (2022) argue that competition with global currencies can further tighten the constraints

of the Mundellian trilemma, potentially leading to national currency crowding-out unless central banks coordinate interest rate policies. Bolt and Van Oordt (2020) study speculation and volatility in cryptocurrencies within a currency competition framework grounded in the Quantity Theory of Money. However, their analysis assumes that the central bank's inflation target for the Dollar price level is always achieved. Biais, Rochet, and Villeneuve (2025) show that currency competition may limit a central bank's ability to set inflation.

Prior experimental work on currency competition, such as Camera, Noussair, and Tucker (2003b), Rietz (2019), and Jiang and Zhang (2018), focuses on competition between fiat currencies or indivisible assets in search-based environments. Ding and Puzzello (2020) and Vidal, Hoyle, Vargas, and Vásquez (2022) examine the role of legal and tax-based government interventions. Jiang, Puzzello, and Zhang (2023) study the quantity theory of money (QTM), but in a single-currency economy. In contrast, our experiment isolates how monetary policy, specifically through proportional transfers akin to interest payments on Dollar balances, shapes currency competition.

Building on Kareken and Wallace (1981); Schilling and Uhlig (2019a), this paper contributes to the theory and the experimental literature on currency competition and monetary policy by studying a novel monetary policy implementation tool: proportional transfers, that is, interest paid on Dollar balances, akin to interest on reserves or interest-bearing CBDC accounts. Unlike suggested in Garratt and Wallace (2018), who conclude that such interest payments merely expand the money supply without affecting behavior and prices, we show that this policy modification is not minor, as it introduces a novel transmission channel. Unlike conventional, symmetric lump-sum transfers employed in Kareken and Wallace (1981); Schilling and Uhlig (2019a), or interest rates on bonds (Benigno, Schilling, and Uhlig, 2022), proportional monetary policy transfers scale with individual Dollar holdings, and thus reshape the competitive dynamics between currencies by altering the relative attractiveness of Dollar usage in goods markets. As we show, the interest on Dollar balances affect not only agents' budget constraints but directly enters their intertemporal consumption-saving decisions and currency invoicing choices. By affecting relative trade incentives, this policy mechanism, as we show, alters both the composition of currency usage and the path of price dynamics. Biais, Rochet, and Villeneuve (2025) study wealth-proportional transfers that scale with public money and capital investment. However, they assume perfect monetary policy pass-through into Dollar prices. In contrast, we endogenize price-level responses and characterize the full equilibrium set, leading to novel equilibrium types, such as a money illusion, see below.

The experimental study most closely related to ours is Cardozo, Rosokha, and Zhang (2024), who also examine monetary policy and the QTM under currency competition. However, following the earlier theoretical literature, they implement monetary policy through symmetric lump-sum transfers. In contrast, we introduce proportional, interest-bearing transfers. Our novel implementation leads to a broader class of equilibrium and fundamentally different outcomes, as detailed below.

Empirical research on currency competition using field data is hindered by regulatory constraints and limited transaction-level data. To overcome this and test our theory, we conduct a controlled laboratory experiment. In our theory and experiment, buyers and sellers trade using two competing currencies: a domestic currency ("Dollar"), subject to active monetary policy, and a competing currency ("Bitcoin"), which represents any alternative currency with muted or independent monetary policy. We envision a future world

in which both currencies are equally accepted in exchange for goods. The experiment features two treatments, one without and one with active monetary policy (Benchmark versus MP). In the benchmark treatment, both Bitcoin and Dollar supplies remain constant. In the monetary policy treatment, the Dollar supply increases by 30% per round, implemented via interest payments on Dollar balances while the Bitcoin supply stays constant. Our experimental design is framed in neutral terms, Currency A (Dollar) and Currency B (Bitcoin), to avoid bias in participants' preferences.

Our setup mirrors real-world cases like El Salvador, where the U.S. Dollar and Bitcoin circulate side by side (Alvarez, Argente, and Van Patten, 2023). Although Bitcoin's legal tender status has weakened since January 2025, such dual-currency systems reflect a broader trend. Our model extends to other plausible scenarios where fiat currencies compete with stablecoins, decentralized cryptocurrencies, or foreign CBDCs, as decentralized and foreign currencies increasingly rival traditional ones in scale.

Both our theory and experiment adopt a general equilibrium perspective: Inflation expectations and monetary policy jointly influence sellers' invoicing and buyers' consumption-savings choices. In turn, these decisions endogenously determine currency dominance in trade and currency velocities, which, in return, shape market clearing goods prices, which adjust flexibly, in either currency and feed back into inflation expectations. In particular, Dollar usage in trade, i.e. its "adoption" or "dominance" relative to Bitcoin, evolves endogenously over time, driven by equilibrium forces.

We keep aggregate output constant across time in theory and the experiment. Therefore, we do not address optimal monetary policy. Rather, we want to isolate the effect of monetary policy on trade allocations, velocity and price pass-through, depending on beliefs. Since prices are flexible, output constancy is without loss of generality, since money is neutral.

The central policy questions we address are: (i) can interest-bearing, proportional monetary policy effectively guide Dollar inflation under currency competition, i.e. does the quantity theory of money hold despite the presence of Bitcoin? (ii) can the central bank deliberately crowd out Bitcoin and increase Dollar trade dominance by raising the interest rate on Dollar balances? (iii) does Dollar monetary policy interfere with Bitcoin prices? While a higher interest rate strengthens incentives to hold Dollars, our analysis reveals that the outcome critically depends on how quickly agents update their inflation expectations.

In line with Kareken and Wallace (1981), in the absence of monetary policy, sellers prefer to transact in the currency with lower expected inflation, that is, the one that better preserves purchasing power. However, once proportional Dollar monetary policy is introduced, both buyers and sellers begin to weigh expected inflation against the benefits of central bank transfers, which grow with larger Dollar holdings.

As our main contribution, we show, both in theory and the experiment, that proportional monetary policy operates through two distinct and inversely related channels: it can either steer domestic Dollar inflation or influence the Dollar's trade share relative to the competing currency, but not both at once. Strengthening one transmission channel inherently weakens the other. The central bank cannot simultaneously achieve both high Dollar dominance and strong price-level control. We theoretically construct both equilibria types and observe them in the lab.

The first type of equilibrium, which we refer to as *Tempered pass-through with Trade shift and Spill-over*, arises when agents adjust their Dollar inflation expectations slowly in re-

sponse to monetary policy. In that case, the pass-through of monetary expansion into Dollar prices is dampened, instead Bitcoin inflation occurs (monetary policy spill-over), and Dollar dominance in trade rises. In this first equilibrium type, proportional policy induces a form of rational money illusion (Shafir, Diamond, and Tversky, 1997), or can give rise to a variant of Gresham's Law ("bad money drives out good," see Fetter 1932; Rolnick and Weber 1986; Greenfield and Rockoff 1995).

This result arises if agents have low inflation expectations in response to monetary policy, and try to take advantage of the transfers. Sellers shift trade into the Dollar, raising Dollar dominance, and buyers reduce Dollar velocity by hoarding balances. Two mechanisms impact Dollar and Bitcoin prices. On the one hand, the trade shift towards the Dollar and the Dollar velocity reduction both weaken the pass-through of monetary policy into market clearing Dollar goods prices, making low inflation expectations accurate *ex post*. That is, while the money illusion, i.e. the belief that interest payments are "costless" in terms of purchasing power, may appear irrational at first, it is rationalized by the self-fulfilling nature of equilibrium. Since, inflation beliefs are self-fulfilling, the money illusion is self-sustaining. This self-fulfilling dynamic breaks the QTM. In the standard single-currency setting, the quantity theory predicts a near one-to-one relationship between money supply and prices (see Friedman, 1956; Allais, 1966; Friedman, 1989; Lucas, 1980; Sargent and Surico, 2011; Teles et al., 2016). Here, instead, an increase in Dollar supply by a given factor does not yield proportional inflation, inflation undershoots in response to the trade shift.

On the other hand, Bitcoin prices rise due to supply scarcity (trade reallocation), despite the absence of an active Bitcoin central bank. The Bitcoin inflation arises as a fixed quantity of Bitcoin chases a reduced quantity of goods offered for trade. This shows how expansive monetary policy in one currency can induce inflationary pressure in another through changes in trade allocation. Our findings challenge the common belief that limiting Bitcoin issuance shields it from inflation. In our model, Bitcoin is a currency with inactive monetary policy and temporarily fixed supply, akin to a non-interest-bearing foreign CBDC. By contrast, stablecoins like Tether or USDC maintain pegs through arbitrage-based mint-and-burn mechanisms that adjust supply in response to demand. While our model does not capture the case of "Bitcoin" as a stablecoin, both theory and experimental results show that trade imbalances triggered by active Dollar monetary policy can put substantial pressure on peg mechanisms, potentially destabilizing pegs, as illustrated by the Swiss National Bank's failed Euro peg.

The second type of equilibria we describe, which we call *Strong pass-through via Expectations updating*, arises when agents revise their inflation expectations rapidly in response to monetary policy, and hence avoid the money illusion. Instead, they spend Dollars quickly and shift trade toward the currency with lower expected inflation, Bitcoin. As a result, despite interest payments on Dollar balances, monetary policy passes through strongly into Dollar prices, validating the initial inflation expectations. Therefore, this type of equilibrium is likewise self-fulfilling. Thiers' Law applies: agents prefer trading in the currency with lower inflation expectations, i.e. Bitcoin. Dollar prices evolve closer to the QTM.

Our regressions based on the experimental data confirm the inverse relationship between Dollar dominance and monetary policy pass-through: as Dollar trade shares rise in response to proportional monetary policy, Dollar goods prices fall (pass-through weakens) while Bitcoin prices rise. Overall, price responses fall short of what Dollar supply changes alone would predict under the QTM.

Our results speak directly to a pressing policy question: Can a central bank deliberately

crowd out Bitcoin, i.e., increase the Dollar's trade dominance, by adjusting the interest rate on Dollar balances? While a higher interest rate strengthens incentives to hold Dollars, our analysis shows that the resulting effect critically depends on how agents revise their inflation expectations in response to policy. Only if expectations update slowly, the increased interest rate leads to higher Dollar usage with limited inflation. However, generically, inflation expectations are not independent of policy. Moreover, because the central bank cannot directly steer private expectations, it cannot unilaterally select the equilibrium. This insight places fundamental limits on monetary sovereignty in dual-currency environments: the central bank can influence the direction of monetary transmission, but not its destination.

Previous theoretical and experimental work cannot replicate the equilibrium that involves a trade shift and a money illusion with Bitcoin spill-overs. Our findings confirm the multiplicity result of Schilling and Uhlig (2019a), showing that monetary policy may affect either Dollar or Bitcoin prices. Unlike their setup, where all goods are sold in both currencies, we allow sellers to choose the invoicing currency. This feature, combined with proportional monetary policy, generates equilibria with observable trade shifts, a novel outcome not present in Schilling and Uhlig (2019a). Garratt and Wallace (2018) show that a currency's value increases with its usage share and decreases with its supply, treating usage and supply as independent. In contrast, we demonstrate that interest-bearing monetary policy endogenously links supply and usage: an increase in supply can raise usage, thereby dampening or amplifying price effects relative to models assuming independence. At the same time, our findings generalize the results in Biais, Rochet, and Villeneuve (2025), who assume perfect monetary policy pass-through and conclude that agents always shift trade into the less inflationary currency. Their analysis captures the second equilibrium type we identify. By endogenizing inflation expectations, we show that a first equilibrium type also exists, in which slow expectation updating leads to Dollar hoarding, a rise in Dollar trade, and Bitcoin inflation, even when the Dollar is more inflationary. This crucial distinction implies that, under endogenous pass-through, currency competition does not generically constrain Dollar monetary policy: the central bank cannot reliably crowd in or crowd out Bitcoin by adjusting interest rates alone. Our experimental results challenge those of Cardozo, Rosokha, and Zhang (2024), who, under symmetric lump-sum transfers, find that agents shift toward the less inflationary currency (Thiers' law), leading to strong price pass-through consistent with the QTM. In other words, they recover only our strong pass-through equilibrium, but not the equilibrium with rising Dollar trade dominance and Bitcoin price spillovers.

Our results suggest that in the future, central banks, which currently pledge never to set positive interest rates on CBDCs, possibly out of concern for disintermediating commercial banks, may nevertheless be forced to do so, see (Andolfatto, 2021; Fernández-Villaverde, Sanches, Schilling, and Uhlig, 2021; Keister and Sanches, 2023). In particular, central banks may need to offer positive interest rates on CBDCs to remain competitive against foreign CBDCs, or cryptocurrencies that yield positive returns, thereby preventing a loss of trade share to these alternative currencies. While in our main analysis, Bitcoin serves as a placeholder for a foreign currency with temporarily muted and sovereign monetary policy (foreign CBDC, non-interest-bearing stablecoin) we consider a robustness check, where "Bitcoin" also pays a return on holdings, potentially different from the Dollar rate. The resulting monetary policy outcomes then depend on the interest rate differential. A higher

Bitcoin rate reduces the incentive to hold or trade Dollars, potentially reversing Dollar dominance or weakening Dollar pass-through.

Our theoretical analysis further examines deviations from the QTM under both perfect foresight and strategic uncertainty. We find that even under perfect foresight, pass-through from proportional monetary policy is incomplete, yielding only a tempered version of the theory. We confirm this in the lab, where Dollar inflation systematically undershoots the QTM benchmark. Under strategic uncertainty, inflation undershooting becomes even more pronounced.

In detail, we show that trade reallocation effects, such as Gresham's Law (crowding out Bitcoin) or Thiers' Law (crowding in Bitcoin), can arise even under perfect foresight. That is, even when agents have correct expectations and face no strategic uncertainty, interest-bearing Dollar policy can induce substantial shifts in currency trade shares, and in either direction. Thus, changes in currency dominance do not require belief misalignment or coordination failure but can result solely from policy-driven incentives.

Despite these shifts, all symmetric perfect foresight equilibria feature a tempered but contained pass-through of monetary policy into Dollar prices: Dollar inflation equals the discounted interest rate on Dollar balances, thus, we show that a tempered version of the QTM applies. Bitcoin inflation remains fixed at the discount rate, indicating no spillovers from Dollar policy into Bitcoin prices, regardless of trade share or velocity adjustments. This shows that stronger deviations, both above and below the tempered QTM and spillover to Bitcoin, require strategic uncertainty. Following Sargent and Wallace (1973), we formalize how such deviations arise when agents correct their expectations on inflation, trade shares, or velocities over time, leading to under- or overshooting of Dollar inflation relative to the tempered QTM.

A complementary strand of the literature examines exporting firms' invoicing currency decisions and the emergence of dominant currencies under nominal rigidities (Gopinath, Boz, Casas, Díez, Gourinchas, and Plagborg-Møller, 2020; Amiti, Itskhoki, and Konings, 2022; Mukhin, 2022). This approach emphasizes how sticky prices expose exporting firms to exchange rate fluctuations and how invoicing choices can serve as a hedge against exchange rate pass-through. In contrast, our framework features fully flexible prices, as in Kareken and Wallace (1981), eliminating exchange rate exposure through price adjustment. Here, currency choice is instead driven by inflation risk and monetary policy, since sellers anticipate becoming buyers in the future and want to sell for or hold the currency with higher purchasing power.

There is a large literature that develops and tests microfoundations for money's acceptance in trade by explaining how intrinsically worthless objects can function as media of exchange. These models typically show how money facilitates transactions by resolving the double coincidence of wants problem in decentralized barter or search-based markets (Kiyotaki and Wright, 1989, 1993; Rocheteau and Wright, 2005; Lagos and Wright, 2005; Camera and Corbae, 1999). Experimental work on these models has focused on the emergence of money (Brown, 1996; Duffy and Ochs, 1999, 2002; Camera, Noussair, and Tucker, 2003a; Camera and Casari, 2014), price formation (Duffy and Puzzello, 2014a,b), and the essentiality of money in monetary search environments (Jiang, Norman, Puzzello, Sultanum, and Wright, 2024). Following Kareken and Wallace (1981), our theoretical and experimental framework employs centralized goods markets, and assumes the use of money in trade, rather than deriving it from first principles. Our approach reduces structural assumptions, allowing us to focus on monetary policy under currency competition in a controlled lab

setting where subjects have limited cognitive capacity.

The rest of the paper is organized as follows. Section 2 presents the model, Section 4 derives our main theoretical results and testable hypotheses, Section 3 dives deeper into the analysis of the QTM in our model. This section is quite technical and could be skipped over, as Section 5 then details the experimental design, Section 6 reports on the experimental results, and Section 7 concludes.

2 The Model

Building on Schilling and Uhlig (2019a), we consider an infinite-horizon endowment economy in discrete time, indexed by $t = 1, 2, \ldots$. The infinite time horizon has the advantage that, unlike in overlapping generations models such as Kareken and Wallace (1981), agents can adjust their behavior in response to monetary policy not only through prices and trade shares, but also through savings decisions, i.e., velocities.

2.1 General Setting

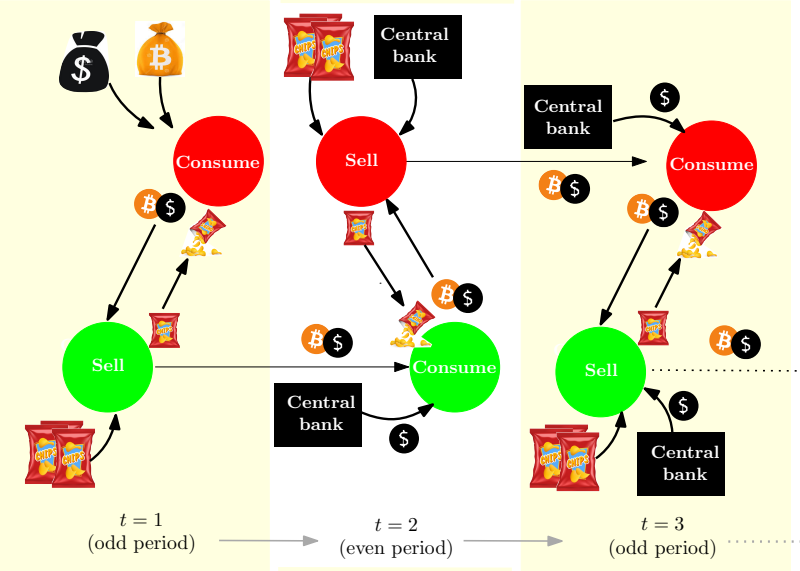
Goods and media of exchange There is a single, perishable consumption good, referred to as packages (of "chips") which can be traded using either of two competing currencies. We may label these currencies as "Dollars" and "Bitcoins." The term "Dollar" denotes a currency whose supply is determined at the discretion of a monetary authority, such as a central bank or a smart contract capable of responding endogenously to market conditions.[1] Conversely, the term "Bitcoin" serves as a proxy for currencies that lack such a discretionary monetary authority or for which monetary policy remains inactive.[2] In the experimental implementation, we refer to the currencies more neutrally as "currency A" and "currency B" to avoid bias stemming from subjects' potential predispositions toward Bitcoin or the Dollar. In the model, both currencies are assumed to be equally accepted for transactions in the goods market.

Buyers and sellers To match the experimental setting, and in contrast to Schilling and Uhlig (2019a,b), we consider a discrete and finite number of agents. Specifically, the economy consists of two equally sized and infinitely lived groups: N "green" agents and N "red" agents, resulting in a total of $2N$ agents. All agents derive utility from consuming the perishable good, but not from holding money balances. At each time t, agent i obtains utility $u(c_{i,t})$ from consumption $c_{i,t} \geq 0$, where the utility function $u(\cdot)$ is strictly increasing, strictly concave, twice continuously differentiable, and satisfies $u(0) = 0$.

Following Schilling and Uhlig (2019a,b), we introduce a transactional motive for money by assuming that agent groups alternate roles between buyers (consumers) and sellers of the consumption good over time, as illustrated in Figure 2. This structure resembles overlapping generations models (Kareken and Wallace, 1981; Manuelli and Peck, 1990; Garratt and Wallace, 2018), where the young (goods sellers) demand money to build savings, and the old (buyers) spend money to purchase goods.

[1] For example, one may consider the Terra-Luna swap mechanism, which allowed users to exchange Terra for Luna and vice versa by burning or minting Luna, with conversion rates that adjusted based on market prices.

[2] While the Bitcoin protocol can be interpreted as a constrained form of central banking – since it specifies a predetermined supply path until a cap of 21 million coins is reached – it differs fundamentally from the Dollar in that its supply cannot be adjusted discretionarily.



Notes: Two agent-groups, the *red* and the *green* agents, alternate in the role of sellers and buyers of the single consumption goods, referred to as chip packages.

Figure 2: Schematic representation of the structure of the economy

In even periods, red agents have a symmetric, exogenous individual endowment of $\bar{y}$ units (of chips packages), which they can sell to green agents in exchange for either Dollars or Bitcoin. In these periods, green agents act as buyers and can consume. The roles reverse in odd periods: green agents become sellers with the same endowment $\bar{y}$, and red agents become buyers. Hence, agents alternate between being sellers and buyers over time. There is no idiosyncratic nor aggregate risk, the aggregate supply of the consumption good in any period t is $Y = N\bar{y}$, and the individual, symmetric endowments are constant across time, at $\bar{y}$ for all $t > 0$. We hold output constant to isolate the effects of monetary policy on trade shares, velocity, and price pass-through. Since we assume flexible prices, holding output constant is without loss of generality: money is neutral and would not affect production in our framework.

To finance purchases, each buyer is endowed in period $t = 1$ with d_1 Dollars and b_1 Bitcoin. This implies an initial aggregate money supply of $D_1 \equiv Nd_1$ Dollars and $B_1 \equiv Nb_1$ Bitcoin. In all subsequent periods, agents' money balances evolve based on their trading history and potentially through monetary policy, as described below.

Agents derive utility only when they are in the buyer role, i.e., they do not consume in periods in which they are sellers. Since the consumption good is perishable and cannot be stored, sellers at every t have a strict incentive to sell all of their package endowment to the buyers of that period. By doing so, they convert their goods into currency, which can then be used to finance consumption in the subsequent period when their role switches. Therefore, agents derive utility only in every other period, and choose their consumption and currency savings to maximize expected discounted lifetime utility,

$$U = \sum_{t=0}^{\infty} \xi_t \, \beta^t \, \mathbb{E}[u(c_t)], \quad \begin{cases} \text{if green agent:} & \xi_t = \begin{cases} 0 & t = 2k+1, k = 0,1,2,.. \\ 1 & t = 2k, k = 0,1,2,.. \end{cases} \\ \text{if red agent:} & \xi_t = \begin{cases} 1 & t = 2k+1, k = 0,1,2,.. \\ 0 & t = 2k, k = 0,1,2,.. \end{cases} \end{cases} \qquad \beta \in (0,1). \quad (1)$$

Trade and market-segmentation Unlike Schilling and Uhlig (2019a,b), where all goods are simultaneously available for sale against both currencies, our model assumes semi-segmented goods markets. In each period, sellers must preallocate their individual endowments across two currency-denominated, centralized markets. Specifically, let $x_{i,t} \geq 0$ denote the quantity of packages seller i offers for sale in the Bitcoin-denominated market, and let $z_{i,t} \geq 0$ denote the quantity offered in the Dollar-denominated market. Sellers are subject to the allocation feasibility constraint: $x_{i,t} + z_{i,t} \leq \bar{y}$,.

The total package supply available for purchase in each currency market, $Y_t^D, Y_t^B = Y - Y_t^D$ is determined by the sellers' allocation decisions:

$$Y_t^D = \sum_{i=1}^{N} z_{i,t}, \qquad Y_t^B = \sum_{i=1}^{N} x_{i,t}. \tag{2}$$

Importantly, each seller can choose to allocate all, some (interior), or none of their packages to either the Dollar- or the Bitcoin-denominated market. We define the Dollar trade share as the share of output offered for sale in the Dollar market, $k_t \equiv \frac{Y_t^D}{Y} \in [0, 1]$.

The Dollar trade share is a key variable in our analysis since it reflects the sellers' joint allocation decision across the Dollar- versus the Bitcoin-denominated markets, i.e. indicates the relative importance of each currency in trade. A higher Dollar allocation, $Y_t^D > Y_t^B$, indicates that sellers, on average, prefer receiving Dollars over Bitcoin, a situation we refer to as *Dollar dominance in trade*.

After the sellers have allocated their packages across markets, the Bitcoin- and Dollar-denominated goods markets open for buyers to trade. From the buyers' perspective, the two markets are segmented, and there is no direct exchange between currencies. Upon entering the markets, buyers observe the aggregate package allocations, Y_t^D and Y_t^B, which in turn influence the market clearing prices in period t, as detailed below.

After allocating packages to the Dollar and Bitcoin markets, sellers cannot reallocate during the trading stage. Consequently, they cannot adjust to unexpected differences in trade conditions across markets within the same period. Their strategic responses are delayed and affect only future periods. Nevertheless, from the sellers' perspective, the two currency markets are strategically interconnected. Knowing they will act as buyers in the subsequent period, sellers choose their package allocations to equalize the expected utility of receiving Dollars versus Bitcoins. In this sense, although the goods markets are formally segmented, they are indirectly linked through the sellers' intertemporal optimization and expectations about future trade and currency usage.

Finally, markets are centralized, and there are no search frictions or costs associated with accessing either market, i.e. buyers and sellers can freely and instantaneously engage in trade in both markets.

Prices and budgets Prices adjust flexibly to clear markets. Let P_t denote the market-clearing price of a package in the Dollar-denominated market, and let $\hat{P}_t$ be the market-clearing Bitcoin price of a package. While excluding direct currency exchange, define Q_t as the implicit nominal exchange rate, that is, the price of one Bitcoin in terms of Dollars, where the law of one price (purchasing power parity) implies

$$Q_t = \frac{P_t}{\hat{P}_t}. \tag{3}$$

Buyer i's consumption $c_{i,t}$ in period t can be decomposed into the quantity of goods purchased with Dollars $q_{i,t}^D$ versus Bitcoin, $q_{i,t}^B$, $c_{i,t} = q_{i,t}^D + q_{i,t}^B$. Consumption happens in-

stantaneously after a purchase. Each buyer faces two currency-specific budget constraints:

$$P_t q^D_{i,t} \leq d_{i,t}, \tag{4}$$

$$\hat{P}_t q^B_{i,t} \leq b_{i,t}, \tag{5}$$

where $d_{i,t}$ and $b_{i,t}$ denote the buyer's holdings of Dollar and Bitcoin, respectively, at the beginning of period t, i.e., prior to trade.

Monetary policy and Money balances In the absence of a Bitcoin central bank, and abstracting from Bitcoin mining or the loss of Bitcoin through forgotten keys, the Bitcoin supply is assumed to be constant over time, i.e., $B_t \equiv \bar{B}$. Following Schilling and Uhlig (2019a), we introduce a Dollar central bank that aims to implement an inflation target by adjusting the supply of Dollars, which it can issue at zero cost. A key departure from prior theoretical work lies in the mechanism of monetary expansion. Unlike in Kareken and Wallace (1981); Garratt and Wallace (2018); Schilling and Uhlig (2019a), where the central bank (or government) conducts monetary policy through symmetric lump-sum transfers, our central bank expands the Dollar supply by remunerating individual Dollar balances with a gross interest $m \geq 1$ at the end of each period, after trade has occurred. This policy results in *asymmetric* transfers across agents, with the amount of the transfers being proportional to each agent's individual Dollar holdings. In the real world, for instance, the central bank pays interest rates on reserves, and may pay interest rates on central bank digital currency holdings.

The aggregate Dollar supply evolves according to

$$D_t = mD_{t-1} = m^{t-1}D_1,\ t > 2, \qquad D_1 = N \times d_1,$$

where d_1 denotes the initial Dollar endowment per agent, D_1 is the initial Dollar supply in $t = 1$, and D_t denotes the Dollar supply at the beginning of period t, i.e., after the central bank has applied interest to balances from period $t-1$ and before trade begins in t. If $m = 1$, Dollar monetary policy is mute, and the Dollar supply remains constant over time. Define the realized Dollar inflation as $\Pi_t = \frac{P_t}{P_{t-1}}$, and the Bitcoin inflation accordingly.

To describe the evolution of money balances, consider an agent who acts as a buyer, entering the period t with $d_{i,t}$ Dollars and $b_{i,t}$ Bitcoin. After spending part of her Dollar and Bitcoin balances on consumption, she is paid the interest rate m on the remaining Dollar balances, and then becomes a seller in the following period $t+1$. Her updated money balances as a seller at the beginning of period $t+1$ are given by: $d_{i,t+1} = m\left(d_{i,t} - q^D_{i,t}P_t\right)$, and $b_{i,t+1} = b_{i,t} - q^B_{i,t}\hat{P}_t$, where the term $d_{i,t+1}/m$ represents the unspent Dollar balance (i.e., savings) carried over from period t, which is then augmented by the gross interest $m \geq 1$. The Bitcoin balance is carried forward without interest. These balances constitute the agent's initial money holdings when entering the seller role in period $t+1$. Conversely, an agent acting as a seller in period t augments her Dollar and Bitcoin balances through sales revenues, and her Dollar balance also receives a proportional transfer from the central bank in the form of interest payments. Her updated balances at the beginning of period $t+1$ are: $d_{i,t+1} = m\left(d_{i,t} + z^s_{i,t}P_t\right)$, and $b_{i,t+1} = b_{i,t} + x^s_{i,t}\hat{P}_t$. Individual money balances need to sum up to the total supply, i.e. no currency is lost, $B = \sum_{i=1}^{2N} b_{i,t}$, and $D_t = \sum_{i=1}^{2N} d_{i,t}$.

2.2 Market clearing and equilibrium

The pre-trade allocation of the sellers' goods endowments across the two currency-specific markets gives rise to two separate market-clearing conditions

$$\begin{cases} Y & = Y_t^D + Y_t^B \\ Y_t^D = \sum_{i=1}^N z_{i,t} & = \sum_{i=1}^N q_{i,t}^D, \\ Y_t^B = \sum_{i=1}^N x_{i,t} & = \sum_{i=1}^N q_{i,t}^B. \end{cases} \tag{6}$$

Velocity and Savings rate Unlike overlapping generations models (Kareken and Wallace, 1981; Manuelli and Peck, 1990; Garratt and Wallace, 2018), which inherently imply an equilibrium velocity of one, as agents spend all balances in their final period, our framework features infinitely lived agents. Therefore, velocity in our framework emerges as a meaningful equilibrium object, allowing us to study endogenous and time-varying velocities in response to monetary policy, possibly attenuating its direct pass-through to goods prices.

By design, our model imposes an upper bound of one on the velocity of either currency. Accordingly, the velocity in our setting corresponds to the share of the total currency supply that is spent within a given period:

$$V_t^B = \frac{\hat{P}_t \sum_i^N q_{i,t}^B}{B} \in [0,1], \qquad \text{and} \qquad V_t^D = \frac{P_t \sum_i^N q_{i,t}^D}{D_t} \in [0,1]. \tag{7}$$

The summation reflects that only the buyers, not the sellers, can spend currency. We define the *Dollar* and *Bitcoin* savings rates in the economy as the share of unspent currency at time t (before money balances are augmented by the central bank at the end of t):

$$s_t^B = 1 - V_t^B \in [0,1], \qquad s_t^D = 1 - V_t^D \in [0,1]. \tag{8}$$

Timing within period Each period t is subdivided into sequential stages reflecting the timing of decisions and information flows:

1. *Sellers move first.* Sellers in t observe all prices, quantities, and velocities from period $t-1$ and earlier. Based on this information, they decide how to allocate their goods across the two markets. In the aggregate, they determine the trade allocations Y_t^D and Y_t^B. At this point, trade has not opened yet, meaning that contemporaneous prices P_t and $\hat{P}_t$ for period t have not yet formed and are therefore not observable to sellers. To reflect these facts, we will use the notation t^-, indicating that t-sellers draw on all information available *earlier* than t, but not including t, when making their decisions.[3]
2. *Buyers move second.* After sellers have moved, trade opens to buyers, who observe the sellers' trade shares Y_t^D and Y_t^B. Market-clearing prices P_t, $\hat{P}_t$, and velocities V_t^D, V_t^B form and become observable. Buyers then make consumption and saving decisions based on current allocations, prices, and velocities, while forming expectations about future prices P_{t+2}, $\hat{P}_{t+2}$, when they are buyers again, using all available period-t information.

While the model is deterministic, it admits, as we show, infinitely many perfect foresight equilibria. In practice, however, agents cannot be expected to coordinate on a par-

[3] We chose against the notation $\mathbb{E}_{t-1}[.]$, as this would give the impression that $t-1$ sellers were moving.

ticular equilibrium, a limitation that mirrors laboratory settings. The absence of a coordination device gives rise to strategic uncertainty, introducing stochastic features into the deterministic framework. Outside the perfect foresight case, we assume agents are rational and choose strategies based on their expectations of future prices and quantities, using all information available at the time of action. Section 4 analyzes both perfect foresight and rational expectations equilibria. The following definition encompasses both cases.

Definition 2.1 (Equilibrium)**.** *Given monetary policy $m \geq 1$, an equilibrium of the trade game between red and green agents consists of:*

(i) Dollar and Bitcoin price sequences $\{P_t\}_{t\geq 0}$ and $\{\hat{P}_t\}_{t\geq 0}$, implying an exchange rate sequence $\{Q_t\}_{t\geq 0}$ with $Q_t = \frac{P_t}{\hat{P}_t}$;

(ii) Package allocation decisions by sellers to the Dollar market $\{z_{i,t}\}_{t\geq 0}$ and the Bitcoin market $\{x_{i,t}\}_{t\geq 0}$, which in the aggregate determine the output allocated to the Dollar market $\{Y_t^D\}_{t\geq 1}$ and to the Bitcoin market $\{Y_t^B\}_{t\geq 1}$, where $Y_t^B = Y - Y_t^D$, and the Dollar trade share $k_t = Y_t^D / Y$;

(iii) Consumption-savings decisions by buyers in the Dollar market $\left\{q_{i,t}^D, d_{i,t+1}\right\}_{t\geq 0}$ and the Bitcoin market $\left\{q_{i,t}^B, b_{i,t+1}\right\}_{t\geq 0}$, implying currency velocities V_t^D and V_t^B,

such that:

1. *Sellers' allocation decisions to the Dollar and Bitcoin markets maximize expected utility and are feasible given their wealth (b_t, d_t), expectations over current and future prices $((P_t, \hat{P}_t), (P_{t+1}, \hat{P}_{t+1}))$, the history of past prices, market allocations, currency velocities, and monetary policy;*
2. *Buyers' consumption-savings decisions in the Dollar and Bitcoin markets maximize expected utility and are feasible given their wealth (b_t, d_t), expectations over future prices and consumption, the history of past prices, market allocations, currency velocities, and monetary policy;*
3. *Prices clear their respective markets.*

By construction, the model rules out both debt and barter.[4] As a result, the only way for sellers to secure positive future utility is to accept money in exchange for their perishable goods today, anticipating that future sellers, when roles are reversed, will likewise accept money in return. We use a rather restrictive definition for monetary equilibria:

Definition 2.2 (Strong Monetary Equilibrium)**.** *A monetary equilibrium is an equilibrium in which both currencies retain value and are used in trade by at least one agent in every period $t \geq 1$. Formally,*

$$P_t \sum_{i=1}^{N} q_{i,t}^D > 0, \qquad \text{and} \qquad \hat{P}_t \sum_{i=1}^{N} q_{i,t}^B > 0, \qquad \text{for all } t \geq 1. \tag{9}$$

While the environment admits non-monetary equilibria, where both currencies are valueless, as well as equilibria in which only one currency retains value, our analysis focuses on monetary equilibria in which both currencies circulate and are actively used in trade.

[4] One common rationale for the absence of debt in monetary models arises in search-theoretic frameworks, where the probability that two agents never meet again is non-negligible. In such settings, the lack of repeated interactions undermines the enforceability of credit arrangements. We rule out barter to simplify the model, as search-theoretic models have already established that in environments with random matching, money arises as a medium of exchange, alleviating the double coincidence of wants problem.

3 Quantity Theory of Money under Currency Competition

In this section, we introduce the Quantity Theory of Money and examine how currency competition challenges its predictions.

3.1 Classic QTM in a Single currency economy

In a single-currency economy where all goods Y are sold for Dollars at the market-clearing price P_t^S, and the Dollar supply follows the deterministic growth path $D_t = mD_{t-1}$, the Quantity Theory of Money (QTM) (Fisher, 1911; Friedman, 1956) implies that the Dollar value of goods must equal total Dollar expenditure:

$$P_t^S \, Y = mD_{t-1} V_t^D, \tag{10}$$

where V_t^D denotes the Dollar velocity at time t, i.e., the share of Dollar balances spent on goods. Since markets clear sequentially, this yields a recursive expression for the price level:

$$P_t^S = m \, \frac{V_t^D}{V_{t-1}^D} \, P_{t-1}^S. \tag{11}$$

In words, Dollar inflation equals the money growth rate m multiplied by the change in velocity. When velocity is constant, monetary policy fully passes through into prices.

3.2 Challenges to the QTM in a dual-currency economy

In this section, we motivate our main study, outlining how currency competition challenges the QTM: monetary policy may affect not only Dollar-denominated goods prices and Dollar velocity but also Dollar-denominated trade. Sellers can reallocate trade across currencies in response to monetary policy, thereby altering the relative size of currency-specific markets. Following the QTM, and taking into account the market segmentation, the total quantity of output sold in each market must equal the real value of the corresponding currency spent in that market. That is, for each period t:

$$Y_t^D = \frac{D_t V_t^D}{P_t}, \qquad \text{and} \qquad Y_t^B = \frac{BV_t^B}{\hat{P}_t} = \frac{BV_t^B}{P_t} Q_t. \tag{12}$$

Currency competition, hence, directly affects market-clearing Dollar prices through adjustments in the denominator of the pricing equation, see (11).

Suppose sellers can choose the currency in which to sell, and let Y_t^D denote the Dollar trade allocation, as before, and Y_t^B the Bitcoin trade allocation. Denote by $\Delta_t := Y_t^D - Y_{t-1}^D$ the change in the Dollar trade allocation and $\hat{\Delta}_t = Y_t^B - Y_{t-1}^B = Y_{t-1}^D - Y_t^D < 0$ a corresponding change in the Bitcoin trade allocation. We obtain a first important result:

Proposition 3.1 (Monetary policy pass-through under currency economy)**.** *Let $\Delta_t > 0$ denote an increase in Dollar trade between two periods, implying a drop in Bitcoin trade, $\hat{\Delta}_t < 0$. Then, all else equal, currency competition dampens monetary policy pass-through into Dollar prices and amplifies it into Bitcoin prices:*

- ***Dollar.*** *Under currency competition, the Dollar price evolves as:*

$$P_t = m \cdot \frac{V_t^D}{V_{t-1}^D} \cdot \left(\frac{V_{t-1}^D D_{t-1}}{\Delta_t P_{t-1} + V_{t-1}^D D_{t-1}} \right) \cdot P_{t-1}, \tag{13}$$

with the dampening term

$$\left(\frac{V_{t-1}^{D} D_{t-1}}{\Delta_t P_{t-1} + V_{t-1}^{D} D_{t-1}}\right) \in (0,1), \tag{14}$$

- ***Bitcoin.*** *Under currency competition, the Bitcoin price evolves as:*

$$\hat{P}_t = \frac{V_t^B}{V_{t-1}^B} \cdot \left(\frac{V_{t-1}^{B} B}{\hat{\Delta}_t \hat{P}_{t-1} + V_{t-1}^{B} B}\right) \cdot \hat{P}_{t-1}, \tag{15}$$

with the amplification factor

$$\left(\frac{V_{t-1}^{B} B}{\hat{\Delta}_t \hat{P}_{t-1} + V_{t-1}^{B} B}\right) > 1, \tag{16}$$

To see the result in Proposition 3.1, first, consider the case where sellers leave the trade share unchanged, i.e., $\Delta_t = Y_t^D - Y_{t-1}^D = 0$. This scenario trivially holds in the single-currency setting discussed above. Given a constant Dollar allocation, sequential clearing in the Dollar market requires:

$$0 = Y_t^D - Y_{t-1}^D = D_{t-1}\left(\frac{m V_t^D}{P_t} - \frac{V_{t-1}^D}{P_{t-1}}\right). \tag{17}$$

Setting the bracket to zero, yields the market clearing Dollar goods price, which is equal to the pricing equation derived earlier in the single-currency environment, Equation (11). Now consider a rise in Dollar trade $\Delta_t = Y_t^D - Y_{t-1}^D > 0$ which implies a negative Bitcoin trade wedge $\hat{\Delta}_t = Y_t^B - Y_{t-1}^B < 0$. Sequential Dollar market clearing from Equation (17) implies:

$$\Delta_t \equiv D_{t-1}\left(\frac{m V_t^D}{P_t} - \frac{V_{t-1}^D}{P_{t-1}}\right) > 0. \tag{18}$$

Sequential market clearing in the Bitcoin market requires

$$\hat{\Delta}_t \equiv B\left(\frac{V_t^B}{\hat{P}_t} - \frac{V_{t-1}^B}{\hat{P}_{t-1}}\right) < 0, \tag{19}$$

Equation (18) can be solved for the Dollar price P_t as a function of the trade wedge Δ_t, yielding (13). Solving Equation (19) for the Bitcoin price yields (15). The dampening term in (14) equals one if and only if the trade allocation stays constant $\Delta_t = 0$. Similarly, the amplification term in (16) equals one if and only if $\hat{\Delta}_t = 0$, i.e., when Bitcoin trade remains constant. If the Dollar trade share shrinks, $\Delta_t = Y_t^D - Y_{t-1}^D < 0$, the effect reverses.[5]

Proposition 3.1 clearly shows that currency competition affects the monetary policy pass-through into Dollar prices. Nevertheless, the result comes with an important caveat. They are derived under the assumption that currency velocities remain unaffected by monetary policy and trade reallocation. Proposition 3.1 therefore offers only a partial equilibrium response, or a first approximation, of equilibrium pass-through, as it abstracts from how currency competition alters the incentives of buyers to save and sellers to consume.

To address this limitation, we next characterize the equilibrium conditions under currency competition with proportional monetary policy in general equilibrium.

[5]Note that the Dollar trade share cannot fall below zero, so the change in the Dollar trade share has a natural lower bound $\Delta_t \geq -Y_{t-1}^D$. As the Dollar trade share approaches this lower bound, the denominator in the amplification term, $\Delta_t P_{t-1} + V_{t-1}^D D_{t-1}$, approaches zero by market clearing, since $\Delta_t \to -Y_{t-1}^D$ implies $\Delta_t P_{t-1} \to -Y_{t-1}^D P_{t-1} = -D_{t-1} V_{t-1}^D$. As a result, the amplification factor diverges to infinity, and Dollar inflation is maximally magnified.

4 Model analysis, Theoretical results and Hypotheses

In this section, we present our main theoretical results, which characterize the equilibrium conditions of the model. These conditions provide the basis for our testable hypotheses in the experimental analysis. The corresponding derivations can be found in Appendix A.1.

Lemma 4.1 (Efficiency)**.** *For any monetary policy $m \geq 1$ considered above, all packages offered for sale by sellers are fully purchased by buyers. That is, no goods remain unsold in equilibrium for all $t \geq 1$. In every equilibrium: Aggregate consumption is constant across t, $\sum_{i=1}^{N} c_{i,t} = \sum_{i=1}^{N} c_{i,t+1}$, for all $t \geq 1$.*

We obtain the first testable prediction for our experiment:

Hypothesis 1 (Market efficiency)**.** *All sellers should sell all of their packages in each period $t \geq 1$.*

4.1 Full set of Equilibria

The following propositions present the main theoretical results, describing equilibrium behavior for any monetary policy parameter $m \geq 1$. When $m > 1$, monetary policy is active; when $m = 1$, monetary policy is absent or muted. Throughout, we write c_t instead of $c_{i,t}$, since the equilibrium conditions apply identically to every buyer and seller i.

Proposition 4.1 (Rational Expectations Monetary Equilibrium under Strategic Uncertainty)**.** *For every $m \geq 1$*

1. ***Sellers' indifference (inflation and exchange rates):***
   (a) *t-Sellers strictly prefer selling for Dollars over Bitcoin if they expect:* $\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}} u'(c_{t+1})\right] < m \cdot \mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}} u'(c_{t+1})\right]$.
   (b) *t-Sellers are indifferent between currencies if:*

$$\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}} u'(c_{t+1})\right] = m \cdot \mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}} u'(c_{t+1})\right]. \tag{20}$$

2. ***Buyers' optimization (pricing conditions):***
   (a) *t-Buyers spend all Dollars if: $\beta^2 m^2 \mathbb{E}_t\left[\frac{u'(c_{t+2})}{P_{t+2}}\right] < \frac{u'(c_t)}{P_t}$,*
   and spend all Bitcoins if: $\beta^2 \mathbb{E}_t\left[\frac{u'(c_{t+2})}{\hat{P}_{t+2}}\right] < \frac{u'(c_t)}{\hat{P}_t}$.
   (b) *t-Buyers are indifferent between consuming and saving if:*

$$\frac{u'(c_t)}{P_t} = \beta^2 m^2 \mathbb{E}_t\left[\frac{u'(c_{t+2})}{P_{t+2}}\right], \qquad \textit{(Dollar goods market)} \tag{21}$$

$$\frac{u'(c_t)}{\hat{P}_t} = \beta^2 \mathbb{E}_t\left[\frac{u'(c_{t+2})}{\hat{P}_{t+2}}\right], \qquad \textit{(Bitcoin goods market)}\,. \tag{22}$$

   [leftmargin=0.5in,rightmargin=0.75in]

3. ***Market clearing:*** *the Dollar and Bitcoin-denominated markets clear*

$$\begin{aligned} Y_t^D &= Y - Y_t^B \\ Y_t^D &= \tfrac{D_t V_t^D}{P_t}, \\ Y_t^B &= \tfrac{B V_t^B}{\hat{P}_t}. \end{aligned} \tag{23}$$

Recall that the notation $\mathbb{E}_{t^-}$ indicates that t-sellers choose trade shares based only on information available prior to period t, without observing contemporaneous prices P_t and

$\hat{P}_t$.[6] In contrast, buyers form expectations denoted by $\mathbb{E}_t$, as they observe all period-t information, including prices, while setting velocities.

In the special case of symmetry, $c_t = \bar{y} = c_{t+2}$, and perfect foresight the equilibrium characterization reduces to:

Proposition 4.2 (Symmetric Perfect Foresight Monetary Equilibrium)**.** *For every $m \geq 1$*

1. ***Sellers' indifference (inflation and exchange rates):***
   (a) *Sellers are indifferent between markets if Dollar inflation equals m times Bitcoin inflation:*
   $$\frac{P_{t+1}}{P_t} = m \cdot \frac{\hat{P}_{t+1}}{\hat{P}_t}, \tag{24}$$
   which implies an exchange rate path (Bitcoin price in Dollars) of
   $$Q_{t+1} = mQ_t = m^t Q_1.$$
2. ***Buyers' optimization (pricing conditions):***
   (a) *Buyers are indifferent between consuming and saving if*
   $$\frac{P_{t+2}}{P_t} = \beta^2 m^2, \qquad \textit{(Dollar goods market)} \tag{25}$$
   $$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2 \qquad \textit{(Bitcoin goods market)}\ . \tag{26}$$
3. ***Market clearing:*** *The Dollar and Bitcoin-denominated markets clear*
   $$\begin{aligned} Y_t^D &= Y - Y_t^B = \tfrac{D_t V_t^D}{P_t}, \\ Y_t^B &= \tfrac{BV_t^B}{\hat{P}_t}. \end{aligned} \tag{27}$$

The implications of Proposition 4.2 are heuristically illustrated in Figure 3, focusing on the special case of perfect foresight and a symmetric equilibrium. The figure provides intuition for the interplay between sellers' and buyers' inflation expectations and the resulting price dynamics.

4.2 Equilibrium Types, Selection, and Inflation Expectations

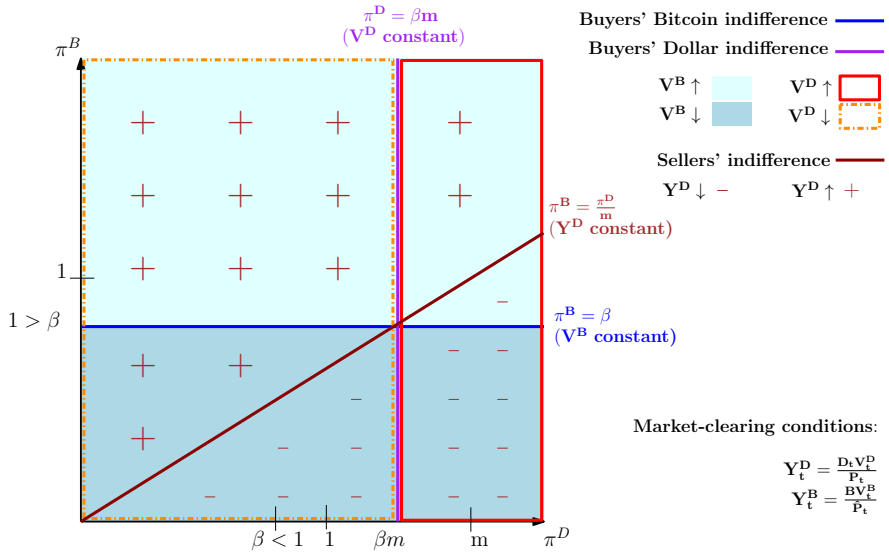
The propositions above characterize the full set of equilibria. While infinitely many equilibria exist, we now outline how buyers and sellers select among them, depending on how they update their inflation expectations in response to monetary policy.

For simplicity, we focus on symmetric equilibria with a representative buyer and seller, $N = 1$, $Y = \bar{y}$, where buyers consume a constant share of output each period, $c_{i,t} = \bar{y} = c_{i,t+1}$, such that marginal utilities cancel out, even in the presence of strategic uncertainty.

Muted monetary policy

In the benchmark case without monetary policy ($m = 1$), the economy is static across time. Currencies are perfect substitutes, akin to the Kareken and Wallace (1981) environment. Inflation expectations of buyers and sellers remain constant, i.e., $\mathbb{E}_t[P_t/P_{t+2}]$ and $\mathbb{E}_{t^-}[P_t/P_{t+1}]$ do not vary with t. Therefore, sellers prefer transacting in the currency expected to retain

[6] We could have chosen the notation $\mathbb{E}_{t-1}$ instead, but chose against it since $\mathbb{E}_{t^-}$ makes clear that it is the t-seller who is acting, not the $t-1$ seller.



Notes: The three solid lines mark the sellers' and the two buyers' indifference conditions in the one-period ahead inflation space, $\pi^D = P_{t+1}/P_t$, $\pi^B = \hat{P}_{t+1}/\hat{P}_t$. Away from the solid lines, either buyers or seller are not indifferent, resulting in a change of velocities V_t^D, V_t^B or the Dollar versus Bitcoin package supply Y_t^D versus Y_t^B. The intersection of all three indifference conditions suggests a unique equilibrium under perfect foresight. However, as we demonstrate in Corollary 4.1, there in fact exist infinitely many symmetric perfect foresight monetary equilibria, distinct combinations of velocities, trade shares, and prices that satisfy the equilibrium conditions.

Figure 3: Heuristic illustration of model dynamics with monetary policy ($m \geq 1$).

its purchasing power, i.e., the one with lower anticipated inflation. According to Propositions 4.2 and 4.1, in equilibrium, expected exchange rates and (inverse) inflation rates are constant over time. While prices of Bitcoin and Dollar goods may differ, they evolve at the same rate to preserve a stable exchange rate. The initial prices, and thus the initial exchange rate Q_1 are indeterminate, but for all following periods, the exchange rate is pinned down by Q_1.

Under perfect foresight, buyer indifference requires that Dollar prices grow at rate $\beta m = \beta$, and Bitcoin prices at rate β per period. Since the discount factor satisfies $\beta < 1$, indifference between consumption and saving requires deflation in both currencies. If prices were constant, or yield inflation, our model predicts that buyers would strictly prefer to spend all of their money today. This result, already established in the infinitely-lived agents model of Schilling and Uhlig (2019a), is intuitive in a deterministic setting: buyers know they will become sellers tomorrow, receiving an exogenous endowment of goods, and thus can fully replenish their balances without discounting. Similarly, in Kareken and Wallace (1981), both currency velocities equal one due to the overlapping generations structure, where the old generation spends all their money before exiting the economy.

Active monetary policy

Our novel monetary policy implementation in the form of interest on Dollar balances creates incentives for buyers and sellers to transact in Dollars: higher Dollar holdings are rewarded by the central bank with larger transfers, which promise higher future consumption. Therefore in our setting, monetary policy alters buyers' and sellers' decision-making by introducing a trade-off between the interest-bearing returns on Dollar balances and the expected inflationary effects of monetary expansion on Dollar goods prices.

While it may seem that the central bank can crowd out Bitcoin through increased Dollar transfers (i.e. by raising m), this is generically not true. With active monetary policy ($m > 1$), inflation expectations should generically be considered as dependent on m, i.e. the agents should revise $\mathbb{E}_t[P_t/P_{t+2}]$ and $\mathbb{E}_{t^-}[P_t/P_{t+1}]$ as functions of m. The adjustment of inflation expectations to monetary policy is, however, not uniquely pinned down by the model, thereby allowing for the existence of multiple equilibria. Even under perfect foresight, the model admits a wide range of equilibria; see Section 4.5.1. Once strategic uncertainty is introduced, two distinct classes of equilibria can be generically distinguished.

Proposition 4.3 (Equilibrium Types under Rational Inflation Expectation Dynamics)**.** *In the presence of proportional monetary policy and currency competition, equilibrium outcomes are shaped by agents' inflation expectations. Generically, two distinct self-fulfilling equilibrium types arise:*

1. *Type 1: Rise in Dollar dominance with tempered pass-through and Bitcoin spillover (money illusion, Gresham's law): If agents maintain low inflation expectations on the Dollar despite monetary expansion, trade shifts toward the Dollar and away from Bitcoin, accompanied by Dollar hoarding. As a result, Dollar inflation remains muted, while Bitcoin prices increase.*
2. *Type 2: Strong Dollar inflation pass-through (Thier's law): When agents form high Dollar inflation expectations in response to monetary policy, they rapidly spend Dollars and shift trade toward Bitcoin. Dollar prices rise sharply, while Bitcoin prices remain stable or fall.*

We next demonstrate how these equilibria are constructed.

Type 1 Equilibrium: Slow Updating of Inflation Expectations

Sellers Sellers' trade allocation decisions are made *before* trade opens, i.e. before observing current prices $(P_t, \hat{P}_t)$ or velocities (V_t^D, V_t^B). The sellers' trade allocations, Y_t^D, Y_t^B, thus, reflect their expectations about present and future market conditions. Sellers also act in anticipation of becoming buyers in period $t+1$. Suppose $m = 1$ and sellers are initially indifferent between currencies: $\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}}\right] = \mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}\right]$. If monetary policy becomes active ($m > 1$), but sellers naively do not revise their expectations (i.e., they hold the expectations $\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}}\right]$ and $\mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}\right]$ constant, the indifference condition is violated:

$$\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}}\right] < m\,\mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}\right]. \tag{28}$$

Sellers now prefer Dollar over Bitcoin payments, and in response increase the Dollar trade allocation Y_t^D, and reduce Bitcoin trade $Y_t^B = Y - Y_t^D$. This trade shift lowers the market-clearing Dollar price ($P_t = mD_{t-1}V_t^D/Y_t^D$), and raises the Bitcoin price ($\hat{P}_t = BV_t^B/Y_t^B$), since a constant quantity of Bitcoin chases fewer goods. Bitcoin inflation is particularly noteworthy as it originates from Dollar monetary policy. In this sense, we observe a monetary policy spillover into a competing currency, transmitted through changes in relative trade volumes rather than through direct monetary interventions in the Bitcoin currency market.[7]

The seller continues to reallocate goods from the Bitcoin to the Dollar market until the prices P_t and $\hat{P}_t$ adjust such that the expected inverse inflation rates are equalized up to the

[7] Scarcity-driven inflation increases have, for instance, been observed during the COVID-19 episode in 2020, when supply chain disruptions led to goods shortages in the United States and Europe, contributing significantly to inflationary pressures.

monetary policy factor m, i.e., condition (28) holds with equality. This means, proportional monetary policy jointly with low inflation expectations updating induces a rational form of money illusion, novel to the existing literature, where sellers prefer transacting in Dollars even when they expect higher Dollar inflation relative to Bitcoin. In the case of perfect foresight, sellers are indifferent between the two currencies only when Dollar inflation exceeds Bitcoin inflation by exactly the interest factor m. By the law of one price, seller indifference also implies that the Bitcoin exchange rate (Bitcoin price in Dollars), $Q_t = P_t/\hat{P}_t$, is expected to grow at rate m, meaning $Q_{t+1} = mQ_t$.[8]

The higher the interest rate on Dollar balances (m), the more expected future Dollar inflation sellers are willing to tolerate before reallocating trade to Bitcoin. Thus, proportional monetary policy increases the Dollar trade share, Y_t^D/Y, unless Dollar inflation expectations adjust upward sufficiently fast with m.

The growth rate m of the exchange rate is particularly interesting. In our model, Bitcoin represents a currency with inactive monetary policy. In contrast, stablecoins like Tether or USDC maintain their peg through active mint-and-burn mechanisms but do not pay interest or transfers to holders. Much of the stablecoin literature adopts partial equilibrium models that emphasize arbitrage as the sole peg-stabilizing mechanism. Our general equilibrium framework challenges this view by demonstrating that trade reallocations can impose substantial pressure on the peg. Our results say, that without such a peg mechanism, Dollar monetary policy would lead the stablecoin to appreciate relative to the Dollar at a rate $Q_{t+1} = mQ_t$. This highlights that active proportional Dollar monetary policy exerts significant pressure on any peg mechanism attempting to stabilize the exchange rate at $Q_{t+1} = Q_t$ solely through supply adjustments. Even if arbitrage mechanisms function as intended, persistent trade imbalances, similar to those that forced the Swiss National Bank to abandon its Euro peg, can eventually overpower arbitrage-based stabilization and result in depegging.

In contrast, in models where monetary policy is implemented via symmetric lump-sum transfers (Kareken and Wallace, 1981; Garratt and Wallace, 2018; Schilling and Uhlig, 2019a), monetary policy does not directly affect agents' choices, i.e., other than through changes in inflation expectations, since the transfer size is independent of agents' behavior.[9] In particular, these frameworks cannot induce a trade shift toward the Dollar, as agents continue to favor the less inflationary currency. If anything, Dollar monetary policy leads to an upward revision of Dollar inflation expectations.

Buyers After sellers in period t choose their trade allocations, trade opens and buyers decide on consumption and savings across currencies. At the start of period t, they observe current trade shares Y_t^D and Y_t^B, along with past prices, trade allocations, and velocities for both currencies. They then solve two indifference conditions, one per currency market.

Consider the buyer, who is indifferent in the Dollar market under muted monetary policy, $m = 1$: $\frac{1}{P_t} = \beta^2 \mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]$. As the central bank starts paying interest $m > 1$, assume that buyers hold inflation expectations fixed, keeping $\mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]$ constant. Then, at the current Dollar market goods price P_t buyers are no longer indifferent with regard to their con-

[8] In the stochastic case, an equivalent version can be formulated.

[9] In Schilling and Uhlig (2019a), the seller's indifference condition (1) is independent of the central bank transfers τ. As a result, despite the presence of active monetary policy, the sellers' indifference equation takes the same form as in our case with $m = 1$ (mute monetary policy). Similarly, in Kareken and Wallace, the equilibrium exchange rate is unaffected by government monetary transfers.

sumption and savings, and prefer saving Dollars:

$$\frac{1}{P_t} < \beta^2 m^2 \mathbb{E}_t \left[\frac{1}{P_{t+2}} \right]. \tag{29}$$

Such prices cannot constitute part of an equilibrium. Thus, Dollar spending declines, reducing velocity V_t^D, which in turn lowers the market-clearing Dollar price P_t ($P_t = mD_{t-1}V_t^D/Y_t^D$), until the buyer is indifferent again, and (29) holds with equality. Similar to sellers, the buyers exhibit a rational form of money illusion by hoarding Dollars, despite the Dollar being more inflationary than Bitcoin, see below.

The higher the interest rate on Dollar balances m, the more expected future Dollar inflation buyers are willing to tolerate before fully spending their Dollar holdings. With proportional monetary policy, where transfer size is tied to current holdings, the central bank effectively incentivizes buyers to hoard or "trust" the Dollar, even as inflation expectations rise.

In contrast, in models where monetary policy is implemented via symmetric lump-sum transfers (Kareken and Wallace, 1981; Garratt and Wallace, 2018; Schilling and Uhlig, 2019a), direct consumption-savings decisions are unaffected by central bank transfers, which are independent of agents' behavior.[10] As a result, monetary policy through lump-sum transfers fail to sustain Dollar demand once inflation expectations increase.

A similar mechanism applies in the Bitcoin market. As sellers shift trade toward Dollars, Bitcoin inflation rises, prompting buyers to revise their Bitcoin inflation expectations upward. In response, buyers may increase their Bitcoin spending, thereby raising Bitcoin velocity, see Figure 3 for illustration. Our experiment confirms that some single economies, indeed, experience as much Bitcoin inflation as Dollar inflation in the Dollar monetary policy scenario, see the discussion of Single Economies at the end of the paper.

With slow expectation adjustment, both sellers and buyers respond to proportional Dollar transfers by favoring the Dollar, exhibiting money illusion, increasing Dollar dominance, lowering P_t, raising $\hat{P}_t$, and reducing the exchange rate $Q_t = P_t/\hat{P}_t$. This scenario gives the illusion that the central bank can directly crowd out Bitcoin and increase Dollar dominance by paying large interest rates on Dollar balances. However, in the long run, inflationary pressure builds up, prompting updated expectations and shifting equilibrium dynamics.

Type 2 Equilibrium: Rapid Updating of Inflation Expectations

Sellers Assume sellers have adjusted to active monetary policy, $m > 1$, and are indifferent, holding low Dollar inflation expectations (high $\mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}\right]^L$): $\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}}\right] = m \cdot \mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}\right]^L$. Now suppose they revise inflation expectations upwards (i.e., lowering $\mathbb{E}_{t^-}[P_t/P_{t+1}]^H < \mathbb{E}_{t^-}[P_t/P_{t+1}]^L$). Then sellers are no longer indifferent:

$$\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}}\right] > m \cdot \mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}\right]^H. \tag{30}$$

As the Dollar is now expected to be inflationary relative to current goods prices P_t, the seller prefers to trade in Bitcoin, reducing the Dollar trade allocation Y_t^D and increasing Bitcoin trade Y_t^B. By market clearing, this reallocation raises the Dollar price P_t and lowers the Bitcoin price $\hat{P}_t$.

[10] See Schilling and Uhlig (2019a), the transfers τ do not enter equation (3).

Buyers Similarly, assume buyers are indifferent with regard to Dollar consumption and savings at the current active monetary policy, $m > 1$, holding low inflation expectations (high $\mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]^L$): $\frac{1}{P_t} = \beta^2 m^2 \mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]^L$. If buyers revise their inflation expectations upwards, (i.e., lower $\mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]^H < \mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]^L$), then the current Dollar goods price P_t is too low to sustain buyer indifference,

$$\frac{1}{P_t} > \beta^2 m^2 \mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]^H. \tag{31}$$

Expecting high Dollar inflation, buyers increase current Dollar spending, raising velocity V_t^D and, via market clearing, the Dollar price P_t, until indifference is attained, i.e. (31) holds with equality. Notably, buyers increase their Dollar expenditures under high inflation expectations relative to low inflation expectations, even though the nominal interest rate on Dollar balances remains unchanged.

As buyers and sellers raise their Dollar inflation expectations, their behavior adjusts in a way that monetary policy pass-through into Dollar prices strengthens, Dollar dominance declines, and the Bitcoin price falls (the spill-over is reversed). The exchange rate Q_t rises.

Discussion The belief that the central bank can crowd out Bitcoin through Dollar transfers is misleading. While a higher interest rate m may appear to incentivize sellers to reallocate trade toward Dollars, this reasoning overlooks a key point: inflation expectations are not independent of m. Since m reflects Dollar money growth, it naturally affects agents' expectations about future Dollar inflation, however, not in a unique way. The impact of m on prices, trade and velocities depends critically on how quickly expectations adjust.

Proportional monetary policy leads to one of two outcomes: either a rapid pass-through into higher Dollar prices, consistent with the traditional prediction of the Quantity Theory of Money, or a reallocation of trade toward the Dollar (rising Dollar dominance) jointly with rising Bitcoin inflation (monetary policy spill-over).

The strength of these two effects is inversely related: If inflation expectations adjust slowly, trade shifts toward the Dollar dominate; if expectations adjust quickly, prices respond more strongly. However, the central bank cannot directly control agents' inflation expectations,[11] and thus cannot choose which effect prevails. As shown in the theory construction of perfect foresight equilibria (Section 4.5.1), the same interest rate m can support equilibria with either increasing or decreasing Dollar trade shares, reflecting Gresham's Law (crowding out Bitcoin) or Thiers' Law (crowding in Bitcoin), and likewise, can support different equilibrium velocities.

Most importantly, both equilibrium types are self-sustaining due to the self-fulfilling nature of inflation expectations. That is, the observed money illusion is not irrational: beliefs about future prices shape current behavior in ways that reinforce those beliefs. Low expected Dollar inflation leads agents to adjust their behavior, by hoarding Dollars and increasing Dollar trade, in ways that, indeed, depress the current Dollar goods price P_t, thereby reducing realized inflation $\pi_t = P_t/P_{t-1}$. This outcome validates the initially low inflation expectations and reinforces the belief that Dollar prices will remain stable. The opposite holds under high inflation expectations.

As a result, the central bank's ability to steer the economy through monetary policy is constrained by the endogenous, persistent nature of private inflation beliefs.

[11] Effective communication and forward guidance fall outside the scope of our model.

Buyer versus seller indifference Understanding how buyers' and sellers' inflation expectations align is key. Under perfect foresight, buyer indifference implies seller indifference, but not vice versa. Under strategic uncertainty, differing expectation horizons prevent a direct mapping, requiring separate hypotheses for buyers and sellers (see Hypothesis 3).

4.3 Bitcoin as a foreign CBDC with active monetary policy

In our setting, "Bitcoin" serves as a placeholder for a foreign currency with passive monetary policy. It can be interpreted as a foreign central bank digital currency (CBDC), such as a potential European CBDC, competing with the U.S. Dollar. While the ECB may not currently plan to pay interest on such a CBDC, it is reasonable to consider a scenario where it does. If "Bitcoin" were to yield an interest rate n on Bitcoin balances, and the Bitcoin supply would grow accordingly, i.e. $B_t = n^{t-1}B_1$, the seller's indifference condition would adjust to reflect the relative return on holding each currency:

$$\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}}u'(c_{t+1})\right] = \frac{m}{n}\cdot\mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}u'(c_{t+1})\right]. \tag{32}$$

Thus, an interest rate n paid on Bitcoin balances would partially offset, or potentially overcompensate, the Dollar central bank's incentives induced via the interest rate m. Furthermore, in line with the above, a rise in n should lead agents to revise their Bitcoin inflation expectations, a process which, analogously to the Dollar case, may unfold either rapidly or gradually.

For $n > m$, depending on the speed of Bitcoin inflation expectation updating and prevailing Dollar inflation beliefs, trade may shift toward Bitcoin, or Bitcoin monetary policy may result in stronger Bitcoin inflation pass-through. In contrast, when $n < m$, the Bitcoin interest rate dampens the Dollar central bank's influence, either by limiting the shift toward Dollar-denominated trade or by weakening the transmission of monetary policy into Dollar inflation.

The buyers' consumption-savings indifference equation in the Dollar and Bitcoin market would respectively change into

$$\frac{u'(c_t)}{P_t} = \beta^2 m^2 \mathbb{E}_t\left[\frac{u'(c_{t+2})}{P_{t+2}}\right], \qquad \text{(Dollar goods market)}, \tag{33}$$

$$\frac{u'(c_t)}{\hat{P}_t} = \beta^2 n^2 \mathbb{E}_t\left[\frac{u'(c_{t+2})}{\hat{P}_{t+2}}\right], \qquad \text{(Bitcoin goods market)}. \tag{34}$$

In contrast, if Bitcoin featured active monetary policy but implemented symmetric lump-sum transfers rather than interest payments, the sellers' and buyers' indifference conditions would remain unchanged from those stated in our Propositions.

4.4 Testable hypothesis

Based on these theoretical insights, we form a set of alternative testable hypotheses, in the absence ($m = 1$) and presence ($m > 1$) of monetary policy:

Hypothesis 2 (Benchmark: currency competition without monetary policy ($m = 1$))**.**
Equilibrium E0: No monetary policy, steady expectations

- *Sellers hold trade shares constant*
- *Buyers hold currency velocities constant*

- *Constant exchange rate, with possibly different Dollar and Bitcoin prices, that may drift over time but at the same rate.*

When introducing Dollar monetary policy, we conjecture that the experimental monetary policy economies will exhibit one of two distinct dynamics:

Hypothesis 3 (Monetary policy implications under currency competition ($m > 1$))**.**

1. ***EMP1: No (or Weak) Inflation Expectations Updating in Response to Monetary Policy (Gresham's Law)***
   - *Rise in Dollar dominance and Bitcoin crowding out as sellers reallocate trade toward Dollars away from Bitcoin, (higher Y_t^D and lowering Y_t^B) (Sellers' Money Illusion)*
   - *Buyers hoard Dollars, reducing its velocity V_t^D (Buyers' money illusion).*
   - *Dampened monetary policy pass-through into Dollar prices: Dollar prices P_t grow slow or even decline*
     - *Dollar monetary policy spill-over into Bitcoin: Bitcoin prices $\hat{P}_t$ rise.*
     - *Bitcoin exchange rate $Q_t = P_t / \hat{P}_t$ increases slowly or remains flat.*
2. ***EMP2: Rapid Inflation Expectations Updating in Response to Monetary Policy (Thiers's Law)***
   - *Decline in Dollar dominance and Bitcoin crowding-in as sellers anticipate Dollar inflation, and reduce Dollar-denominated trade (lower Y_t^D and raise Y_t^B) (no money illusion)*
   - *Buyers reduce Dollar savings (no money illusion), raising velocity V_t^D*
   - *Strong monetary policy pass-through into Dollar prices:*
     - *Dollar goods price P_t rises fast in response to m.*
     - *No or reversed Dollar monetary policy spill-over into Bitcoin, Bitcoin prices $\hat{P}_t$ fall or stay constant*
     - *Exchange rate Q_t rises quickly.*

4.5 Equilibrium existence, dynamics and construction

4.5.1 Symmetric perfect foresight monetary equilibria

Since the theoretical framework is fully deterministic, we begin by solving for perfect foresight equilibria. Under perfect foresight, all agents correctly anticipate future prices, trade shares, and velocities. To simplify the construction and interpretation of results, we restrict attention to symmetric settings.[12] Constant consumption over time jointly with symmetry implies constant marginal utility, which, in effect, reduces the stochastic discount factor to a constant, resembling the case of risk neutrality. Given the imposed symmetry of equilibrium, we may analyze the economy through the lens of a representative buyer interacting with a representative seller.

Since construction of perfect foresight equilibria is technically involved, we relegate the full derivation to the appendix section A.1.2 and summarize their key properties in the following corollary. For brevity, we refer to the symmetric perfect foresight monetary equilibrium as an SPFM equilibrium throughout the remainder of the paper.

[12] Under constant output, symmetry implies that all buyers consume identical quantities of goods at each date ($c_{i,t} = c_{j,t}$ for all i, j and t), and that consumption remains constant over time ($c_{i,t} = \bar{y} = c_{i,t+1}$). All buyers also divide their expenditures across currencies in the same way ($q_{i,t}^B = q_{j,t}^B$ and $q_{i,t}^D = q_{j,t}^D$), and all sellers implement the same allocation of their goods between markets ($x_{i,t} = x_{j,t}$ and $z_{i,t} = z_{j,t}$).

Corollary 4.1 (Properties of SPFM equilibria)**.** *The following statements hold for every $m \geq 1$, i.e., whether monetary policy is active or mute.*

1. *All SPFM equilibria feature direct but tempered (discounted) pass-through of monetary policy into Dollar prices, with no spill-over into Bitcoin.*

$$\frac{P_{t+2}}{P_t} = \beta^2 m^2, \quad \frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2. \tag{35}$$

2. *There exist SPFM equilibria featuring both rising and falling Dollar trade shares (Prop. A.2):*

$$Y_t^D = \Delta_t^{Y,D} Y_{t-1}^D \quad \textit{with either} \Delta_t^{Y,D} \in (0,1) \textit{ or } \Delta_t^{Y,D} > 1.$$

   (a) *$\Delta_t^{Y,D} \in (0,1)$ corresponds to declining Dollar dominance (Bitcoin crowding-in), and $\Delta_t^{Y} > 1$ to increasing Dollar dominance (Bitcoin crowding-out).*

   (b) *Hence, both Gresham's Law (inflationary Dollar crowds in) and Thiers' Law (less inflationary Bitcoin crowds in) can apply.*

   (c) *There exists an SPFM equilibrium with a constant Dollar trade share (Proposition A.1).*

3. *Both rising and falling Dollar and Bitcoin velocities can occur in equilibrium (Prop. A.3).*

$$V_t^D = \Delta_t^{V,D} V_{t-1}^D \quad \textit{with } \Delta_t^{V,D} \in (0,1) \textit{ or } \Delta_t^{V,D} > 1.$$

   or

$$V_t^B = \Delta_t^{V,B} V_{t-1}^B \quad \textit{with } \Delta_t^{V,B} \in (0,1) \textit{ or } \Delta_t^{V,B} > 1.$$

   (a) *However, a constant Dollar velocity equilibrium exists if and only if $\beta = 1$ (no discounting). In that case, both currency trade shares are also constant.*

   (b) *For $\beta < 1$, constant velocity is not compatible with equilibrium (Proposition A.1).*

4. *A rise in the Dollar trade allocation ($\Delta_t^{Y,D} > 1$) can be accompanied by either an increase ($\Delta_t^{V,D} > 1$) or a decrease ($\Delta_t^{V,D} \in (0,1)$) in Dollar velocity over time. In contrast, a decline in the Dollar trade allocation ($\Delta_t^{Y,D} \in (0,1)$) requires a decline in Dollar velocity in equilibrium, $\Delta_t^{V,D} \in (0,1)$. Conversely, an increase in Dollar velocity ($\Delta_t^{V,D} > 1$) necessarily requires a rise in the Dollar trade allocation ($\Delta_t^{Y,D} > 1$) over time, whereas a drop in Dollar velocity ($\Delta_t^{V,D} \in (0,1)$) does not necessarily require a rise in the Dollar trade allocation.*

Importantly, the proposition demonstrates that even under perfect foresight, trade need not shift in a single direction in response to Dollar monetary policy. Both crowding out of Dollars (declining Dollar dominance, $\Delta^{Y,D} \in (0,1)$), where agents move toward the less inflationary Bitcoin (Thier's law), and crowding in (rising Dollar dominance, $\Delta^{Y,D} > 1$), where agents shift trade into the more inflationary Dollar (Gresham's law), exhibiting a rational form of money illusion, can occur.

Even under perfect foresight, it is therefore generically not true that the Dollar central bank can reliably attract users into the Dollar simply by paying interest on reserves to defend its dominance against Bitcoin. Nor is it generically true that agents can consistently resist money illusion. Put differently, belief-driven miscoordination is not necessary for the more stable currency to dominate or be dominated in trade. The same applies to velocities: they may either rise or fall over time. This means that Dollar hoarding in response to monetary policy, i.e., reduced velocity, is only one possible equilibrium outcome. Increased Dollar spending, corresponding to higher velocity, is equally consistent with equilibrium.

Interestingly, the direction of adjustment in both velocities and trade shares is independent of agents' inflation expectations. A robust feature of all SPFM equilibria is that they exhibit identical, direct but tempered monetary policy pass-through into Dollar prices, with $\frac{P_{t+2}}{P_t} = \beta^2 m^2$, with monetary policy pass-through into Dollar prices uniformly scaled by the discount factor. In other words, while the central bank's monetary policy interest rate does influence Dollar prices, its effect is systematically tempered by discounting, see Equations 35. Thus, the Quantity theory of money holds in a weaker form. We call this pass-through a tempered form of the Quantity Theory of Money (TQTM, hereafter). This means that even though trade shares and velocities adjust in response to monetary policy, as shown in our equilibrium construction in Section A.1.2, these adjustments offset each other within Equation (13), thereby keeping the overall monetary policy pass-through into Dollar prices constant across equilibria. This result also implies that stronger deviations from the Quantity Theory of Money (QTM), as observed in the experiment, require the presence of strategic uncertainty and miscoordination among agents, as discussed in Section 4.5.2. Also, see that in every SPFM equilibrium, monetary policy shocks are exclusively absorbed through adjustments in the Dollar price level, Dollar and Bitcoin velocities and trade shares, while Bitcoin prices remain unaffected.

Proportional monetary policy is not necessary for a rise in the Dollar trade share (Dollar dominance) or a decline in Dollar velocity. Even under mute policy, such shifts can occur in equilibrium, including under perfect foresight when expectations are correct (see the detailed construction in Appendix A.1.2). In fact, under perfect foresight, the range of trade and velocity shifts sustainable in equilibrium is identical under both muted and active monetary policy.[13]

The above equilibria describe monetary equilibria. If sellers refuse Bitcoin for goods, $Y_t^B = 0$, it loses all purchasing power and its price becomes indeterminate. Thus, for both currencies to retain value, trade allocations must be positive $Y_t^B, Y_t^D \in (0, Y)$ for all t. In contrast, a zero currency velocity with positive goods supply offered against that currency cannot constitute any equilibrium. Since goods are perishable, sellers would accept any positive price rather than let goods go unsold. By Lemma 4.1, all packages must be sold in equilibrium. Hence, zero velocity is only consistent with equilibrium if the corresponding goods allocation is also zero, implying a non-monetary equilibrium.

4.5.2 Rational expectations equilibria under strategic uncertainty

Agents cannot *ex ante* predict which of the infinitely many SPFM equilibria will prevail. This equilibrium multiplicity introduces strategic uncertainty, which introduces stochasticity in both the theoretical model and experimental outcomes. The strategic uncertainty gives rise to a richer set of equilibria, characterized by more complex and nuanced patterns of price formation, an environment we now explore. In particular, we now illustrate how even the tempered version of the QTM can fail under strategic uncertainty, when buyers and sellers misjudge future goods prices.

We adapt the approach of Sargent and Wallace (1973), who decompose inflation realizations into expected future inflation and, in turn, into expectations over future market-clearing quantities. While their analysis focuses on a single-currency model, we extend it

[13] However, under mute policy, perfect foresight requires that both Dollar and Bitcoin inflation equal the discount factor (deflation), thus, such trade and velocity shifts then cannot be attributed to a "money illusion." The only difference between active and mute policy lies in the resulting equilibrium Dollar inflation rate, βm, which is constant across all possible equilibria within policy treatment, but differs across policy treatment.

to our dual-currency setting. This allows us to infer subjects' implicit inflation expectations from observed deviations from the QTM.

We continue to focus on symmetric equilibria with two agents, a representative buyer and a representative seller. Via symmetry, i.e. $c_t = \bar{y} = c_{t+2}$, the representative buyer adjusts current Dollar goods prices through consumptions and savings, i.e., velocity, until indifference is attained,

$$P_t = \frac{1}{\beta^2 m^2}\mathbb{E}_t\left[\frac{1}{P_{t+2}}\right]^{-1} = \frac{1}{\beta^2} D_t\left(\mathbb{E}_t\left[\frac{Y^D_{t+2}}{V^D_{t+2}}\right]\right)^{-1}. \tag{36}$$

The realized Dollar price and the realized Dollar velocity, jointly reflect the buyer's t-expectations about the future Dollar price in $t+2$. Realized Dollar inflation can therefore be expressed as in Equation (37) below, i.e. as the evolution of price expectations over time. Furthermore, prices must not only satisfy intertemporal indifference conditions but also clear goods markets. Therefore, expectations about future prices in $t+2$ implicitly entail expectations about future velocities and trade shares:

Lemma 4.2 (Realized inflation reflects expectations on trade and velocity)**.** *Under strategic uncertainty,*

a) Realized inflation in t+2 depends on the change of buyers' inflation expectations (i.e. the change of expectations about trade quantities and velocities) over time:

$$\frac{P_{t+2}}{P_t} = \beta^2 m^2 \cdot \mathbb{E}_{t+2}\left[\frac{1}{P_{t+4}}\right]^{-1} \mathbb{E}_t\left[\frac{1}{P_{t+2}}\right] \tag{37}$$

$$= \beta^2 m^2 \cdot \mathbb{E}_{t+2}\left[\frac{Y^D_{t+4}}{V^D_{t+4}}\right]^{-1} \cdot \mathbb{E}_t\left[\frac{Y^D_{t+2}}{V^D_{t+2}}\right]. \quad \textit{(Dollar)}, \tag{38}$$

b) For Bitcoin,

$$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2 \cdot \mathbb{E}_{t+2}\left[\frac{1}{\hat{P}_{t+4}}\right]^{-1} \mathbb{E}_t\left[\frac{1}{\hat{P}_{t+2}}\right] \tag{39}$$

$$= \beta^2 \cdot \mathbb{E}_{t+2}\left[\frac{Y - Y^D_{t+4}}{V^B_{t+4}}\right]^{-1} \cdot \mathbb{E}_t\left[\frac{Y - Y^D_{t+2}}{V^B_{t+2}}\right], \quad \textit{(Bitcoin)}. \tag{40}$$

Using these characterizations, we derive conditions on agents' inflation expectations that lead to deviations from the TQTM.

Proposition 4.4 (Equilibrium deviations from the TQTM)**.** *Under strategic uncertainty, monetary policy pass-through and deviations from the (Tempered) Quantity Theory of Money depend on the evolution of price or trade expectations.*

1. ***Dampened pass-through:*** *If buyers' price expectations are decreasing over time, or if their expectations about Dollar dominance in trade are increasing, or if their expectations about Dollar velocity are decreasing over time,*

$$\mathbb{E}_t\left[\frac{Y^D_{t+2}}{V^D_{t+2}}\right] \leq \mathbb{E}_{t+2}\left[\frac{Y^D_{t+4}}{V^D_{t+4}}\right], \quad \Leftrightarrow \quad \mathbb{E}_t\left[\frac{1}{P_{t+2}}\right] \leq \mathbb{E}_{t+2}\left[\frac{1}{P_{t+4}}\right] \tag{41}$$

then realized inflation undershoots, and monetary policy pass-through is even weaker than under SPFM equilibria (experimentally observed):

$$\frac{P_{t+2}}{P_t} \leq \beta^2 m^2.$$

2. ***Amplified pass-through:*** *If buyers' price expectations are increasing over time, or if their expectations about Dollar dominance in trade are declining, or if their expectations about Dollar velocity are increasing over time,*

$$\mathbb{E}_t\left[\frac{Y^D_{t+2}}{V^D_{t+2}}\right] > \mathbb{E}_{t+2}\left[\frac{Y^D_{t+4}}{V^D_{t+4}}\right], \quad \Leftrightarrow \quad \mathbb{E}_t\left[\frac{1}{P_{t+2}}\right] > \mathbb{E}_{t+2}\left[\frac{1}{P_{t+4}}\right] \tag{42}$$

then inflation overshoots, and monetary policy pass-through is improved compared to the SPFM case:

$$\frac{P_{t+2}}{P_t} > \beta^2 m^2.$$

3. ***Bitcoin spillovers:*** *If and only if buyers' expectations about Bitcoin prices increase over time, or if their expectations about Bitcoin trade declines (equivalently, expectations about Dollar trade increase), or if their expectations about Bitcoin velocity rise over time,*

$$\mathbb{E}_t\left[\frac{Y - Y^D_{t+2}}{V^B_{t+2}}\right] > \mathbb{E}_{t+2}\left[\frac{Y - Y^D_{t+4}}{V^B_{t+4}}\right] \quad \Leftrightarrow \quad \mathbb{E}_t\left[\frac{1}{\hat{P}_{t+2}}\right] > \mathbb{E}_{t+2}\left[\frac{1}{\hat{P}_{t+4}}\right] \tag{43}$$

then Bitcoin inflation overshoots its benchmark β^2: $\frac{\hat{P}_{t+2}}{\hat{P}_t} > \beta^2$.

In particular, pass through is dampened more than under the tempered GTM, $\frac{P_{t+2}}{P_t} < \beta^2 m^2$, if expected future prices exceed realized future prices, $\mathbb{E}_t\left[\frac{1}{P_{t+2}}\right] \leq \frac{1}{P_{t+2}}$.

The equilibrium constructions under perfect foresight in Section 4.5.1 imply that stronger deviations from the Quantity Theory of Money (beyond the tempered version) and monetary policy spillovers into Bitcoin prices arise only under strategic uncertainty, when expectations over prices, trade shares, or velocities evolve over time. Our Proposition 4.4 formalizes this implication.

Schilling and Uhlig (2019a) first showed that under currency competition, monetary expansions may raise the price of a competing currency rather than the domestic one, challenging the QTM. However, their analysis does not identify the underlying mechanism. We contribute to this debate in three key ways. First, we fully characterize symmetric perfect foresight equilibria and show that proportional monetary policy always passes through to Dollar prices, though tempered by discounting. Under perfect foresight, no spillovers to Bitcoin occur, trade shares and velocity adjust to preserve equilibrium. Second, we show that under strategic uncertainty, time-evolving expectations lead to deviations from the QTM, including policy undershooting or overshooting and spillovers into Bitcoin prices. This prediction is confirmed in our lab experiment, where coordination frictions trigger belief-driven reallocations across currencies, as discussed below. Third, unlike Schilling and Uhlig (2019a), who model lump-sum transfers, we model monetary policy as interest on Dollar balances, which shifts intertemporal incentives. This structural shift amplifies the agent's responses to monetary policy, and generates richer dynamics in trade shares and velocity.

In sum, we show that monetary policy pass-through and spill-over hinges critically on expectation formation: perfect foresight yields stable, Dollar-contained transmission without spill-over to Bitcoin, while strategic uncertainty permits cross-currency spillovers and departures from the QTM.

5 The Laboratory experiment

5.1 The Experimental environment

We design a group experiment with a between-subject design based on our theoretical framework. In each session, we run an experimental economy composed of 12 subjects, six 'red agents' and six 'green agents' who alternate in the role of buyers and sellers in every period.[14] Each treatment, the benchmark ($m = 1$) and active monetary policy ($m > 1$), involves 6 independent economies playing 4 experimental sequences (24 sessions), totaling 144 participants.

Sequences of play To emulate an infinite-horizon economy and discounting in the lab, we use independent repetitions, called sequences, of the experimental game with a stochastic ending, following the related literature (Fréchette and Yuksel, 2017). The stochastic ending prevents backward induction and induces impatience among subjects. Our subjects play repeatedly sequences composed of an unknown number of rounds so as to fill a two-hour lab session. Sequence lengths were randomly drawn from a geometric distribution with success parameter 1/6. In other words, at the beginning of each round, a sequence continues with probability $\beta = 5/6$, which acts as a proxy for the discount factor of the theoretical model. This probability is common knowledge among participants. With probability 1/6, a sequence ends and a new one begins among the same participants if enough time remains: participants were recruited for 2 hours and 15 minutes, with sequences designed to not exceed 1 hour and 50 minutes. This timing ensures that the end of the final sequence was kept sufficiently distant to remain unpredictable, maintaining a constant perceived ending probability throughout the experiment. To ensure comparability across sessions, the sequence lengths drawn for the first session are implemented for all sessions. Each round within a sequence represents one time period of the model.

The sequence lengths balance the trade-off between emulating impatience with shorter sequences and allowing sufficient learning opportunities inherent to lab experimentation in longer sequences. After a two-period training sequence to familiarize subjects with the trading interface and tasks without affecting their earnings, four sequences of play followed, consisting of seven, eleven, six, and eight periods, totaling 32 periods of actual play.

Trading in the lab In the experiment, we use two separate, currency-specific auction houses with a continuous double auction (CDA) mechanism, see the trading interface in Appendix D.2 for illustration. CDA experiments are well-known in the experimental literature to quickly and accurately converge to the predictions of the competitive market model and induce market clearing even with few traders and limited information; see, e.g., Smith (1982); Plott (2008). We use the labels "Currency A" for Dollars and "Currency B" for Bitcoin to avoid framing. The sellers submit ask prices, while buyers submit bids, with each bid consisting of a quantity and a unit price. The experiment enforces budget and capacity constraints. Buyers may submit multiple bids, but once accepted, their outstanding bids are deleted if they exceed their budget. Participants can retract bids or asks as long as they are not accepted. A first-come-first-match rule applies: trade occurs whenever a seller's ask price is less than or equal to a buyer's bid price. The transaction price in a match is always the seller's ask price. If multiple matches are feasible, an incoming buyer

[14] Six market participants are considered sufficient to induce competition and hinder collusion, see e.g. Dufwenberg and Gneezy (2000), while keeping the scale of the experiment small enough to collect 12 independent observations, see below.

is matched to the seller offering the lowest ask price that is less than or equal to the buyer's bid. Conversely, an incoming seller is matched to the buyer with the highest bid that is greater than or equal to the seller's ask. The number of packages exchanged is always the minimum of the buyer's demand and the seller's supply. If a seller has remaining packages, he may be rematched with another buyer. Additionally, each market has a shortcut for participants to instantly accept the best standing trade.

Sequence of events Each round of a given sequence proceeds as follows:

1. In the first round of each sequence ($t = 1$), six out of the 12 subjects are randomly assigned to start as buyers, the other six as sellers. Each buyer receives $d_{i,1} = 100$ Dollar and $b_{i,1} = 100$ Bitcoin, while each seller is endowed with $y_{i,1} = 5$ packages. In subsequent rounds ($\forall\, t > 1$), sellers continue to receive $y_{i,t} = 5$ packages, while buyers' money balances reflect the proceeds from the previous rounds' sales, possibly adjusted by central bank policy (see Section 5.2). Hence, $B = 600$, $D_1 = 600$ and $Y = 30$.
2. Sellers have 30 seconds to allocate their packages between the two currency-specific auction houses. Any allocation is feasible, the only exception to the theory being that the sellers can only allocate, and the buyers can only purchase full (integer) packages.
3. Subjects trade for a maximum of 90 seconds (the auction houses may close earlier if one side of the market becomes exhausted): buyers accumulate packages towards their real-world earnings, and sellers accrue Dollar and Bitcoin balances from sales proceeds.
4. After trade closes, monetary policy multiplies each Dollar (currency A) by factor $m \geq 1$ for both buyers and sellers, $D_t = m^t\, 600$. The quantity of Bitcoin does not change across rounds.
5. After each round, participants are informed whether the sequence continues, in which case their roles flip, currency balances carry over to the next round, and unsold packages perish. If the sequence ends, a new sequence starts, with balances reinitialized as in Step 1.

Payoff Subjects are paid based solely on the number of packages they purchase, with payoffs converted to euros using the CRRA function $\frac{\sqrt{\#\text{packages} \times 100}}{10}$ to mimic consumption smoothing. Balances in experimental currencies (Dollars and Bitcoin) are not paid out, preventing hoarding and reinforcing their role as fiat money (intrinsically worthless). Since roles alternate, subjects earn only every other period when they are buyers; as sellers, they accumulate currency to spend in future rounds. Final earnings are based on two randomly chosen sequences to limit wealth effects while ensuring reasonable payoffs. Payments were made anonymously via bank transfer. Average earnings were €13 (€2 standard deviation), excluding a €9 show-up fee.

5.2 Experimental treatments

To test the equilibrium predictions from Section 4, we implement two treatments, each consisting of six independent experimental economies. In the muted monetary policy treatment ($m = 1$), the Dollar supply is fixed at $D_t = 600 = B$, equal to the Bitcoin supply. In the active monetary policy treatment ($m = 1.3$), each subject's Dollar balance grows by 30%

per round, generating proportional transfers, that are asymmetric across subjects (Jiang, Puzzello, and Zhang, 2021), with the Dollar supply evolving as $D_t = 1.3^t \cdot 600$.

5.3 Lab implementation

The experiment was conducted using the oTree platform (Chen et al., 2016) and was run in-person at the CREED lab of the University of Amsterdam. Six sessions took place in Spring 2022 and six in Spring 2023 (with both treatments run each time), with a total of $12 \times 2 \times 6 = 144$ unique student participants. On average, participants were 22 years old; 52% identified as female,[15] around 60% studied Economics or Business, and most others Social Sciences or Law. Approximately 60% were from Europe and 30% from Asia; 91% reported being proficient in English, the experiment's language. Fewer than half had prior lab experiment experience. Treatment assignment was randomized and balanced across demographics.[16]

Participants first read the instructions privately at their own pace, followed by a verbal reading by the experimenter, all experimental material is provided in Appendix D. Participants then completed a four-question comprehension quiz before starting the game. At the end of the last sequence, participants completed a questionnaire on demographics, strategies, and comments.

6 Experimental results

We begin by examining the dynamics of unsold packages and subjects' utility (payoff) as measures of market efficiency, pooling data across all experimental economies; see Figure 4.

Experimental results 1 (Market efficiency)**.** *Across both treatments, the number of unsold packages declines significantly over rounds, yielding a significant increase in subjects' payoffs across rounds and sequences.*

We observe a steady increase in efficiency across rounds, consistent with Hypothesis 1. This indicates that repeated trading rounds and independent sequences fostered learning and a reduction of market frictions and miscoordination.

We now turn to the key experimental results on the effects of Dollar monetary policy on currency competition. Figure 5 displays the dynamics of the median values and the interquartile ranges of these variables across trading rounds and experimental sequences in the two treatments, figures of individual economies are deferred to Appendix B. We begin by summarizing our main findings before presenting a detailed analysis below:

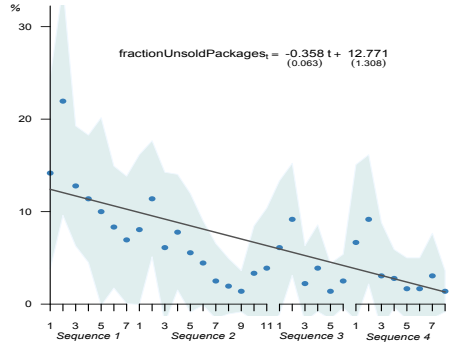
Experimental results 2 (Economies with muted monetary policy)**.** *The experimental data are consistent with equilibrium E0 (see Hypothesis 2), where the Dollar sales share, the prices in the Dollar and Bitcoin-denominated markets, and the resulting exchange rate are constant over time. Savings in both currencies persist over time at least partly due to strategic currency hoarding.*

As for the active monetary policy treatment, overall, our data initially support the equilibrium EMP1 of Hypothesis 3, indicating an equilibrium with partial monetary policy pass-through. However, as experimental sequences progress and subjects gain experience, the Dollar price pass-through strengthens. Subjects gradually revise their inflation expectations and anticipate rising inflation, leading to a reversal and decline in the Dollar trade

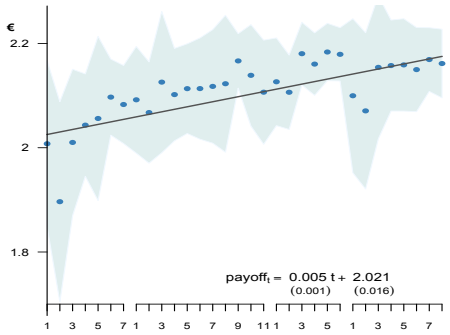
[15] Response options were male, female, and other.

[16] The F-statistic of joint significance of the demographics on treatment assignments are 2.00 and 1.22 for Trs. `noInfl` and `infl`.

(a) Average seller's unsold packages



(b) Average buyers' payoff



The dots indicate the average per period, the shaded blue area ± one standard deviation. The black line is the trend, represented by the linear regression line of the variable. The robust standard errors are reported between brackets underneath the estimated coefficients.

Figure 4: Efficiency indicators averaged across all treatments and markets over time.

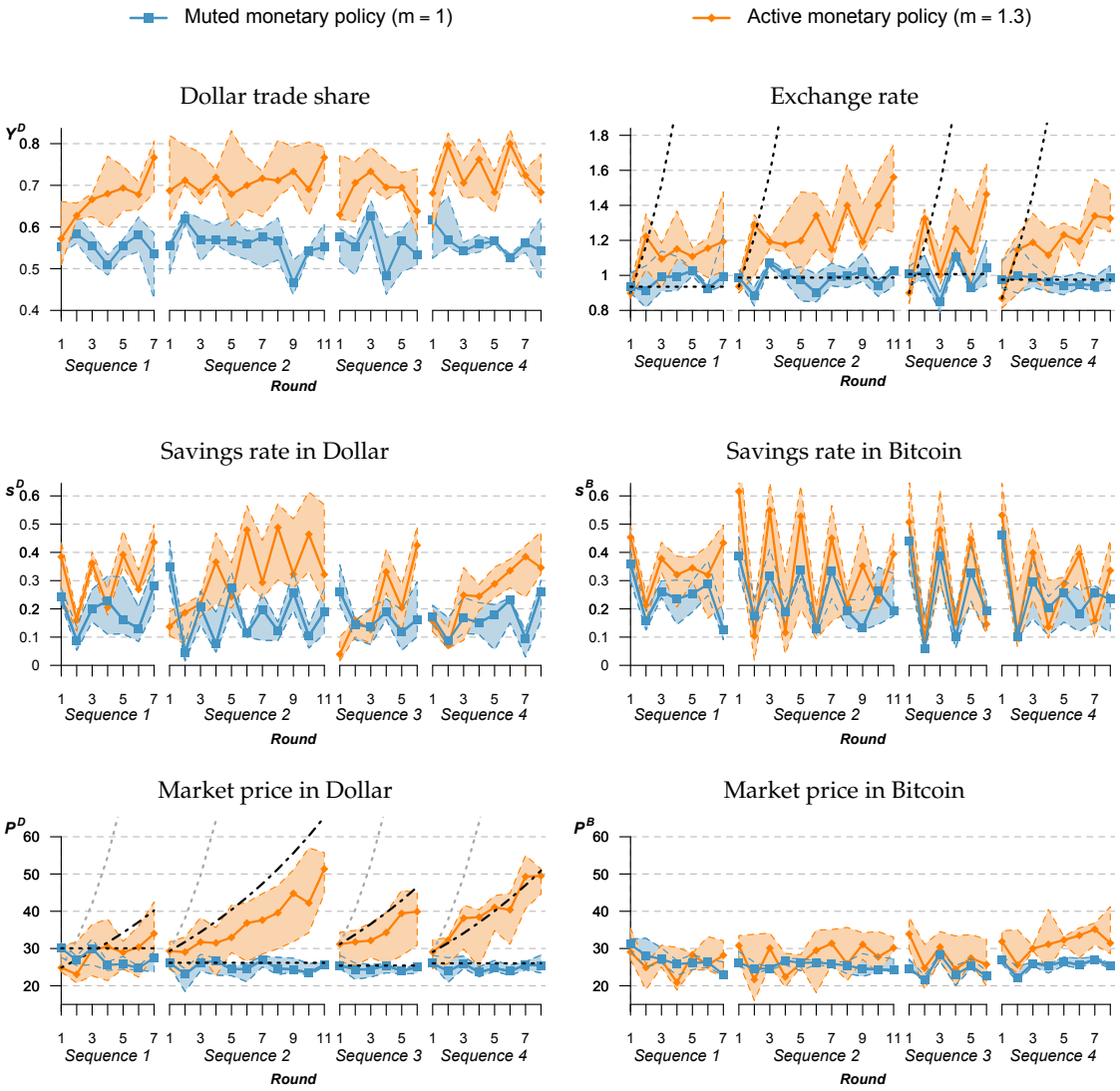
share and a rise in the Dollar velocity (i.e., a drop in savings rates). This behavioral adjustment results in stronger, though still incomplete, price pass-through, which closely matches the prediction of tempered QTM, shifting the equilibrium dynamics closer to the full pass-through equilibrium EMP2.

Experimental results 3 (Economies with active monetary policy)**.**

- ***Early experimental sequence 1-2 ("infant behavior") are consistent with Hypothesis EMP1:***
  - *The Dollar trade share rises over time or stabilizes at levels above 50%,*
  - *Dollar velocity drops over time, i.e. savings rates increase,*
  - *There is Dollar inflation, but below the rate suggested by the QTM (i.e. $\pi < 1.3$).*
  - *As the Dollar trade share reaches a high enough level, there is Bitcoin inflation due to scarcity (monetary policy spill-over)*
  - *The Bitcoin price in Dollars (exchange rate) strictly increases over time.*
- ***Later experimental sequences (adapted behavior/experience/Learning) show a gradual transition from EMP1 to EMP2***
  - *The Dollar trade share stabilizes before decreasing.*
  - *Dollar velocity is lower, and grows slower or flattens out (i.e. savings rates grow more slowly or stabilize compared to earlier sequences).*
  - *Dollar goods prices rise faster compared to earlier sequences, i.e. the pass through of monetary policy into inflation is higher in later rather than early experimental sequences, and matches the TQTM benchmark in the last sequence, $\pi = \frac{5}{6} * 1.3$*
  - *Bitcoin goods prices remain high as long as the Dollar trade share is high, but decline as the Dollar trade share comes down.*

6.1 Discussion: overall experimental dynamics

We first assess time variation in the main variables; see the regressions in Appendix Table C.2.



Notes: Median values per round across six independent experimental economies. The dashed colored lines represent Quartile 1 and Q3. The shaded areas depict the interquartile range (50% of observations). The black dotted lines represent theoretical reference values: a stable 30% growth path for the exchange rate in panel b) and a 30% growth path (1.3 slope, grey) respectively $\beta*$ 30% growth path (black) for the Dollar price in Panel e) given the median initial values in each sequence observed in the experiment. Prices are computed as an average weighted by sold quantities per round.

Figure 5: Dynamics with and without monetary policy

Muted monetary policy ($m = 1$) Under muted monetary policy ($m = 1$), subjects use both currencies roughly equally, with Dollar sales fluctuating between 50–60% and trending slightly downward toward 50%; see the blue lines in Figure 5b and Column I of Appendix Table C.2. Transaction prices in both currencies are similar, resulting in a stable exchange rate over time averaging around one; see Figures 5f, 5g), and 5c, and Column IV-VI of Table C.2. Constancy of the exchange rate is consistent with Equilibrium E0 of Hypothesis 3, and aligns with the seminal result of Kareken and Wallace (1981).

Note that our muted monetary policy treatment presents a subtle benchmark: since both currencies are perfect substitutes, the initial exchange rate $P_1/\hat{P}_1$ is indeterminate, as highlighted by Kareken and Wallace (1981), and may differ from one. Consequently, an

exchange rate different from one could have arisen even under our muted monetary policy benchmark. However, once realized in $t = 1$, it anchors all subsequent exchange rates.

Unlike in Kareken and Wallace (1981), where the overlapping generations model gives rise to a currency velocity of one per period, in our model, agents are infinitely lived, so that velocities can be smaller than one. In the experiment, we observe that savings rates oscillate across rounds due to role alternation between buyers and sellers, but remain stable across every other round. More surprisingly, subjects do not fully spend their currency in each round, despite several features of the experimental design that should discourage saving: (i) a high discount rate ($\beta = 5/6$), meaning the experimental sequence continues with probability only $1/6$ each round; (ii) currency balances are not paid out after the experiment (fiat property); (iii) the absence of income shocks and (iv) a utility function bounded below by $u(0) = 0$, implying no penalty for zero consumption.

On average, subjects save about 20% of their Dollar holdings (implying a velocity of 80%) and slightly less in Bitcoin, corresponding to a velocity of approximately 75%; see Figures 5d-5e and Columns (II)-(III) of Table C.2. Absent expectations of strong deflation, which would contradict the consistently observed price trends in the experimental markets, positive saving rates likely reflect market frictions or strategic behavior.

Frictions may result from buyer-seller miscoordination, causing rationing. For example, slower buyers may miss purchasing opportunities to faster competitors and be forced to pay higher prices, as reflected in the strategy-related terms highlighted in the word cloud (Figure D.4). Additionally, since sellers cannot reallocate packages across markets within a trading round, they are unable to react promptly to price signals. Our data also speak to strategic currency hoarding for precautionary motives in response to perceived future income risk stemming from the strategic uncertainty inherent to group dynamics. The asymmetry observed between consumption levels across buyers of a same economy provides support for this perceived risk; see Table C.1 in Appendix C.

Experimental dynamics with active monetary policy ($m = 1.3$) The picture changes markedly under active Dollar monetary policy ($m = 1.3$), see the orange lines in Figures 5. Although the initial Dollar trade share is similar across treatments in the first sequence, it rises significantly over time under monetary expansion, implying a corresponding decline in Bitcoin trade. This pattern is evident in both the first and second experimental sequences, see also Column I of Table C.2. Dollar saving rates are higher and rise over time under active monetary policy compared to the muted policy case, while Bitcoin saving rates remain stable; see also Columns (II)–(III) of Table C.2.

The most striking result emerges from the Dollar transaction prices: under active monetary policy, both currencies exhibit significant inflation. However, Bitcoin inflation cannot be attributed to an increase in its supply, which remains fixed. Conversely, Dollar inflation falls short of the rate predicted by the QTM, which would imply a price increase by a factor of $m = 1.3$ per round. The dotted grey line in the Dollar transaction price Figure 5 illustrates the QTM benchmark, $P_t^D = 1.3^{t-1} P_1$, showing the path the price level would follow had the theory held exactly. In this sense, part of the "missing" Dollar inflation can be found in Bitcoin prices, i.e., there is a monetary policy spill-over into Bitcoin prices. Consistent with this, the Bitcoin exchange rate rises over time (see Col. IV–VI of Table C.2), but by less than a factor of 1.3 per round. The dotted black line in the Dollar transaction price Figure 5 illustrates the tempered QTM benchmark, $P_t^D = \left(\frac{5}{6} 1.3\right)^{t-1} P_1$.

Importantly, we show in theory that a rise in the Dollar trade share (Dollar dominance)

or a decline in Dollar velocity does not require active monetary policy. Such shifts can occur in equilibrium even under mute policy, including under perfect foresight (see the detailed construction in Appendix A.1.2). In fact, under perfect foresight, the range of trade and velocity shifts sustainable in equilibrium is identical under both muted and active monetary policy.[17]

This raises the question: why do trade and velocity shifts emerge in the laboratory under active monetary policy, but not under inactive policy? In the lab, repeated policy interventions continuously shape agents' expectations, prompting them to adjust behavior by rebalancing intertemporal utility through changes in trade shares and velocity. When monetary policy is inactive, inflation expectations remain stable, allowing aggregate beliefs to converge quickly and leading to stable trade allocations and velocity.

6.2 Discussion: endogenous monetary policy pass-through and spillover

Regression results in Table 1 reveal the dynamic interdependence among the key equilibrium variables. A rising Dollar trade share and declining Dollar velocity both significantly reduce contemporaneous Dollar prices, dampening Dollar inflation (Column I). This inverse relationship is stronger under active monetary policy (Column II). Most notably, the regression confirms a scarcity-induced monetary spillover effect into Bitcoin: an increase in the Dollar trade share, mirrored by a decrease in the Bitcoin trade share, significantly raises contemporaneous Bitcoin prices, as does an increase in Bitcoin velocity, and these effects are amplified when monetary policy is active (Dollar inflation (Column I). These patterns persist when analyzing rates of change rather than levels; see Table C.3 in Appendix C), with Bitcoin inflation significantly higher under active than muted monetary policy (Dollar inflation (Column I).

Once the central bank pays interest on Dollar balances, both buyers and sellers shift behavior to benefit from the proportional transfers. If transfers had been symmetric, as in the theoretical model by Schilling and Uhlig (2019a), and independent of agents' actions or currency holdings, then higher inflation expectations would have led to a decline in Dollar trade shares, as sellers would prefer transacting in the less inflationary currency (consistent with our theory for $m = 1$). Similarly, Dollar velocity would have increased, as buyers would advance purchases to avoid trading at higher future prices. This mechanism is confirmed in the experimental findings of Cardozo, Rosokha, and Zhang (2024), who, as in the theory by Schilling and Uhlig (2019a), implement symmetric lump-sum transfers in a currency competition setting and find that rising the Dollar supply shifts trade into the more stable currency, avoiding the money illusion.

In contrast, our experimental results show that under proportional monetary transfers, i.e. with interest rates on Dollar balances, subjects on average exhibit money illusion: sellers increasingly favor accepting Dollars, raising the Dollar trade share, while buyers hoard them, reducing Dollar velocity over time. This behavior emerges despite the Dollar being explicitly designed to become more inflationary across rounds. The pattern suggests that agents underweight future Dollar inflation in their decision-making in order to benefit from the transfers. Their actions (an increase in the Dollar trade share and a decline in Dollar velocity) eventually contribute to lower-than-expected Dollar price realizations through market clearing (see Equation (27)). As a result, the price pass-through falls short of the 30%

[17] However, under mute policy, perfect foresight requires that both Dollar and Bitcoin inflation equal the discount factor (deflation), thus, such trade and velocity shifts then cannot be attributed to a "money illusion." The only difference between active and mute policy lies in the resulting equilibrium Dollar inflation rate, βm, which is constant across all possible equilibria within policy treatment, but differs across policy treatment.

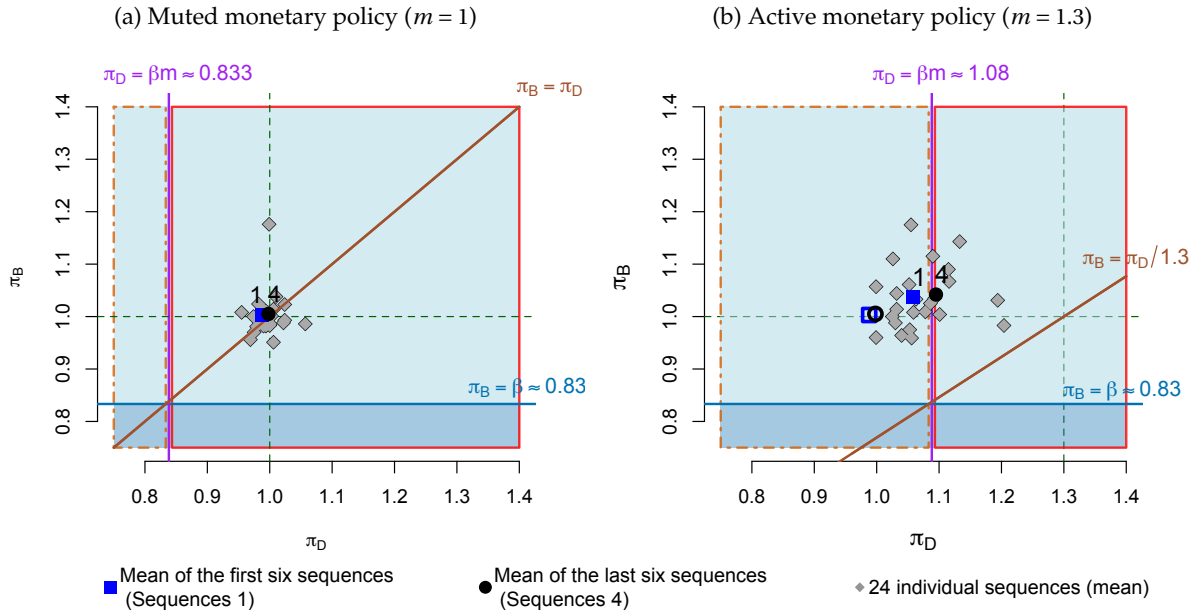
Dependent variable:	Dollar price		Bitcoin price	
	(I)	(II)	(III)	(IV)
Dollar trade share $\left(\frac{Y_t^D}{Y}\right)$	-18.381^{***}	-5.804^{**}	1.802	7.377^{***}
	(3.910)	(2.609)	(2.803)	(2.495)
Dollar velocity (V_t^D)	11.361^{***}	14.444^{***}		
	(4.027)	(3.344)		
Bitcoin velocity (V_t^B)			30.438^{***}	10.631^{***}
			(4.549)	(3.358)
$m = 1.3$ (omitted: $m = 1$)	12.540^{***}	41.049^{***}	4.681^{***}	-13.253^{*}
	(0.918)	(7.968)	(0.545)	(7.696)
$m = 1.3 \times \frac{Y_t^D}{Y}$		-31.189^{***}		-7.497
		(6.617)		(5.334)
$m = 1.3 \times V_t^D$		-11.357		
		(7.287)		
$m = 1.3 \times V_t^B$				30.319^{***}
				(7.200)
Constant	26.476^{***}	16.949^{***}	1.853	13.703^{***}
	(3.694)	(2.697)	(4.200)	(2.857)
Pseudo R-squared	0.279	0.283	0.288	0.321
Observations	384	384	384	384

Notes: Estimates of $P^X_{s,t} = \alpha_1 + \beta_1\left(\frac{Y^D_{s,t}}{Y_{s,t}}\right) + \beta_2 V^X_{s,t} + \beta_3 \mathbf{1}_{\{m=1.3\}} + \varepsilon_{s,t}$, (Cols. I and III) and $P^X_{s,t} = \alpha_1 + \beta_1\left(\frac{Y^D_{s,t}}{Y_{s,t}}\right) + \beta_2 V^X_{s,t} + \beta_3 \mathbf{1}_{\{m=1.3\}} + \beta_4\left(\mathbf{1}_{\{m=1.3\}} \times \frac{Y^D_{s,t}}{Y_{s,t}}\right) + \beta_5\left(\mathbf{1}_{\{m=1.3\}} \times V^X_{s,t}\right) + \varepsilon_{s,t}$, $X = D, B$, $t = 1, \ldots, 32$, $s = 1, \ldots, 6$ the sessions (Cols. II and IV) with robust least-squares, clustered robust standard errors at the session level. Velocities and prices are averages over two consecutive periods to account for the alternating buyer roles; *p<0.1; **p<0.05; ***p<0.01.

Table 1: Relationship between velocities, Dollar trade share, and prices

benchmark, and these lower price realizations validate the *ex ante* lower inflation expectations, which make the resulting strategic responses self-confirming *ex post*. Thus, our results stand in contrast to Cardozo, Rosokha, and Zhang (2024), where agents avoid money illusion. We attribute this discrepancy to differences in monetary policy implementation since their lump-sum transfers do not generate behavioral incentives for currency-specific hoarding or trade allocation.

Concerning Bitcoin prices, as predicted by the theory, Dollar monetary policy induces a scarcity-driven increase in Bitcoin prices, i.e. Bitcoin inflation: when sellers reallocate packages toward the Dollar market to take advantage of transfers, fewer goods remain for sale in the Bitcoin market. Given Bitcoin's fixed supply, this negative supply shock exerts upward pressure on Bitcoin prices, as a constant quantity of Bitcoin chases fewer goods, leading to Bitcoin inflation despite the absence of active monetary policy in the Bitcoin market. The observed spillover of Dollar monetary policy into Bitcoin prices resembles the "unconventional monetary policy effect" described in Corollary 4 of Schilling and Uhlig (2019a), which links Dollar policy to Bitcoin prices. However, unlike Schilling and Uhlig (2019a), where monetary policy transfers are lump-sum, symmetric, and hence independent of agent behavior, and all goods are offered in both currencies, our setting features



Average inflation rates per sequence are shown for all 24 sequences under treatment $m = 1$ and all 24 under $m = 1.3$, represented by gray diamonds. Solid blue squares indicate the average inflation rates of the first sequences ('1') across the six economies, while solid black circles represent the averages of the fourth sequences ('4'). RHS: The blue square and black circle contours correspond to the averages under mute monetary policy, included for direct comparison.

Figure 6: Average realized inflation rates in the (π^D, π^B) space.

proportional transfers and semi-segmented markets: sellers commit *ex ante* to a single trade allocation in each round. As a result, proportional Dollar transfers systematically reallocate trade volume toward the Dollar market, with sellers exhibiting money illusion. Both this money illusion and the resulting scarcity-driven Bitcoin inflation are absent in Schilling and Uhlig (2019a).

6.3 Discussion: learning across sequences

We now examine how subjects' behavior evolves across experimental sequences. At the start of each new sequence, when budgets are reset, subjects can draw on their experience from the previous sequence to revise their inflation expectations. This learning, in turn, may influence their choices regarding currency velocity and trade shares, thereby affecting inflation realizations in the subsequent sequence. Figure 6 reports the mean inflation realizations (grey) across all $4 \times 6 = 24$ experimental sequences with four sequences conducted in six independent economies using the same (π^D, π^B) state space as in Figure 3 of the theory in Section 4. The figure also compares the average inflation in the first sequence (solid blue) and the last sequence (solid black), each averaged across all six economies. The scatterplots in Figure 7 further illustrate how subjects adjust their behavior across repeated sequences.

Learning under muted monetary policy ($m = 1$)

In Figure 6a, we observe a strong concentration around the Dollar-Bitcoin ("currency A" versus "currency B") inflation couple $(1, 1)$, indicating that across experimental economies

and sequences, prices in both currencies remained stable and approximately equal over time. This suggests that under muted policy, subjects do not perceive a need to adjust or improve upon the strategies adopted in earlier periods.

Similarly, Figure 7 shows that subjects in the monetary policy treatment make only modest adjustments to their currency allocations, trade shares, and currency velocities over time.[18] Under muted monetary policy (circles), sellers consistently offer and sell slightly more goods for Dollars than for Bitcoin, as indicated by the majority of circles lying below the 45-degree line. This occurs despite the two currencies being perfect substitutes in the benchmark setting.[19] The share of goods offered for Dollars remains largely stable across sequences (compare the solid blue to the solid black circle in Figure 6a). The share of goods sold for both Dollars and Bitcoin increases slightly from the first to the last sequence (Figure 6b, likely due to improved coordination and familiarity with the experimental environment, which reduces the number of unsold packages.

Regarding currency velocities, Figure 7c reports the average velocities in each currency in the (V_D, V_B) plane. The subjects increase both Bitcoin and, even more markedly, Dollar velocity from the first to the last experimental sequence. This could speak to growing awareness of the probability that a sequence may end, leading to forfeited currency balances that are not carried over. Consequently, subjects increasingly opt to spend rather than hold money balances, especially in later sequences. Recall that currency balances are not paid out after the experiment to implement the fiat currency property (i.e., they are inherently worthless).

Learning under active monetary policy ($m = 1.3$)

Figure 6b shows that under active monetary policy, realized Dollar-Bitcoin inflation pairs are more dispersed than under muted policy, suggesting heterogeneous expectations and thus differing equilibria across experimental economies. Yet, all sequences share two robust features: (i) realized Dollar inflation consistently falls short of the QTM ($\pi_D \ll 1.3 = m$), and (ii) Bitcoin inflation is frequently above one ($\pi_B \gg 1$), despite a constant Bitcoin supply. Moreover, Dollar inflation tends to be lower in early sequences and higher in later ones, whereas Bitcoin inflation shows no such time trend. These patterns indicate that subjects update their expectations about future Dollar inflation as they gain experience. Nevertheless, the increase in Dollar supply does not fully pass through into Dollar prices.

We observe similar learning dynamics in allocation, trade shares, and velocities under active monetary policy, see Figure 7. Like under muted policy, there is a preference for selling in Dollars, but it is significantly more pronounced under active monetary policy. Comparing early and late experimental sequences, the Dollar allocation, and consequently, the Dollar trade share, is lower in the early sequences but increases over time, indicating a decline in Bitcoin trade. In the first sequence, subjects gradually shift toward Dollars, whereas in later sequences, they enter with a clear preference for Dollar transactions, reflecting updated expectations about the benefits of Dollar-denominated trade. However, this aggregate pattern masks variation across individual economies, some of which show a reversal or even collapse in the Dollar trade share toward the end of the sequences.

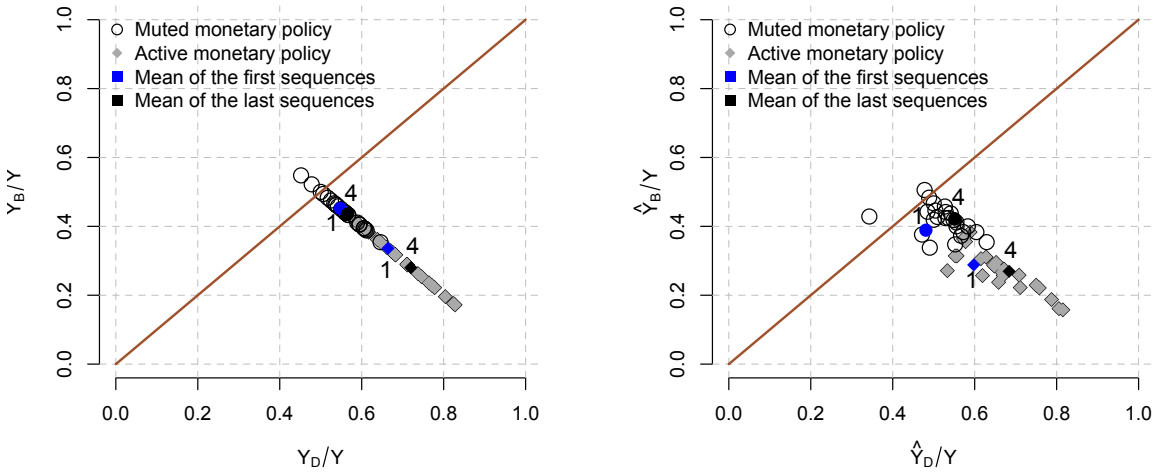
Likewise, currency velocities exhibit greater dispersion under active than muted monetary policy, reflecting increased variation in equilibrium outcomes. On average, both Dollar

[18] Dollar sales shares, market prices, exchange rates and saving rates are not significantly different between the first and the last sequences – the lowest p-value is 0.132. All tests are exact Wilcoxon rank sum tests at the matching group level with six observations in each group.

[19] Since the currencies are theoretically perfect substitutes, the model cannot account for this deviation.

(a) Market size by currency: allocation share (goods offered per currency)

(b) Market size by currency: trade share (goods sold per currency)



(c) Average dynamics of currency velocities

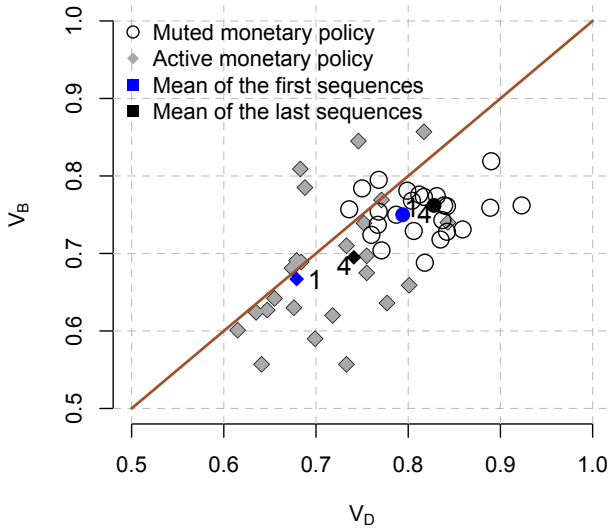


Figure 7: Average currency allocations, trade shares, and velocities across experimental sequences and economies. In the lab, some goods offered for currency remain unsold. Therefore, the allocation shares Y_t^D/Y and the trade share $\hat{Y}_t^D/Y$ can differ. In theory, there should not be any unsold packages, $Y_t^D = \hat{Y}_t^D$.

and Bitcoin velocities are lower with active than muted monetary policy, consistent with higher saving behavior. However, in both treatments, especially under active policy, the average Dollar velocity increases from the first (blue) to the last (black) sequence, indicating that subjects learn to anticipate future Dollar inflation, causing them to reduce their savings accordingly, as saved currency would inflate fast.

Single Economies Figure B.4 in the appendix illustrates notable heterogeneity across experimental economies. Economy 3 (purple) persistently exhibits a strong money illusion, maintaining Dollar trade shares near 90% throughout all sequences. In contrast, Economy 1

attempts to resist this illusion: while its Dollar trade share rises to around 70% in the second sequence, it subsequently drops below 50%. Across all sequences, Economy 1 consistently trades fewer goods in Dollars compared to Economy 3.

Figure B.6 shows that Economy 5 in the active monetary policy treatment experiences extreme Dollar inflation by the end of Sequence 2. In Sequences 3 and 4, possibly in response to this inflation episode, Economy 5 significantly increased Dollar velocity (i.e., reduced savings), as shown in Figure B.10, while maintaining a high Dollar sales share. This indicates that while buyers adapt their behavior by spending Dollars more quickly, sellers continue to prefer transacting in Dollars.

Figure B.8 reveals that several economies under active monetary policy, particularly Economies 2 and 5, experience strong Bitcoin inflation. In Economy 2, the scarcity effect on Bitcoin prices was so pronounced that Bitcoin inflation nearly matched Dollar inflation, with Bitcoin-denominated goods selling for 30–50 Bitcoin, comparable to Dollar prices ranging between 30–50 and occasionally reaching 70.

7 Conclusions

This study examines currency competition between a centrally managed currency, the Dollar, and a decentralized alternative in rigid supply, Bitcoin. We analyze how central bank monetary policy influences the relative usage, velocity, and inflation dynamics of the two currencies. Both theoretical modeling and laboratory evidence show that proportional monetary transfers, such as interest payments on reserves or CBDC balances, can increase the usage of the central bank's currency. However, this comes at the cost of reduced price control: increased Dollar usage does not translate into proportionally higher inflation as predicted by the quantity theory of money, due to agents' strategic behavior and slow adjustment of inflation expectations.

We further find that Dollar monetary policy produces unintended spillover effects into the Bitcoin market. By shifting trade away from Bitcoin, Dollar monetary policy induces relative scarcity in Bitcoin transactions, which in turn contributes to rising Bitcoin inflation, even though Bitcoin lacks its own monetary authority. This channel reflects a rational form of money illusion: agents strategically favor transacting in the more inflationary currency when it offers higher nominal returns, consistent with Gresham's law. This behavior is clearly observed in our experimental data.

These findings highlight the challenges central banks face in maintaining monetary dominance in an environment where alternative currencies operate outside their policy reach. Currency competition distorts the standard transmission mechanisms of monetary policy and introduces complex interdependencies between coexisting currencies. As the monetary system evolves toward greater pluralism, central banks must anticipate strategic substitution, expectation-driven dynamics, and behavioral responses when designing effective and credible policy frameworks.

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A Online Appendix

A.1 Theoretical Appendix

Proof. [Proof Lemma 4.1] For buyers, by the set-up of the model, consumption occurs solely through currency to purchase packages. If trade occurred in the previous period, at least one buyer in each market holds either Dollars or Bitcoins, enabling trade. Since sellers prefer to sell rather than let packages decay, and buyers derive positive utility from acquiring additional packages while sellers incur zero utility from decay, trade results in gains. Consequently, a mutually agreeable price can be found for both parties to trade all packages. □

A.1.1 Equilibrium Characterization

With monetary policy, the central bank multiplies every Dollar in the economy with the multiplier $m \geq 1$ per period. In the experiment, $m = 1.3$, but we hold m general in the calculations here. The green agent's optimization problem changes with regard to the Dollar balances. Green agents are buyers and hence consume in even periods, and are sellers in odd periods. As before, let $\xi_t = 1$ when t is even, and zero when odd. The green agent's Lagrangian reads

$$
\begin{aligned}
L = \sum_{t=0}^{\infty} \xi_t \beta^t \mathbb{E}_t \Big[& u(c_t) + \lambda_{13,t}(\hat{P}_t q_t^B) + \hat{\lambda}_{13,t}(b_t - \hat{P}_t q_t^B) && (44)\\
& + \lambda_{14,t}(P_t q_t^D) + \hat{\lambda}_{14,t}(d_t - P_t q_t^D) && (45)\\
& + \lambda_{15,t}(q_t^D + q_t^B - c_t) && (46)\\
& + \lambda_{16,t}(b_t - \hat{P}_t q_t^B - b_{t+1}) && (47)\\
& + \lambda_{17,t}(m(d_t - P_t q_t^D) - d_{t+1}) \Big] && (48)\\
+ (1-\xi_t)\beta^t \mathbb{E}_{t^-} \Big[& \lambda_{19,t}(y_t - x_t - z_t) && (49)\\
& + \lambda_{20,t^-}(b_t + \hat{P}_t x_t - b_{t+1}) && (50)\\
& + \lambda_{21,t^-}(m(d_t + P_t z_t) - d_{t+1}) && (51)\\
& + \lambda_{22,t^-} x_t + \lambda_{23,t^-} z_t \Big] && (52)
\end{aligned}
$$

Here, $\mathbb{E}_{t^-}$ denotes expectations formed at time t before prices are realized, that is, when the seller makes decisions without observing the current-period price levels P_t and $\hat{P}_t$. Since these prices are not measurable with respect to $\mathbb{E}_{t^-}$, sellers choose their allocations (x_t, z_t) at this stage based on anticipated rather than realized prices. Technically, one should index these choices with t^- to reflect the timing, but for simplicity, we omit this. This is valid, as (x_t, z_t) are fully determined by the seller's decision.

The following first order conditions apply. If t is even and $t+1$ is odd,

$$\begin{array}{lll}
I. & \frac{\partial L}{\partial c_t} & = u'(c_t) - \lambda_{15,t} = 0 \\
II. & \frac{\partial L}{\partial q_t^D} & = \lambda_{14,t} P_t - \hat{\lambda}_{14,t} P_t + \lambda_{15,t} - \lambda_{17,t} P_t\, m = 0 \\
III. & \frac{\partial L}{\partial q_t^B} & = \lambda_{13,t} \hat{P}_t - \hat{\lambda}_{13,t} \hat{P}_t + \lambda_{15,t} - \lambda_{16,t} \hat{P}_t = 0 \\
IV. & \frac{\partial L}{\partial x_{t+1}} & = -\lambda_{19,t+1} + \lambda_{20,t+1^-} \hat{P}_{t+1} + \lambda_{22,t+1^-} = 0 \\
V. & \frac{\partial L}{\partial z_{t+1}} & = -\lambda_{19,t+1} + \lambda_{21,t+1^-} P_{t+1}\, m + \lambda_{23,t+1^-} = 0 \\
VI. & \frac{\partial L}{\partial b_t} & = \hat{\lambda}_{13,t} \beta^t + \lambda_{16,t} \beta^t - \lambda_{20,t-1^-} \beta^{t-1} = 0 \\
VII. & \frac{\partial L}{\partial d_t} & = \hat{\lambda}_{14,t} \beta^t + \lambda_{17,t} \beta^t\, m - \lambda_{21,t-1^-} \beta^{t-1} = 0 \\
VIII. & \frac{\partial L}{\partial b_{t+1}} & = -\lambda_{16,t} \beta^t + \beta^{t+1}\, \lambda_{20,t+1^-} = 0 \\
IX. & \frac{\partial L}{\partial d_{t+1}} & = -\lambda_{17,t} \beta^t + \beta^{t+1}\, m\, \lambda_{21,t+1^-} = 0
\end{array} \tag{53}$$

Assume that sellers sell some packages for both Bitcoins and Dollars in every period, i.e. $x_t > 0$ and $z_t > 0$ for all t. Assume, that buyers purchase some packages using Bitcoin and Dollars in every period, $q_t^D, q_t^B > 0$. In equilibrium one implies the other since sellers cannot sell if buyers do not buy. Then, market clearing prices P_t and $\hat{P}_t$ for packages denominated in Dollars and Bitcoin are well-defined, and $\lambda_{13,t} = \lambda_{14,t} = \lambda_{22,t^-} = \lambda_{23,t^-} = 0$. Solving for the Lagrange multipliers, the FOCs IV and V yield

$$\mathbb{E}_{t^-}\left[\frac{\hat{P}_t}{\hat{P}_{t+1}}\, u'(c_{t+1})\right] = m\ \mathbb{E}_{t^-}\left[\frac{P_t}{P_{t+1}}\, u'(c_{t+1})\right] \tag{54}$$

In the deterministic case, the equation simplifies to

$$\frac{P_{t+1}}{P_t} = m\, \frac{\hat{P}_{t+1}}{\hat{P}_t}. \tag{55}$$

In the deterministic case, the seller's indifference equation has a straightforward implication for the exchange rate,

$$Q_{t+1} = m\, Q_t \tag{56}$$

The initial exchange rate Q_0 remains undetermined, as in Kareken Wallace. Further, one obtains

$$0 \leq \hat{\lambda}_{14,t} = \frac{1}{P_t} u'(c_t) - \beta^2 m^2\, \mathbb{E}_t\left[\frac{1}{P_{t+2}} u'(c_{t+2})\right] \tag{57}$$

and

$$0 \leq \hat{\lambda}_{13,t} = \frac{1}{\hat{P}_t} u'(c_t) - \beta^2\, \mathbb{E}_t\left[\frac{1}{\hat{P}_{t+2}} u'(c_{t+2})\right] \tag{58}$$

If not all Bitcoins and Dollars are spent in every period, $\hat{P}_t q_t^B < b_t$ and $P_t q_t^D < d_t$,i.e., if there are savings, then $\hat{\lambda}_{13,t} = 0 = \hat{\lambda}_{14,t}$. In that case, FOC VIII and IX yield the consumption-Euler equations for consumption-savings decisions in Bitcoins

$$\frac{u'(c_t)}{\hat{P}_t} = \beta^2\, \mathbb{E}_t\left[\frac{u'(c_{t+2})}{\hat{P}_{t+2}}\right] \tag{59}$$

and Dollars

$$\frac{u'(c_t)}{P_t} = \beta^2 m^2\, \mathbb{E}_t\left[\frac{u'(c_{t+2})}{P_{t+2}}\right]. \tag{60}$$

In the deterministic case, those equations reduce to

$$\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2 \frac{u'(c_{t+2})}{u'(c_t)} \tag{61}$$

and Dollars

$$\frac{P_{t+2}}{P_t} = \beta^2 m^2 \frac{u'(c_{t+2})}{u'(c_t)}. \tag{62}$$

A.1.2 Perfect Foresight Equilibrium Construction

We now construct the full set of symmetric perfect foresight monetary equilibria. Each equilibrium features either constant or changing Dollar trade allocations, and either constant or changing currency velocities. We analyze all possible combinations case by case.

Proposition A.1 (Existence of steady state symmetric perfect foresight equilibria)**.** *Assume the central bank conducts monetary policy, $m \geq 1$.*

1. ***Constant trade share Equilibrium***

   For any $\beta \leq 1$, there exists a symmetric perfect foresight equilibrium in which both buyers and sellers value and use both currencies, and trade shares remain constant over time,i.e., $Y_t^D = Y_{t-1}^D$ and $Y_t^B = Y_{t-1}^B \in (0,1)$ for all $t \geq 2$. Maintaining constant trade shares in equilibrium requires that currency velocities decline over time at the constant rate

   $$V_t^D = \beta V_{t-1}^D \leq V_{t-1}^D \in (0,1], \qquad \text{and} \qquad V_t^B = \beta V_{t-1}^B \leq V_{t-1}^B \in (0,1], \tag{63}$$

   implying increasing currency savings rates across time

   $$s_t^D = 1 - V_t^D = 1 - \beta + \beta s_{t-1}^D \geq s_{t-1}^D \tag{64}$$

   $$s_t^B = 1 - V_t^B = 1 - \beta + \beta s_{t-1}^B \geq s_{t-1}^B. \tag{65}$$

   The currency inflations are given by

   $$P_{t+1}/P_t = \beta m, \qquad \textit{Dollar} \tag{66}$$

   $$\hat{P}_{t+1}/\hat{P}_t = \beta < 1, \qquad \textit{Bitcoin (deflation)} \tag{67}$$

   In this equilibrium, the $t = 1$ prices, velocities, and trade shares are undetermined but must satisfy: $Y_1^B, Y_1^D = 1 - Y_1^B \in (0,1)$, resulting in prices and velocities $P_1, \hat{P}_1 > 0$, $V_1^B, V_1^D \in (0,1]$.

2. ***Constant velocity Equilibrium***

   - ***Steady state Equilibrium:*** *If $\beta = 1$, there exists a symmetric perfect foresight equilibrium in which both buyers and sellers value and use both currencies, and in which the velocities and trade shares of both currencies remain constant and strictly positive over time, that is, $Y_t^D = Y_{t-1}^D \in (0,1)$ and $Y_t^B = Y_{t-1}^B \in (0,1)$, $V_t^D = V_{t-1}^D \in (0,1]$, $V_t^B = V_{t-1}^B \in (0,1]$, Dollar inflation is given by $P_{t+1}/P_t = \beta m$ whereas Bitcoin inflation equals $\hat{P}_{t+1}/\hat{P}_t = \beta < 1$ (deflation), with arbitrary initial values $Y_1^D, Y_1^B \in (0,1)$, $V_1^D, V_1^B > 0$, and $P_1, \hat{P}_1 > 0$.*
   - *For $\beta < 1$, there does not exist a symmetric perfect foresight equilibrium in which both buyers and sellers value and use both currencies and both currency velocities remain constant and strictly positive over time.*

We next investigate the existence of symmetric perfect foresight equilibria featuring a specified change in either the Dollar trade share or the velocities.

Proposition A.2 (Equilibrium Construction: Shift in Dollar Trade Share)**.** *Consider a symmetric, perfect foresight monetary equilibrium in which the Dollar trade share changes by a factor* $\Delta_t^{Y,D} > 0$*, such that*

$$Y_t^D = \Delta_t^{Y,D} Y_{t-1}^D.$$

Let initial conditions Y_1^B*,* $Y_1^D = Y - Y_1^B > 0$*, and velocities* $V_1^B, V_1^D \in (0,1]$ *and prices* $P_1, \hat{P}_1 > 0$ *be given.*

Then, any trade share adjustment $\Delta_t^{Y,D} \in \left(0, \frac{1}{\beta V_{t-1}^D}\right]$ *satisfying the feasibility condition*

$$\frac{Y}{Y_{t-1}^D} - \frac{Y_{t-1}^B}{Y_{t-1}^D \beta V_{t-1}^B} \leq \Delta_t^{Y,D} < \frac{Y}{Y_{t-1}^D}$$

can be implemented in equilibrium. The corresponding adjustments in the Bitcoin trade share, currency velocities, and prices are uniquely determined as follows:

1. ***Bitcoin trade share****:*

$$\Delta_t^{Y,B} = \frac{Y - \Delta_t^{Y,D} Y_{t-1}^D}{Y_{t-1}^B} > 0, \quad \textit{so that} \quad Y_t^B = \Delta_t^{Y,B} Y_{t-1}^B.$$

2. ***Velocities****:*

$$V_t^D = \beta \Delta_t^{Y,D} V_{t-1}^D \in (0,1], \qquad V_t^B = \beta V_{t-1}^B \frac{Y - \Delta_t^{Y,D} Y_{t-1}^D}{Y_{t-1}^B} > 0, \quad \textit{so that} \quad Y_t^B = \Delta_t^{Y,B} Y_{t-1}^B \in (0,1].$$

3. ***Prices****:*

$$\frac{P_t}{P_{t-1}} = \beta m, \qquad \frac{\hat{P}_t}{\hat{P}_{t-1}} = \beta.$$

Proposition A.2 shows how intended shifts in the Dollar trade share influence not only the Bitcoin trade share but also both Dollar and Bitcoin velocities, through the buyers' and sellers' indifference conditions and market-clearing constraints. The growth constraint

$$\frac{Y}{Y_{t-1}^D} - \frac{Y_{t-1}^B}{Y_{t-1}^D \beta V_{t-1}^B} \leq \Delta_t^{Y,D} \leq \min\left(\frac{Y}{Y_{t-1}^D}, \frac{1}{\beta V_{t-1}^D}\right)$$

on the Dollar trade share guarantees feasibility of the implementation. It reflects two core requirements: (i) currency velocities must not exceed one per period, and be positive and (ii) both Dollar and Bitcoin trade allocations, Y_t^D and Y_t^B, must remain strictly positive to sustain a monetary equilibrium.

In the next proposition, we construct a symmetric perfect foresight equilibrium that implements a targeted evolution of Dollar velocity, denoted by $\Delta_t^{V,D} > 0$. Specifically, $\Delta_t^{V,D} > 1$ corresponds to rising Dollar velocity, while $\Delta_t^{V,D} \in (0,1)$ indicates a decline.

Although Dollar and Bitcoin velocities may initially appear decoupled, they are interlinked via market clearing through the endogenous trade shares. This interdependence restricts the degrees of freedom: only one velocity path can be freely specified.

Without loss of generality, we target the Dollar velocity path and derive the implied Bitcoin velocity dynamics, $\Delta_t^{V,B} > 0$, along with all remaining equilibrium quantities necessary to implement the desired Dollar velocity path.

Proposition A.3 (Equilibrium Construction: Shift in Dollar Velocity)**.** *Consider a symmetric, perfect foresight monetary equilibrium in which the Dollar velocity changes by a factor* $\Delta_t^{V,D} > 0$*,*

such that

$$V_t^D = \Delta_t^{V,D} V_{t-1}^D.$$

Let initial conditions Y_1^B, $Y_1^D = Y - Y_1^B > 0$, *velocities* $V_1^B, V_1^D \in (0,1]$, *and prices* $P_1, \hat{P}_1 > 0$ *be given.*

Then, any velocity adjustment $\Delta_t^{V,D} \in \left(0, \frac{1}{V_{t-1}^D}\right]$ *satisfying the feasibility condition*

$$\frac{\beta Y - Y_{t-1}^B}{Y_{t-1}^D} \leq \Delta_t^{V,D} < \beta \frac{Y}{Y_{t-1}^D}$$

can be implemented in equilibrium. The required adjustments in the Bitcoin velocity, trade allocations, and prices are given by:

1. ***Bitcoin velocity****:*

$$\Delta_t^{V,B} = \beta \left(\frac{Y - \frac{1}{\beta} \Delta_t^{V,D} Y_{t-1}^D}{Y_{t-1}^B} \right) \in (0,1], \qquad \textit{so that} \qquad V_t^B = \Delta_t^{V,B} V_{t-1}^B.$$

2. ***Trade allocations****:*

$$Y_t^D = \frac{1}{\beta} \Delta_t^{V,D} Y_{t-1}^D \in (0, Y), \qquad Y_t^B = \frac{1}{\beta} \Delta_t^{V,B} Y_{t-1}^B \in (0, Y).$$

3. ***Prices****:*

$$\frac{P_t}{P_{t-1}} = \beta m, \qquad \frac{\hat{P}_t}{\hat{P}_{t-1}} = \beta.$$

The proposition shows that both an increase in Dollar velocity ($\Delta^{V,D} > 1$) and a decrease ($\Delta^{V,D} \in (0,1)$) can arise under perfect foresight, that is, if agents could coordinate perfectly.

Proposition A.3 shows that a targeted shift in Dollar velocity affects not only the Dollar trade allocation but also spills over into Bitcoin, altering both its velocity and trade share, through the indifference conditions of buyers and sellers and the market-clearing constraints.

A.1.3 Proof: Perfect Foresight Equilibrium construction

We postpone the proof of Proposition A.1 to the end as it is a special case of the previous Propositions.

Proof: Equilibrium construction with directed shifts in trade share

Proof. [Proposition A.2]

Directed change in trade share We want to construct a symmetric perfect foresight equilibrium in which the Dollar trade allocation evolves at a particular rate $\Delta_t^{Y,D} > 0$, where $\Delta_t^{Y,D} > 1$ indicates an increase in the Dollar trade share over time, whereas $\Delta_t^{Y,D} \in (0,1)$ indicates a decline. In this equilibrium, we want both currencies to have value, so we choose initial trade allocations such that $Y_1^B, Y_1^D > 0$.

Given the past trade allocations Y_{t-1}^B, Y_{t-1}^D, the desired law of motion for our Dollar trade allocation requires $Y_t^D = \Delta_t^{Y,D} Y_{t-1}^D$. Given this desired change in the Dollar trade allocation, we require a corresponding adjustment of the Bitcoin trade allocation by a, so far

unknown, factor $\Delta_t^{Y,B} > 0$. $Y_t^B = \Delta_t^{Y,B} Y_{t-1}^B$ where feasibility establishes the following connection between the desired Dollar trade change $\Delta_t^{Y,D}$ and the accordingly required Bitcoin trade change $\Delta_t^{Y,B}$: $\Delta_t^{Y,B} Y_{t-1}^B = Y - Y_t^D = Y - \Delta_t^{Y,D} Y_{t-1}^D$, that is,

$$\Delta_t^{Y,B} = \frac{Y - \Delta_t^{Y,D} Y_{t-1}^D}{Y_{t-1}^B}. \tag{68}$$

Given the desired change in the Dollar trade share $\Delta_t^{Y,D} > 0$, feasibility requires the Bitcoin trade share to evolve according to the factor (68). Moreover, feasibility of the Dollar trade change $\Delta_t^{Y,D} > 0$ further requires that $Y - \Delta_t^{Y,D} \cdot Y_{t-1}^D > 0$, which we assume to hold from here onward.

To support the desired change in the trade share, we next construct the required change in velocities. Sequential market clearing in the Dollar market between the present and the previous period requires:

$$\left\{ \frac{mD_{t-1}V_t^D}{P_t} = Y_t^D = \Delta_t^{Y,D} Y_{t-1}^D = \Delta_t^{Y,D} \frac{D_{t-1}V_{t-1}^D}{P_{t-1}} \right\} \Leftrightarrow \left\{ \frac{P_t}{P_{t-1}} = \frac{m}{\Delta_t^{Y,D}} \frac{V_t^D}{V_{t-1}^D} \right\} \tag{69}$$

and sequential Bitcoin market clearing requires

$$\left\{ \frac{BV_t^B}{\hat{P}_t} = Y_t^B = \Delta_t^{Y,B} Y_{t-1}^B = \Delta_t^{Y,B} \frac{BV_{t-1}^B}{\hat{P}_{t-1}} \right\} \Leftrightarrow \left\{ \frac{\hat{P}_t}{\hat{P}_{t-1}} = \frac{1}{\Delta_t^{Y,B}} \frac{V_t^B}{V_{t-1}^B} \right\}. \tag{70}$$

With (69), sequential Dollar market clearing across two periods, hence, requires

$$\frac{P_t}{P_{t-2}} = \frac{P_t}{P_{t-1}} \frac{P_{t-1}}{P_{t-2}} = \frac{m^2}{\Delta_t^{Y,D} \Delta_{t-1}^{Y,D}} \frac{V_t^D}{V_{t-1}^D} \frac{V_{t-1}^D}{V_{t-2}^D} \tag{71}$$

whereas buyers' indifference between consumption and savings in the Dollar market in a symmetric equilibrium at time $t-2$ requires $\frac{P_t}{P_{t-2}} = \beta^2 m^2$. Market clearing jointly with buyer indifference thus requires $\frac{P_t}{P_{t-1}} = \beta m$ and, matching terms, $\frac{1}{\Delta_t^{Y,D}} \frac{V_t^D}{V_{t-1}^D} = \beta$ or $V_t^D = \beta \Delta_t^{Y,D} V_{t-1}^D$. The last equation pins down the equilibrium evolution of the Dollar velocity given the desired change in the Dollar trade share. This velocity is however only feasible for $V_t^D \in (0,1]$, that is, we require a growth constraint on the Dollar trade share, $\Delta_t^{Y,D} \leq \frac{1}{\beta V_{t-1}^D}$. See that for growth $\Delta_t^{Y,D} = 1$, this constraint is always satisfied by assumption. Likewise, in the Bitcoin market, buyer indifference and symmetry require: $\frac{\hat{P}_t}{\hat{P}_{t-2}} = \beta^2$ and jointly with market clearing, matching terms, require: $\frac{1}{\Delta_t^{Y,B}} \frac{V_t^B}{V_{t-1}^B} = \beta$ or $V_t^B = \beta \Delta_t^{Y,B} V_{t-1}^B$. Plugging the required change in the Bitcoin trade share $\Delta_t^{Y,B}$ from equation (68) into the Bitcoin velocity equation, the resulting law of motion for the Bitcoin velocity is given by:

$$V_t^B = \beta V_{t-1}^B \left(\frac{Y - \Delta_t^{Y,D} Y_{t-1}^D}{Y_{t-1}^B} \right) \tag{72}$$

This final equation determines the change in Bitcoin velocity as a function of the desired change in the Dollar trade share and past trade allocations. For feasibility of the Bitcoin velocity, we require $V_t^B \in (0,1]$, and hence a minimum growth of the Dollar trade share:

$$\frac{Y}{Y_{t-1}^D} - \frac{Y_{t-1}^B}{\beta Y_{t-1}^D V_{t-1}^B} \leq \Delta_t^{Y,D} \tag{73}$$

For growth $\Delta_t^{Y,D} = 1$ the constraint $V_t^B \leq 1$ holds by assumption, since $Y - Y_{t-1}^D = Y_{t-1}^B$. Finally, we confirm that at these given quantities, sellers are indeed indifferent and willing to increase the Dollar trade share by the factor $\Delta_t^{Y,D}$: $\frac{P_t}{P_{t-1}} = \beta m = m\frac{\hat{P}_t}{\hat{P}_{t-1}}$.

□

Proof: Equilibrium construction with directed shifts in velocity

Proof. [Proposition A.3] We aim to construct a symmetric perfect foresight equilibrium featuring a specified evolution of the Dollar velocity. That is, we target a velocity growth rate $\Delta_t^{V,D} > 0$ such that $V_t^D = \Delta_t^{V,D} V_{t-1}^D \in (0,1]$ which entails the first feasibility constraint $\Delta_t^{V,D} \leq \frac{1}{V_{t-1}^D}$ since otherwise, velocity in t would exceed one. Further, we need to calculate the required Bitcoin velocity growth $\Delta_t^{V,B} > 0$ with $V_t^B = \Delta_t^{V,B} V_{t-1}^B \in (0,1]$ to implement the desired Dollar velocity growth. Sequential market clearing across one period yields

$$\left\{P_t Y_t^D = mD_{t-1} V_t^D = mD_{t-1}\Delta_t^{V,D} V_{t-1}^D = m\Delta_t^{V,D} P_{t-1} Y_{t-1}^D\right\} \Leftrightarrow \left\{\frac{P_t}{P_{t-1}} = m\Delta_t^{V,D}\frac{Y_{t-1}^D}{Y_t^D}\right\} \tag{74}$$

$$\left\{\hat{P}_t Y_t^B = BV_t^B = B\Delta_t^{V,B} V_{t-1}^B = \Delta_t^{V,B}\hat{P}_{t-1} Y_{t-1}^B\right\} \Leftrightarrow \left\{\frac{\hat{P}_t}{\hat{P}_{t-1}} = \Delta_t^{V,B}\frac{Y_{t-1}^B}{Y_t^B}\right\} \tag{75}$$

Likewise across two periods. Buyers' indifference in $t-2$ in a symmetric perfect foresight equilibrium with $c_t = \bar{y} = c_{t+2}$ requires $\frac{P_t}{P_{t-2}} = m^2\beta^2$. Indifference jointly with sequential market clearing, hence, requires

$$\frac{P_t}{P_{t-2}} = \frac{P_t}{P_{t-1}}\frac{P_{t-1}}{P_{t-2}} = m^2\Delta_t^{V,D}\Delta_{t-1}^{V,D}\frac{Y_{t-1}^D}{Y_t^D}\frac{Y_{t-2}^D}{Y_{t-1}^D} = m^2\Delta_t^{V,D}\Delta_{t-1}^{V,D}\frac{Y_{t-2}^D}{Y_t^D} = m^2\beta^2 \tag{76}$$

Across one period, the Dollar trade allocation and velocity growht are connected by $\Delta_t^{V,D}\frac{Y_{t-1}^D}{Y_t^D} = \beta$ Thus, for a given desired change in Dollar velocity $\Delta_t^{V,D} > 0$ and a given past Dollar trade allocation Y_{t-1}^D, market clearing and buyer indifference requires an equilibrium Dollar trade allocation of

$$Y_t^D = \frac{1}{\beta}\Delta_t^{V,D} Y_{t-1}^D. \tag{77}$$

Feasibility of this trade allocation in a monetary equilibrium requires $Y_t^D \in (0, Y)$, and thus $\Delta_t^{V,D} \leq \beta\frac{Y}{Y_{t-1}^D}$. Similarly, for Bitcoin, in a symmetric perfect foresight equilibrium the buyers' indifference with respect to consumption and savings requires $\frac{\hat{P}_t}{\hat{P}_{t-2}} = \beta^2$. Jointly with sequential market clearing, and across one period, $\frac{\hat{P}_t}{\hat{P}_{t-1}} = \Delta_t^{V,B}\frac{Y_{t-1}^B}{Y_t^B} = \beta$. Thus, for a so far undetermined, change in Bitcoin velocity $\Delta_t^{V,B}$ and a given, past Bitcoin trade share Y_{t-1}^B, market clearing jointly with buyer indifference require

$$Y_t^B = \frac{1}{\beta}\Delta_t^{V,B} Y_{t-1}^B \tag{78}$$

On the other hand, feasibility of the Bitcoin trade allocation requires

$$Y_t^B = Y - Y_t^D \tag{79}$$

$$= Y - \frac{1}{\beta}\Delta_t^{V,D} Y_{t-1}^D \tag{80}$$

where we have plugged in the required Dollar trade share from (77) to implement the Dollar velocity. The constraint $\Delta_t^{V,D} \leq \beta \frac{Y}{Y_{t-1}^D}$ ensures $Y_t^B > 0$ whereas $\Delta_t^{V,D} > 0$ ensures $Y_t^B < Y$. Combining (78) and (79) gives the required change in the Bitcoin velocity as a function of past trade shares to implement the desired Dollar velocity $\Delta_t^{V,D}$ in equilibrium

$$\Delta_t^{V,B} = \beta \left(\frac{Y - \frac{1}{\beta} \Delta_t^{V,D} Y_{t-1}^D}{Y_{t-1}^B} \right) \tag{81}$$

where we require $Y - \frac{1}{\beta} \Delta_t^{V,D} Y_{t-1}^D > 0$ for feasibility. Moreover, by the set-up, velocity cannot exceed one. We hence, require $\frac{\beta Y - Y_{t-1}^B}{Y_{t-1}^D} \leq \Delta_t^{V,D}$. □

Proof: Perfect Foresight Equilibrium with const. trade share or velocity

Proof. [Proposition A.1] We construct two types of equilibria.

Constant trade share equilibrium This is a special case of Proposition A.2 with $\Delta_t^{Y,D} = 1$. Clearly, this equilibrium exists which can be verified by plugging in.

Constant velocity Equilibrium This equilibrium is a special case of Proposition A.3. However, this equilibrium does not exist for $\beta = 1$. The following calculations help seeing that: Assume, in $t = 1$, sellers jointly choose strictly positive goods allocations to both markets $Y_1^B, Y_1^D = Y - Y_1^B > 0$, resulting in market clearing prices and velocities $P_1, \hat{P}_1 > 0$, $V_1^B, V_1^D \in (0, 1]$. We again restrict attention to symmetric equilibria, implying $c_t = \bar{y} = c_{t+2}$.

We want to show that given these intial values, there exists a symmetric perfect foresight equilibrium, i.e. a sequence $\{P_t, \hat{P}_t, V_t^D, V_t^B, Y_t^D, Y_t^B = Y - Y_t^D\}_{t \geq 1}$ such that both goods prices are positive at every t, $P_t, \hat{P}_t > 0$, and both velocities are constant across time, $V_t^D = V_{t-1}^D$ and $V_t^B = V_{t-1}^B$ for all $t > 2$.

Consider again sellers in $t \geq 2$ who do not observe the prices P_t and $\hat{P}_t$ when making their individual, and thus aggregate, allocations Y_t^B and Y_t^D. For sellers to be indifferent between receiving Dollars or Bitcoins in period t, the traded quantities must lead to future and contemporaneous prices that satisfy $\frac{P_{t+1}}{P_t} = m \cdot \frac{\hat{P}_{t+1}}{\hat{P}_t}$. Buyer indifference between consumption and savings in the Dollar market, together with symmetry, requires that $\frac{P_{t+2}}{P_t} = \beta^2 m^2$, while in the Bitcoin market it requires $\frac{\hat{P}_{t+2}}{\hat{P}_t} = \beta^2$.

At constant currency velocities, we want to find the trade allocation Y_t^D, Y_t^B that attains and maintains indifference for both buyers and sellers across time.

Given constant velocities, sequential Dollar Market clearing demands

$$\{P_t Y_t^D = m^2 D_{t-2} V_t^D = m^2 D_{t-2} V_{t-2}^D = m^2 P_{t-2} Y_{t-2}^D\} \Leftrightarrow \left\{ \frac{P_t}{P_{t-2}} = m^2 \frac{Y_{t-2}^D}{Y_t^D} \right\}, \tag{82}$$

and sequential clearing in the Bitcoin market requires

$$\{\hat{P}_t Y_t^B = B V_t^B = B V_{t-2}^B = \hat{P}_{t-2} Y_{t-2}^B\} \Leftrightarrow \left\{ \frac{\hat{P}_t}{\hat{P}_{t-2}} = \frac{Y_{t-2}^B}{Y_t^B} \right\}. \tag{83}$$

Given positive past prices $P_{t-2}, \hat{P}_{t-2} > 0$, positive velocities $V_t^D = V_{t-2}^D > 0$, $V_t^B = V_{t-2}^B > 0$ and positive trade shares today $Y_t^D, Y_t^B > 0$, today's prices must be positive. Or put differently, positive prices today rationalize positive trade shares and velocities for either currency.

To construct an equilibrium, sellers today need to validate past buyers' inflation expectations in either market ex post and vice versa. To keep (past $t-2$) buyers indifferent in the Dollar market, according to (82) the sellers in t have to set Y_t^D such that $\frac{P_t}{P_{t-2}} = m^2\beta^2$ attains, i.e. have to set $\frac{Y_{t-2}^D}{Y_t^D} = \beta^2$, implying an increasing Dollar allocation $Y_t^D = \frac{1}{\beta^2} Y_{t-2}^D > Y_{t-2}^D$, similarly for Bitcoin, $\frac{Y_{t-2}^B}{Y_t^B} = \beta^2$, and thus $Y_t^B = \frac{1}{\beta^2} Y_{t-2}^B > Y_{t-2}^B$. This increase in both allocations will turn out to be not feasible, unless $\beta = 1$. .

While these choices by the t-sellers keep the $t-2$-buyers' indifferent, the choice $Y_t^D = \frac{1}{\beta} Y_{t-1}^D$, and $Y_t^B = \frac{1}{\beta} Y_{t-1}^B$ jointly with the choice $V_t^D = V_{t-1}^D$ and $V_t^B = V_{t-1}^B$ also keeps sellers indifferent: Sequential clearing in the Dollar market one-period ahead requires

$$\{P_t Y_t^D = mD_{t-1} V_t^D = mD_{t-1} V_{t-1}^D = mP_{t-1} Y_{t-1}^D\} \Leftrightarrow \left\{ \frac{P_t}{P_{t-1}} = m \frac{Y_{t-1}^D}{Y_t^D} \right\}, \tag{84}$$

and the Bitcoin market

$$\{\hat{P}_t Y_t^B = BV_t^B = BV_{t-1}^B = \hat{P}_{t-1} Y_{t-1}^B\} \Leftrightarrow \left\{ \frac{\hat{P}_t}{\hat{P}_{t-1}} = \frac{Y_{t-1}^B}{Y_t^B} \right\}, \tag{85}$$

Thus, $V_t^D = V_{t-1}^D$ and $V_t^B = V_{t-1}^B$ jointly with $Y_t^D = \frac{1}{\beta} Y_{t-1}^D$, and $Y_t^B = \frac{1}{\beta} Y_{t-1}^B$ imply $\frac{P_t}{P_{t-1}} = \beta m = m \frac{\hat{P}_t}{\hat{P}_{t-1}}$, validating the $t-1$ sellers' relative inflation expectations ex post.

The buyers' joint choices $V_t^D = V_{t-1}^D$, $V_t^B = V_{t-1}^B$ together with the sellers' joint choices $Y_t^D = \frac{1}{\beta} Y_{t-1}^D$, and $Y_t^B = \frac{1}{\beta} Y_{t-1}^B$ for all $t \geq 2$, with an arbitrary choice $P_1, \hat{P}_1 > 0$, $Y_1^B, Y_1^D = Y - Y_1^B \in (0,1)$, $V_1^D, V_1^B > 0$ appear to constitute a steady state equilibrium.

However, these joint choices are not feasible: Observe that by the construction above, for any $\beta \in (0,1)$, $Y_t^D = Y - Y_t^B = Y - \frac{1}{\beta} Y_{t-1}^B = Y - \frac{1}{\beta}(Y - Y_{t-1}^D) \neq \frac{1}{\beta} Y_{t-1}^D$ for all t. Thus, for any $\beta < 1$, there exists no symmetric perfect foresight monetary equilibrium in which buyers hold velocities constant. Only for the special case $\beta = 1$, the construction above holds.

□

B Single Economies

The following plots display the behavior of individual economies across treatments, whereas the figures above primarily report averages or medians across economies.

It is important to emphasize that, although we label economies as "1–6" across treatments, the participants differ across these economies and treatments. Specifically, the subjects in economies 1–3 of the benchmark treatment are not the same individuals as those in economies 1–3 of the monetary policy treatment. Similarly, economies 4–6 in the benchmark treatment consist of different participants than economies 4–6 in the monetary policy treatment.

B.1 Dollar trade share

Muted Monetary Policy Treatment

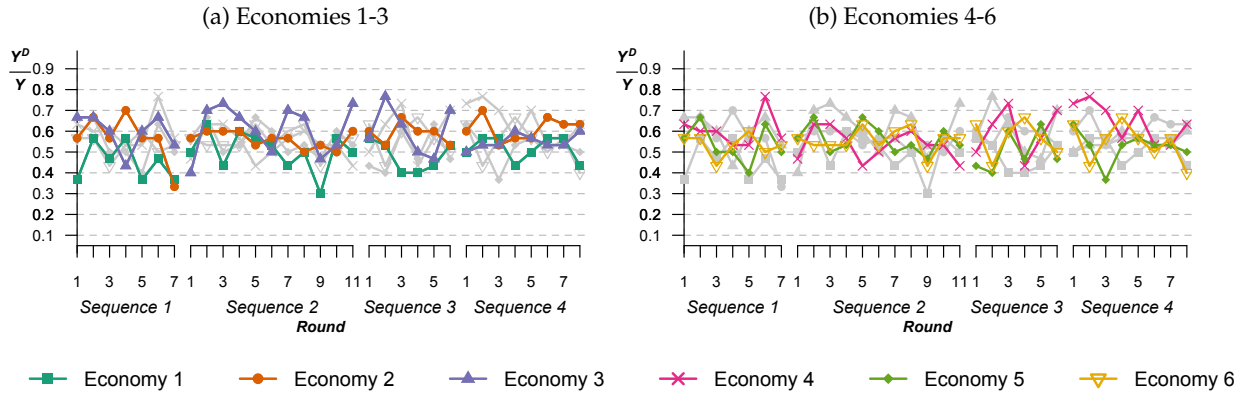


Figure B.1: Dollar trade share across single experimental economies in the benchmark setting

Active Monetary Policy Treatment

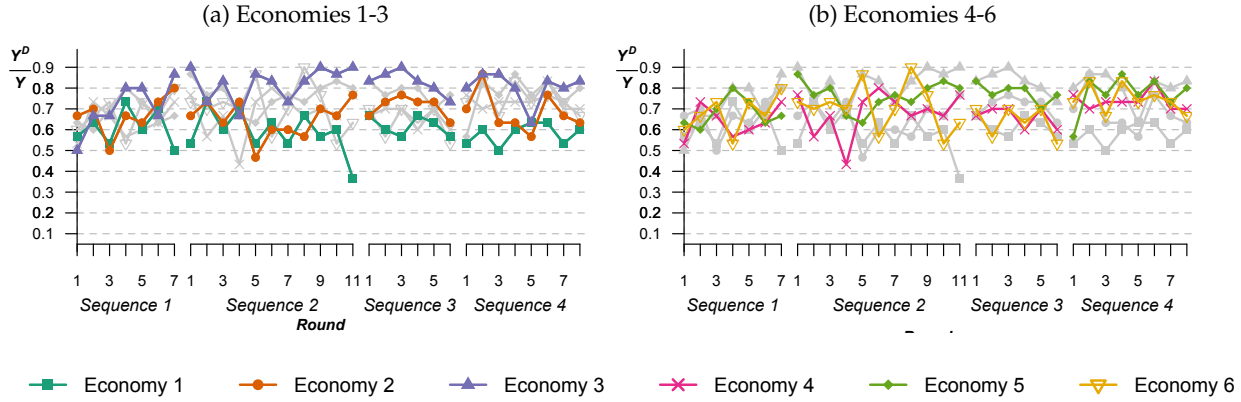


Figure B.2: Dollar trade share across single experimental economies in the monetary policy setting

B.2 Dollar sales share

Muted Monetary Policy Treatment

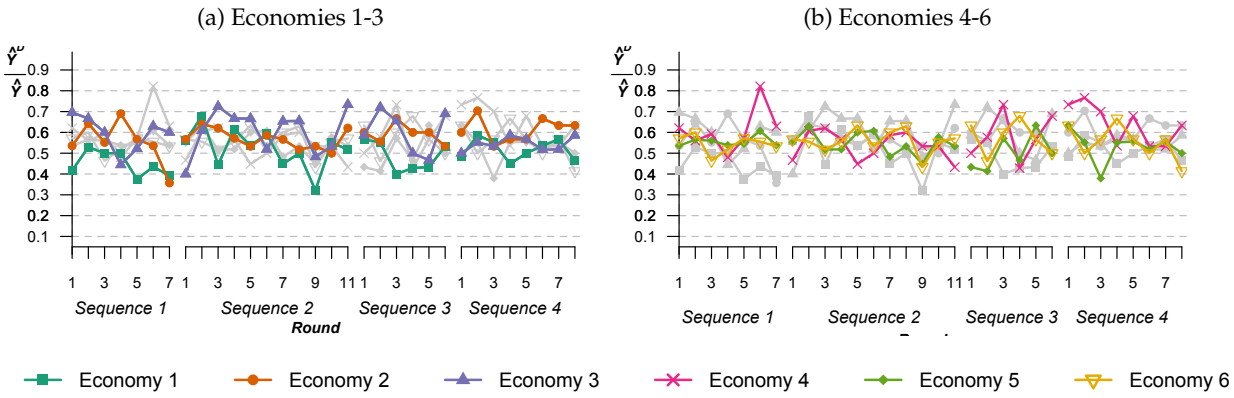


Figure B.3: Dollar sales share across single experimental economies in the benchmark setting

Active Monetary Policy Treatment

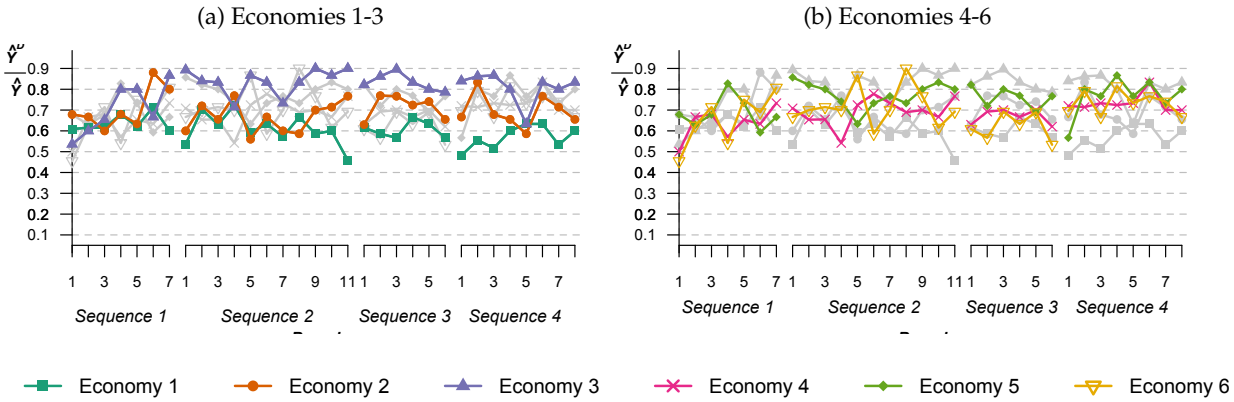


Figure B.4: Dollar sales share across single experimental economies in the monetary policy setting

B.3 Dollar goods price ("currency A")

Muted Monetary Policy Treatment

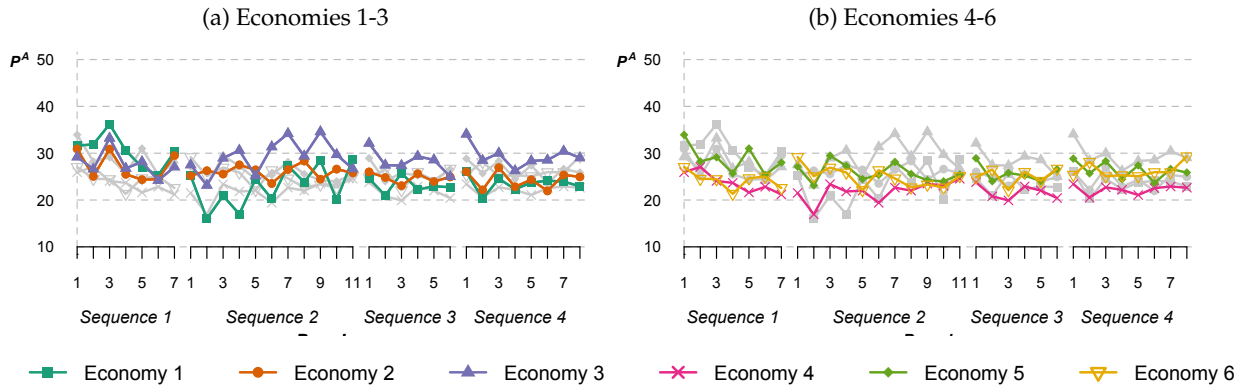


Figure B.5: Realized Dollar goods prices across single experimental economies in the benchmark setting

Active Monetary Policy Treatment

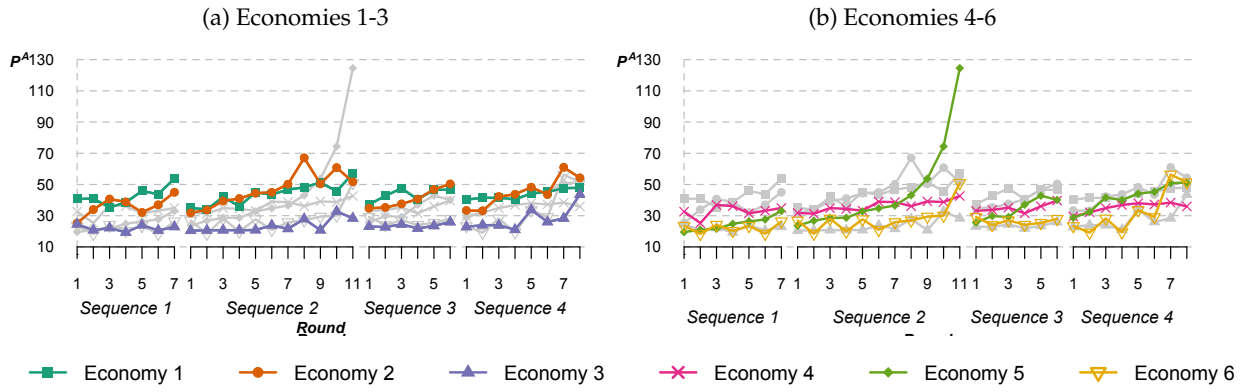


Figure B.6: Realized Dollar goods prices across single experimental economies in the monetary policy setting

B.4 Bitcoin goods price ("currency B")

Muted Monetary Policy Treatment

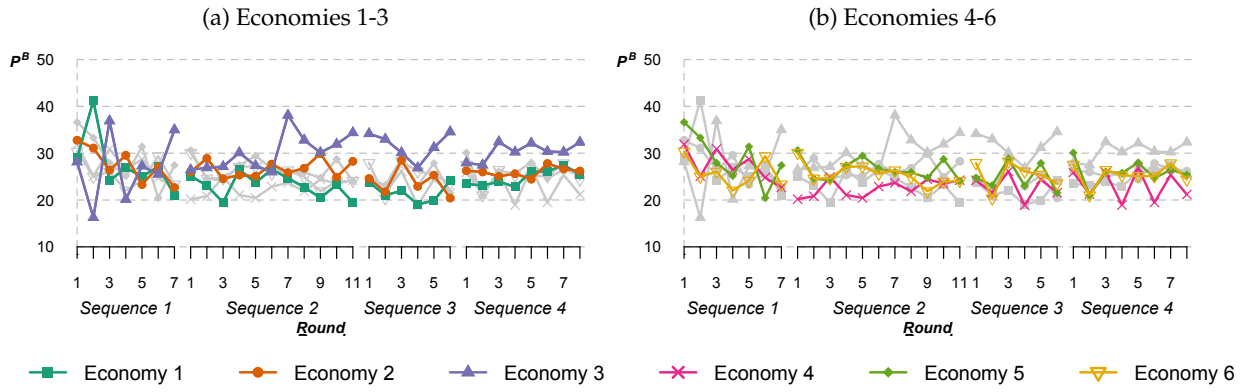


Figure B.7: Realized Bitcoin goods prices across single experimental economies in the benchmark setting

Active Monetary Policy Treatment

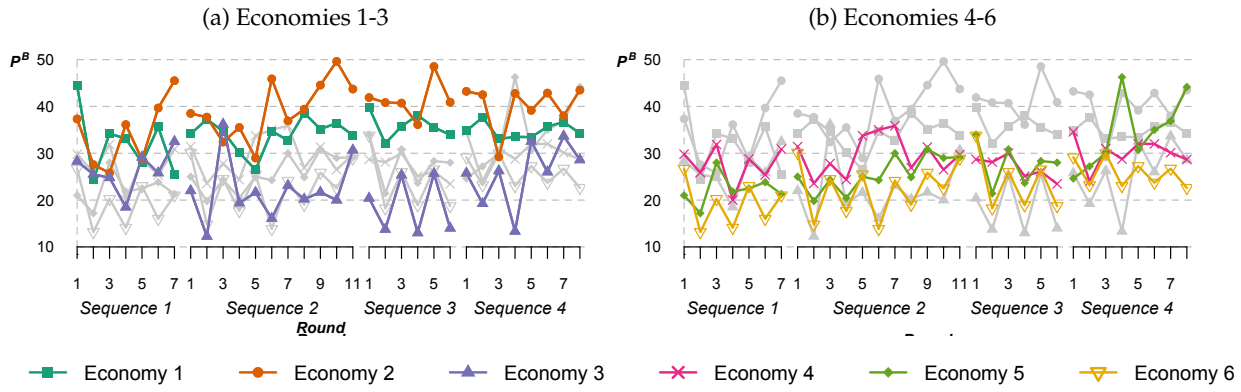


Figure B.8: Realized Bitcoin goods prices across single experimental economies in the active monetary policy setting

B.5 Dollar savings rate

Muted Monetary Policy Treatment

(a) Economies 1-3 (b) Economies 4-6

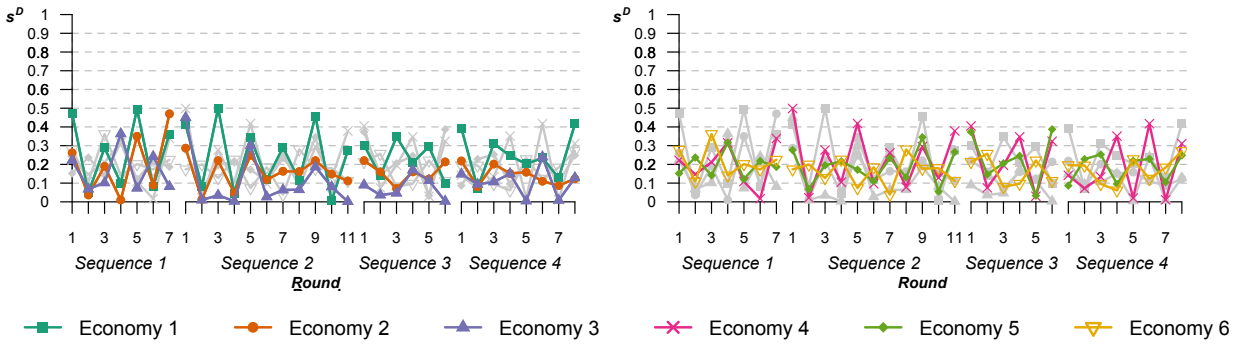


Figure B.9: Realized Dollar savings rate ($s^D = 1 - V^D$) across single experimental economies in the benchmark setting

Active Monetary Policy Treatment

(a) Economies 1-3 (b) Economies 4-6

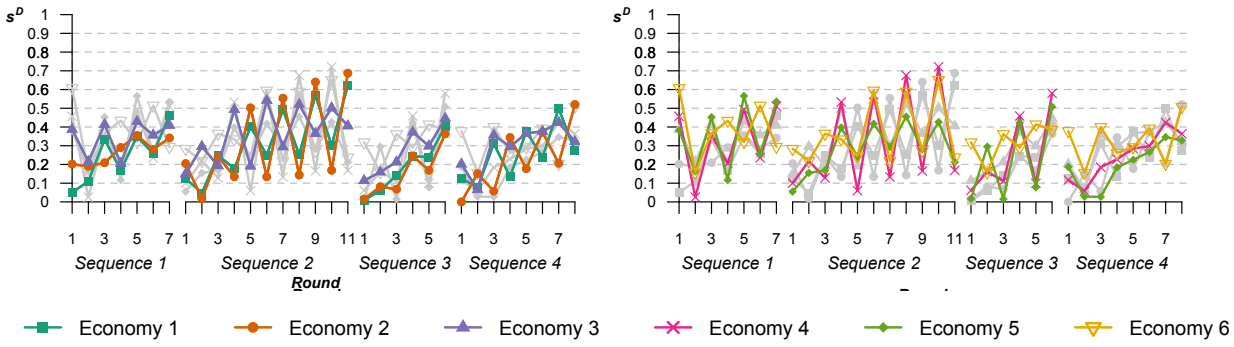


Figure B.10: Realized Dollar savings rate (the share of unspent currency) ($s^D = 1 - V^D$) across single experimental economies in the monetary policy setting

B.6 Bitcoin savings rate

Muted Monetary Policy Treatment

(a) Economies 1-3 (b) Economies 4-6

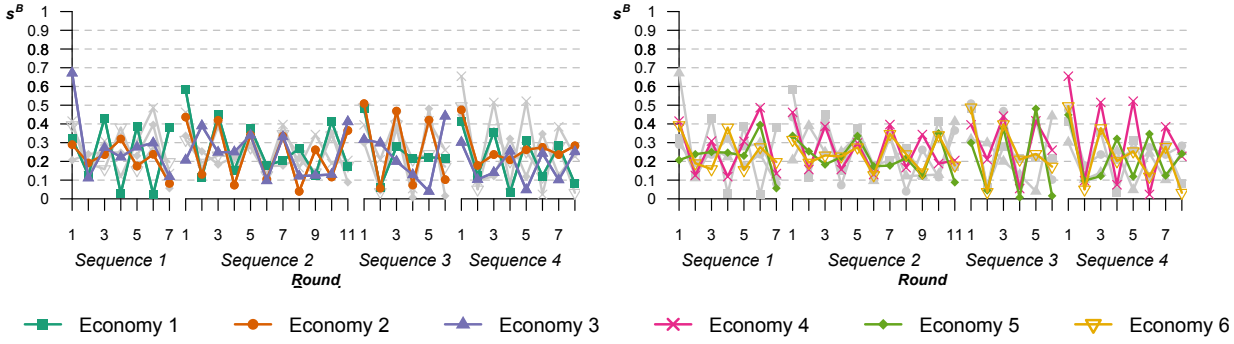


Figure B.11: Realized Bitcoin savings rate ($s^B = 1 - V^B$) across single experimental economies in the benchmark setting

Active Monetary Policy Treatment

(a) Economies 1-3 (b) Economies 4-6

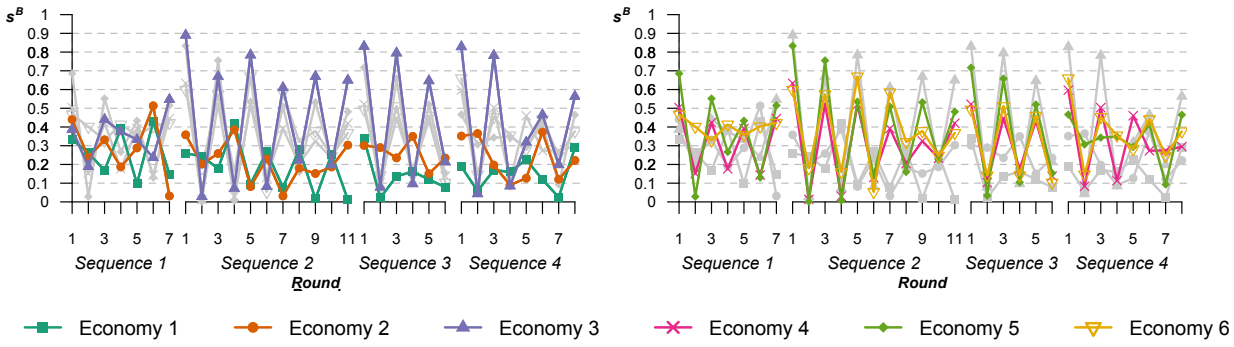


Figure B.12: Realized Bitcoin savings rate (the share of unspent currency) ($s^D = 1 - V^D$) across single experimental economies in the monetary policy setting

C Additional experimental results

	Panel A. Price paid in Dollar	*Panel B. Price paid in Bitcoin*
(I) $m = 1$	0.829 (0.162)	1.040 (0.377)
(II) $m = 1.3$	2.153 (2.133)	1.951 (0.453)
p-value (I) vs. (II)	0.009***	0.026**
	Panel C. Packages bought in Dollar	*Panel D. Packages bought in Bitcoin*
(I) $m = 1$	0.640 (0.030)	0.984 (0.046)
(II) $m = 1.3$	1.395 (0.373)	1.056 (0.049)
p-value (I) vs. (II)	0.004***	0.590
	Panel E. Total consumption	
(I) $m = 1$	56.040 (135.881)	
(II) $m = 1.3$	113.288 (4667.42)	
p-value (I) vs. (II)	0.041**	

Notes: Each cell reports the relative dispersion of a given variable across the six buyers for each treatment, averaged over the 32 paid periods and the six independent sessions; standard deviations are reported next in parentheses. Each p-value corresponds to the exact two-sided Mann-Whitney rank-sum test of cross-treatment comparison, performed on matching-group level with six observations per treatment variable.

Table C.1: Relative dispersion of buyers' prices and consumption levels

Dependent variables:	Dollar trade share	Dollar saving rate	Bitcoin saving rate	Dollar market price	Bitcoin market price	Exchange rate
	(I)	(II)	(III)	(IV)	(V)	(VI)
$\mathbf{1}_{\{m=1.3\}}$ (omitted: $m=1$)	0.102^{***}	-0.056	0.067^{**}	-1.373	1.254	-0.047
	(0.027)	(0.041)	(0.033)	(3.629)	(2.375)	(0.071)
round	-0.004^{***}	-0.002	-0.013^{***}	-0.053	-0.078	0.002
	(0.001)	(0.002)	(0.001)	(0.070)	(0.147)	(0.006)
$\mathbf{1}_{\{m=1.3\}}\times$ round	0.009^{***}	0.034^{***}	0.001	2.341^{***}	0.415^{*}	0.060^{***}
	(0.002)	(0.005)	(0.002)	(0.689)	(0.222)	(0.021)
Constant	0.577^{***}	0.230^{***}	0.310^{***}	24.805^{***}	26.024^{***}	0.975^{***}
	(0.015)	(0.017)	(0.012)	(1.287)	(0.942)	(0.041)
F-stat	4.57^{**}	79.7^{***}	7.00^{***}	103.7^{***}	3.78^{*}	72.3^{***}
R2	0.405	0.295	0.074	0.402	0.086	0.293
Obs.	384	384	384	384	384	384

Notes: OLS estimates with cluster-robust standard errors at the session level reported between brackets, sequence fixed effects included. The F-statistic and p-value correspond to the linear restriction test H_0: round + $\mathbf{1}_{\{m=1.3\}}$ × round = 0, i.e. the variable is not time varying under $m = 1.3$, computed using cluster-robust standard errors. *p<0.1; **p<0.05; ***p<0.01.

Table C.2: Time variation in the main variables

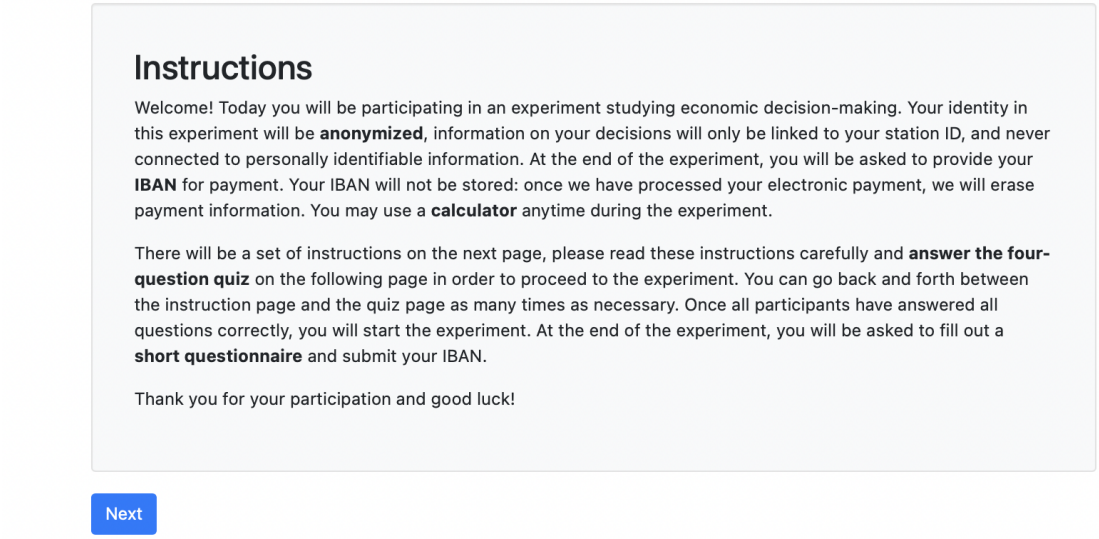
Dependent variable:	Dollar inflation rate		Bitcoin inflation rate	
	(I)	(II)	(III)	(IV)
Change in Dollar trade share ($\Delta\frac{Y_t^D}{Y}$)	-0.313^{***}	-0.287^{***}	0.480^{***}	0.424^{***}
	(0.107)	(0.084)	(0.125)	(0.140)
Change in Dollar velocity (ΔV_t^D)	0.274^{**}	0.095		
	(0.123)	(0.090)		
Change in Bitcoin velocity (ΔV_t^B)			0.033	-0.067
			(0.164)	(0.155)
$m = 1.3$ (omitted: $m = 1$)	0.066^{***}	0.079^{***}	0.036^{***}	0.036^{***}
	(0.010)	(0.015)	(0.011)	(0.011)
$m = 1.3 \times \Delta\frac{Y_t^D}{Y}$		-0.016		0.084
		(0.202)		(0.271)
$m = 1.3 \times \Delta V_t^D$		0.480^{**}		
		(0.240)		
$m = 1.3 \times \Delta V_t^B$				0.208
				(0.309)
Constant	0.007	0.006	0.006	0.006
	(0.005)	(0.005)	(0.006)	(0.006)
Pseudo R-squared	0.155	0.215	0.038	0.035
Observations	336	336	336	336

Notes: See Table 1.

Table C.3: Relationship between velocities, Dollar trade share, and inflation rates

D Experimental material

D.1 Experimental instructions



Instructions

Overview of the experiment

In this experiment, you will be trading with other players to get as many chips as you can by playing a real-time **market game** that uses a double auction mechanism (both buyers and sellers will be making offers). These chips determine your payout at the end of the experiment. To get chips, you will need to buy and sell packages of chips with other participants in the experiment. You will have to buy different types of packages of chips with different currencies. These market games are made up of a sequence of periods. Each sequence consists of **an indefinite number of periods**. Basically, how long it lasts is randomized. The number of periods played in each sequence is randomly determined in the following manner: At the end of each period, the computer will roll a virtual 6-sided dice. If the numbers 2, 3, 4, 5 or 6 are rolled from the dice, the sequence continues and you will continue playing the game, but if a '1' is rolled, the sequence ends and the game will restart. This means that all currency holdings and chips you currently have will disappear, and a new sequence will start. In other words, **after each period, the market game continues with a probability** 5/6 ≃ 83% **or ends with a probability** 1/6 ≃ 17%.

We will run **as many sequences as possible during the time for which you have been recruited**. After a sequence has ended, if there is not enough time remaining to start a new sequence, the experiment ends.

Before beginning the first sequence, you will have **2 practice periods** to familiarize yourself with the interface. Your decisions during those 2 practice periods will have no consequences on the actual experiment and will not count towards your earnings. It will be made clear to you and all other players when the actual experiment will start.

The market game

You are part of a group of **players** participating in markets where you buy and sell packages of chips. The rules are the same for all players. You will be split into equally sized groups of **buyers** and **sellers**. Each player will alternate between the roles of seller and buyer from period to period. Whether you start your first period as a seller or a buyer is randomly determined by the computer. For instance, if you are assigned the role of a buyer in period 1, you will then be a seller in period 2, then a buyer again in period 3, and so on until the sequence ends.

You will buy and sell chips in **two markets that each use different currencies**: Market A using Currency A and Market B using Currency B. Since you will alternate roles, buying chips is possible only every second period (when you are a buyer). Whenever you begin a period as a seller, you will be given 5 packages which you cannot use or keep for yourself, your goal as a seller is to sell these packages in order to increase your currency holdings to buy more packages when you are once again a buyer.

Number of chips per package

Chips are **bought and sold in packages**. Packages come in two types depending on which market you buy them from, the first type of package can only be bought from Market A which uses Currency A, the second type can only be bought from Market B which uses Currency B. When you buy a package, the number of chips you get depends on which currency/market you used to purchase the package and how many packages you already own.

- **Packages bought with currency A** can only be bought from Market A and will yield increasingly fewer chips, the more you purchase of these packages in a given period, the less each new package of this type will be worth to you. The first package bought using Currency A gives you 100 chips, the second package gives you 90 chips, ... , the 10th package only gives you 10 chips, ..., and any additional package beyond the 19th purchased only brings you one chip.

- **Packages bought with currency B** can only be bought from Market B and will always be worth 75 chips per package regardless of how many you have bought.

Package	1st	2nd	3rd	4th	5th	...	10th	11th	12nd	...	19th and beyond
Chip content (in A)	100	90	80	70	60	...	10	9	8	...	1
Chip content (in B)	75	75	75	75	75	...	75	75	75	...	75

Example: You buy 1 package using Currency A and 2 packages using Currency B in the first period of trading. Then you alternate roles to seller in the second period, then in the third period of trading, are a buyer again and you buy 2 more packages in Currency A and 1 more in package in Currency B. In total, you have purchased (100) + (100 + 90) = 290 chips using Currency A and 3 x 75 = 225 chips using Currency B, for a total of 290 + 225 = 515 chips so far.

What happens during a period of the market game

- When you **first start a sequence** as a buyer (which will last a random number of periods), you will receive 100 units of Currency A and 100 units of Currency B.
- At the beginning of **every period** when you are a seller, you will receive 5 packages, you must choose to allocate them to be sold on Market A or Market B.
- At the end of **every period** when you are a seller, you lose all packages you failed to sell.
- In each period, you will participate (either as a seller or as a buyer) in two different markets, one using Currency A (red boxes) and one using Currency B (blue boxes).
- Packages that yield diminishing numbers of chips are sold in Market A for Currency A, Packages that yield constant numbers of chips are sold in Market B for Currency B.
- You will carry over currency changes from period to period according to your actions as a buyer or seller.

Phases within a Period and their time limits

1. Allocating Packages Phase: Sellers' choose what allocation of their 5 packages goes to Market A or Market B (**30 seconds**).
2. Trading Phase: Buyers and Sellers make real-time offers for packages (**90 seconds**).

Note: A trading phase will close before time runs out whenever there are no more packages available for sale or there is no currency left to be spent. Hence, inncludig some waiting time, a period of the market game lasts a maximum of 3 minutes.

Allocating Packages Phase:

- This happens before the trading phase of a period
- Sellers are given 5 packages. They must choose how many of them they want to be offered on Market A and how many can be offered on Market B.

Trading Phase

- Sellers post **asks**, offers to sell a certain number of packages and the price they want to sell.
- Buyers post **bids**; offers to buy a number of packages and the highest price they will pay up to.
- Bids/asks can be changed at any time if they have not yet gone through.
- You can cancel your last bid/ask by clicking the "***Retract last bid***" button and "***Retract last ask***" button

Note: You can shortcut your participation in the market by clicking on the "***Accept best bid***" button as a seller (this means that you accept to sell at the highest price among all prices offered by the buyers), and by clicking the "***Accept best ask***" as a buyer (this means that you accept to buy at the lowest price among all prices offered

by the sellers).

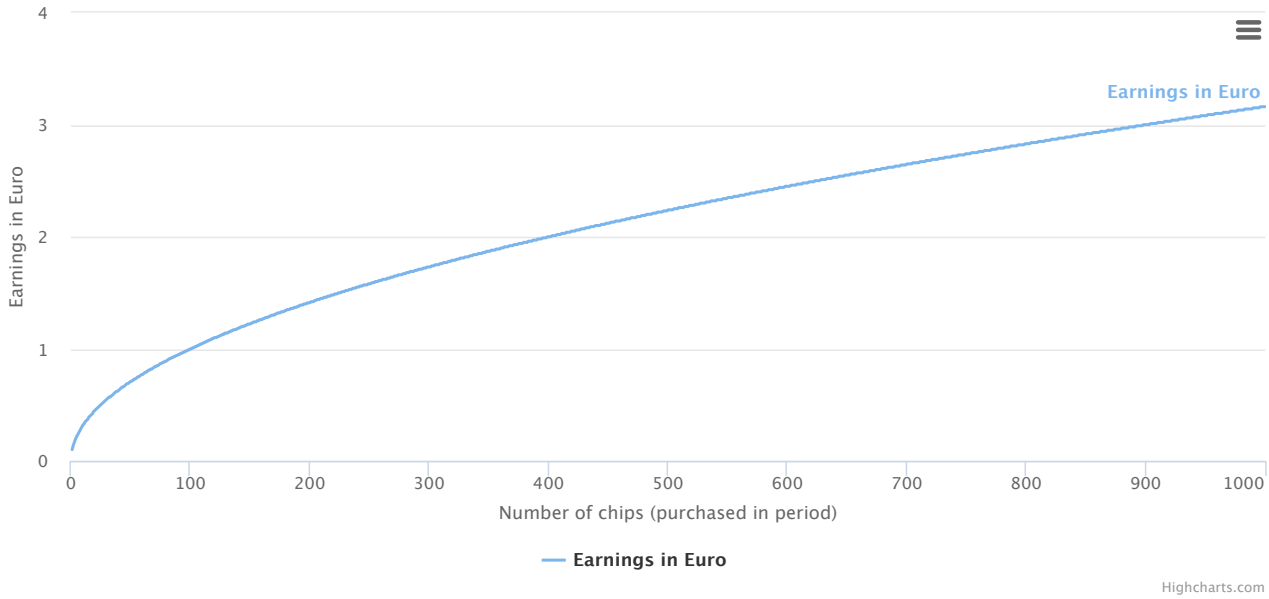
- A trade is finalized every time there is an ask price equal or less than a bid price.
  - The transaction price is the seller's asking price and the number of packages exchanged is the minimum between the number of packages offered by the seller, and desired by the buyer.
  - As a buyer, if no packages are for sale at or below your bid price, you will not buy any packages.
  - As a seller, if no packages are demanded for a price equal or higher to your ask price, you will not sell any packages.

  Example:You are a buyer and your bid is 2 packages at 100 units of Currency A. There is a seller whose ask is 3 packages at 80 units of Currency A. The transaction takes place and you buy from that seller 2 packages at 80 units of Currency A.

- You can submit as many asks and bids as you want as long as the markets are open.
  - As a buyer, you can never spend more currency than what you have allocated to each market. It can happen that you are not able to spend all your currency holdings. In this case, the remaining balance is then transferred to the next period.
  - As a seller, you can never sell more packages than you have allocated to a Market. It can happen that you are not able to sell all your packages. In this case, the unsold packages disappear at the end of that trading phase, which means that they may not be consumed or sold later.

Your earnings at the end of the experiment

The chips you purchase convert into money, hence you can accrue earnings only when you are a buyer. The payoff graphic below indicates how many Euros you can earn (y-axis) as a function of the number of chips you purchase in a given period (x-axis). There is also a slider that you can use to see the exact amount of Euros for each exact number of chips.



The more chips you buy, the more real-life money you can earn at the end of the experiment. However the chips you buy will convert into progressively less currency the more chips you accumulate within a single period.

Your total earnings in each sequence are the sum of your earnings in every period when you are a buyer during that sequence. At the end of the experiment, two sequences will be randomly selected (with equal probability out of all sequences played) and we will pay you **the money you earn during those two sequences, on top of a 9 euro participation compensation for your time and efforts**.

Summary

- You will play several sequences of a market game which lasts a randomized number of periods. After each period, the game ends with a 1/6 ≃ 17% probability. When this happens, all currency holdings are reset to zero and a new sequence starts.
- You will play as many sequences as time allows us. During each sequence, you will play alternating between being buyers and sellers of packages of chips. You can buy and sell chips in Market A using Currency A, or Market B using Currency B.
- At the beginning of each period, when you are a seller, you receive 5 packages of chips to sell to choose to allocate to Market A or Market B, these packages cannot be used or kept by you after each period.
- You start every sequence with 100 units of Currency A and 100 of Currency B. Your changes will carry over from period to period.
- The more packages you buy in Currency A, the fewer chips each additional package contains. Packages bought in Currency B always contain the same amount of chips. This resets every period.
- The more chips you purchase in each period, the higher your payoff but earnings do not increase as fast as the number of chips purchased. Only the total earnings from two sequences plus 9 euros will be paid out to you at the end of the experiment.

Next

Quiz

Instruction

1. Imagine that in a given period, you purchase 3 packages in currency A and 1 in currency B.

(a) How many chips did you purchase?

(b) How many Euros did you make? (Please keep two decimal points)

2. Imagine that you are a seller and your ask is 3 packages at 10 units of currency A. There is a buyer whose bid is 2 packages at 18 units of currency A. Which one of the following applies?

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3. which one of the following applies?

Next

D.2 Graphical user interfaces (GUI)

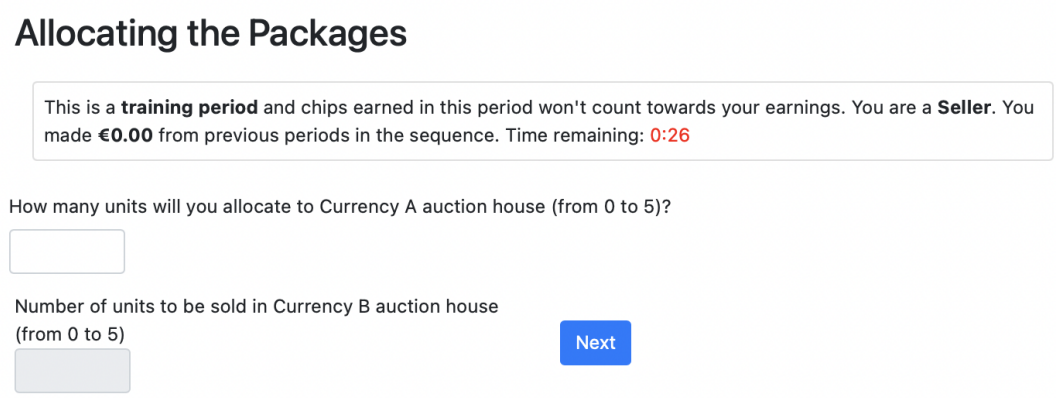


Figure D.1: Screen of the sellers' allocation page of packages between the two markets

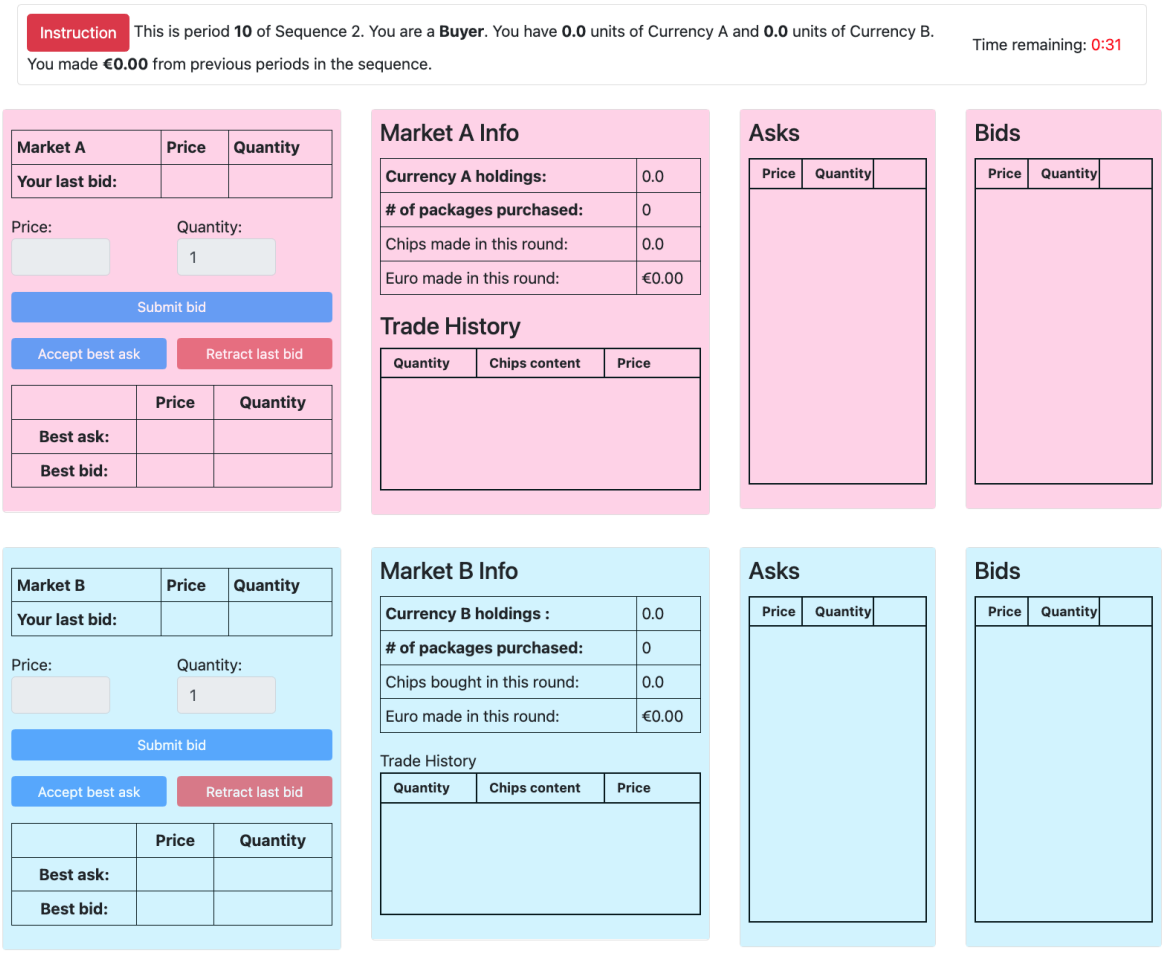


Figure D.2: Graphical user interface of the buyer

Notes: The dollar-denominated and bitcoin denominated trading interfaces are, respectively, on the top (market A in red) and on the bottom (market B in blue). Subjects submit their bids (and symmetrically their asks for the sellers) on the left-hand side column. The middle panel provides the details of the subject's trading history on each market so far in the given round, and the right-hand side panel displays all the asks and bids in each market as soon as they posted. The instructions and the guidance of the experimenter during the training periods make this interface clear to the subjects.

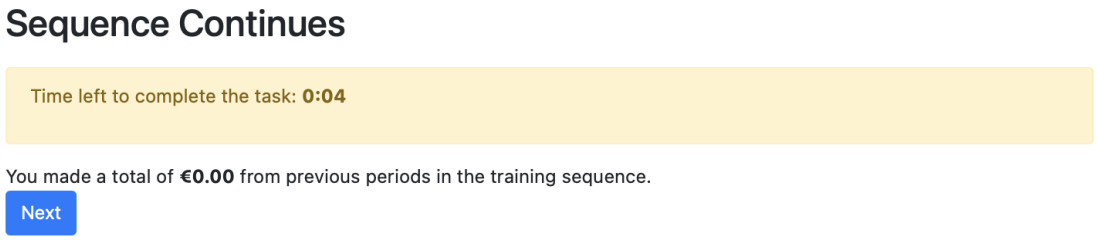


Figure D.3: Screen indicating a continuing sequence

D.3 Wordcloud



Figure D.4: Word cloud of participants' self-reported strategies (post-experiment questionnaire)

Figure D.4 presents a word cloud illustrating subjects' self-reported behaviors and strategies from the open-ended post-experiment questionnaire. The word cloud aggregates responses across all sessions, with larger words indicating more frequent mentions.

Subjects demonstrated a clear awareness of the monetary incentives embedded in the experimental tasks, as evidenced by recurrent terms such as "currency" and "money." The responses also highlight market equilibration processes driven by prices rather than quantities, reflected in words like "prices," "highest," and "lowest."

Additionally, trading strategies emphasized the importance of timing under competitive pressure and strategic uncertainty. Participants mentioned both quick decision-making (e.g., "first," "fast," "quick," "started") and deliberate delays (e.g., "wait," "later," "last," "keep," "end").